EADS Astrium GmbH

Welcome to the ROSETTA Users Manual

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Navigation:

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USER MANUAL Sections on this CD:

EADS Astrium GmbH	ROSETTA Users Manual (Vol. 1)	Doc. No.: RO-DSS-MA-1001
Project: ROSETTA		Issue: 5 Date: 31.10.03 Sheet: 1

Title: **ROSETTA USERS MANUAL**

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DRL-No.:

Model :

Prepared by:	ROSETTA Team	Date:	31.10.2003
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Distribution: see next page

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Ausgabe Issue	*Datum Date*	*Blatt Sheet*	*Beschreibung der Änderung Description of Change*	*Freigabe Release*
1	19.04.00		First Issue	
2	31.01.01		2nd Issue Issue 2 of this document contains some 'old' information from the previous issue, for which updates could not be achieved in time. This is mainly due to the fact, that – at the time of writing - subcontractors are preparing the CDR Data Package, which is however delivered only some weeks after the release of the current issue of the RUM. In particular the various budgets and the Autonomy-Fault Management description in chapter 3 are concerned which are left unchanged from issue 1. The Avionic Section is removed in this issue, as a separate Avionics Users Manual will be available at CDR.	
2a	15.03.01		The updates are mainly concerned with §5.3.3 – TT&C as well as updates in the Annexes. Also some minor changes in Volume 2 have been made.	
2b	24.07.01		Changes are only for Volume 1 of this document. Implementation of CDR RID SYS 303: - enhanced support documentation in the annexes - improved quality of diagrams/figures - TM/TC information now carried via DSDB data sheets - Update of Budgets (Annex 10) - Payload information contained in Annex 12 Propulsion subsystem section (§5.4.2) revised. Various minor corrections/updates throughout the document	
3	31.10.01		A number of 'TBDs' removed in Volume 1 Updates of Power Subsystem Section (§5.3.2) Updates of Thermal Subsystem Section (§5.4.1) Flight Procedures added in Volume 2 (see procedure summary list in §2 of Vol. 2 for details).	

Ausgabe Issue	*Datum Date*	*Blatt Sheet*	*Beschreibung der Änderung Description of Change*	*Freigabe Release*
4	30.04.02		Launch date changed from 22.01.03 to 13.01.03. This results in modifications of the "Mission Day" in various timeline tables. Various figures modified/replaced by newer/better quality versions. • Figure 2-21 • Figure 2-41 • Figure 2-42 • Figure 5-16 (removed KAL) • Figure 5-27 • Figure 5-52 • Figure 5-92a to Figure 5-92ai §3.5, Operational Constraints: expanded TM/TC RSDB codes updated Table 5-1: SS-PDU LCL allocation modified Section 5.3.3.2.2.4 "Initial Status of Transponder" added Document sections in Annex 1 through 12 updated Volume 2 – Procedures updated/added (see procedure summary list in §2 of Vol. 2 for details) Volume 2 – Operational Concept updated Volume 2 – All procedures - with exception of the avionics procedures - are now provided as selfstanding documents. As a consequence the header level has been modified. This header level change is not marked by change bars. Editorial changes.	

Ausgabe *Issue*	*Datum* *Date*	*Blatt* *Sheet*	*Beschreibung der Änderung* *Description of Change*	*Freigabe* *Release*
4a	30.07.02		Implementation of FAR Rid SYS004: ▪ Procedures update (Volume 2) ▪ Chapter "Operational Constraints" update ▪ TM/TC Datasheets update ▪ Editoral changes: removal/update of outdated/inconsistent information	
4b	30.05.03		Update of descriptive part to remove inconsistencies and TBD/TBCs. Constraints section updated and expanded. Now including also constraints from the Avionics User Manual. Annexes updated to the latest document versions TC datasheet updated to last release of RSDB	
5	31.10.03		Updated document to reflect new mission objectives for Churyumov-Gerasimenko	

EADS Astrium GmbH	# Änderungsregister	Dok.-Nr.: RO-DSS-MA-1001
Projekt / *Project* ROSETTA	***Register of Changes***	Ausg./Issue 5 Date: 31.10.03 Blatt/Sheet: 4

Revsion	A	B	C	D	E	F	G	H
Datum / Date Blatt / Sheet								
1								
2								
3								
4								
A								
B								
C								
D								
E								

Revision	A	B	C	D	E	F	G	H
Datum / Date Blatt / Sheet								

LIST OF CONTENTS

LIST OF CONTENTS

LIST OF CONTENTS

LIST OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

1. INTRODUCTION AND MISSION DEFINITION

1.1. Introduction

1.2. Scope of the Document

The purpose of the ROSETTA User's Manual (**RUM**) is to:

- give an overview of the objectives, concept and operation of the ROSETTA mission from the spacecraft point of view
- provide all information necessary for the knowledge and understanding of the ROSETTA system and subsystem design and function from the operational point of view
- provide a comprehensive description of all operations to be conducted, starting from pre-launch shortly before lift-off until end-of mission (nominal operations)
- describe what to do in case of non-nominal spacecraft behaviour or unforeseen events (contingency operations)

1.2.1. Structure of the Document

The structure of the RUM is derived from the requirements provided in AD 1. The document consists of seven sections in several volumes as follows:

- Introduction and Mission Definition
- System Definition
- System Level Operations
- Avionics Definition – including its subsystems. This section has now been transferred to a separate Avionics Users Manual (RO-MMT-MA-2025).
- Platform Definition – including its subsystems
- Experiment Definitions
- A set of Annexes with additional supporting information
- Flight Procedures (Volume 2)

The Mission Definition Section contains the following:

- A brief description of the satellite mission
- Mission requirements and constraints and their impact on spacecraft system design
- Mission phases and their purpose
- Mission control concept

The System Definition section contains:

- A system level description of the spacecraft, showing the definition of the subsystems, the distribution of functions and the interfaces between them
- A high-level experiment description
- The system level configuration in the different mission phases

The System Level Operations part includes:

- A summary of all nominal and backup system level modes, including purpose, subsystem status in the mode, operational constraints and when used.
- A summary of all nominal and backup experimental operational modes, including purpose, when used, operational constraints, resources required and downlink data available.
- The operational concept foreseen for the different mission phases
- The baseline event time line for all mission phases
- The definition of system level autonomy provisions and fault management features

The Platform section is provided in chapter 5 and contains

- Platform Definition
- Platform Description, including functional interfaces, internal and external, budgets, etc.
- External and internal interfaces

Each subsystem is detailed by Subsystem Description, including functional objectives, design description and operating principles and budgets where applicable.

The Annexes provide supporting information consisting of:

- Appendix 1: Spacecraft Build Standard
- Appendix 2: Platform TM/TC Datasheets
- Appendix 3: Power Subsystem Data including
  - Tables of solar array output power generation dependant on temperature.
  - Tables of battery characteristics charge and discharge characteristics dependent on temperature.
- Appendix 4: Documentation related to Propulsion
- Appendix 5: Documentation related to Thermal, including:
  - Tables and graphs showing the expected thermal behavior of the spacecraft for normal and for worst case conditions (cold and hot cases)
  - Results of the ground thermal tests
- Appendix 6: RF Data
  - Polar diagrams of the antenna pattern for each on-board antenna
  - Full transponder characteristics (nominal frequencies and temperature dependencies)
  - RF link budgets for all operational modes and mission phases
  - Location of each antenna in spacecraft body axes
  - Results of the ranging calibration tests, including performance characteristics, system delay measurements and stability.
- Appendix 7: Failure and Contingency Analysis:
  - System Level:
    - Failure Modes, Effects and Criticality Analysis (FMECA)
    - Fault Tree Analysis (FTA) identifying all potential system level failures
    - List of all single point failures
  - Avionics Level:
    - Avionics level Failure Modes, Effects and Criticality Analysis (FMECA)
    - Fault Tree Analysis (FTA) identifying all potential Avionics level failures
    - List of all single point failures
  - Platform Level:
    - Platform level Failure Modes, Effects and Criticality Analysis (FMECA)
    - Fault Tree Analysis (FTA) identifying all potential platform level failures
    - List of all single point failures

- Appendix 8: Subsystem On-Board Software
  - Breakdown of each subsystem memory showing RAM and ROM address areas, areas allocated for program code, buffer space and working parameters (e.g. content of protected memory)
  - Word by word listing of program code
  - Word by word listing of all software data areas (referencing the software parameter reference number, and mnemonics)
  - On-board Software Development Environment description (SDE) and SDE Users Manual
  - On-board Software Validation Facility (SVF) description and SVF Users Manual
  - OBCP URDs
- Appendix 9: Spacecraft Configuration Drawings
- Appendix 10: System Budgets
- Appendix 11: Documentation related to the Mechanical Subsystem
- Appendix 12: Further documentation related to operations

1.3. Documentation

1.3.1. Applicable Documents

[AD1] Operations Interface Requirements Document RO-ESC-RS-5001

1.3.2. Reference Documents

Document reference	Document title
[RD1]	TCS Design Description Report RO-MMS-DS-3101
[RD2]	Electrical Block Diagramm BB2480123001A00
[RD3]	Avionics User Manual RO-MMT-MA-2025
[RD4]	System Autonomy Software URD RO-DSS-RS-1016
[RD5]	Autonomy and Operational Requirement Specification RO-DSS-RS-1008
[RD6]	ROSETTA Platform Technical Budgets Report RO-MMB-RP-3106/2
[RD7]	ESA PSS-04-105
[RD8]	Space / Ground Link Budgets at S/X-Band RO-DSS-TN-1025
[RD9]	DMS Software RO-MMT-RP-2014
[RD10]	AOCMS Software RO-MMT-RP-2031
[RD11]	PM Firmware RO-SES-LI-2049
[RD12]	SSMM Software RO-SES-TN-2082
[RD13]	STR Software RO-GAL-RP-2008

Document reference	Document title
[RD14]	NavCam Software RO-GAL-RS-2007
[RD15]	Power Budget Report RO-DS-RP-1015
[RD16]	Additional Power Consumption in Case of Single Failure RO-DSS-TN-1084
[RD17]	RO-AEA-0047/00
[RD18]	Operations Interface Requirements Document RO-ESC-RS-5001
[RD19]	Space/Ground Interface Control Document RO-ESC-IF-5002
[RD20]	Packet Telemetry Standard ESA-PSS-04-106
[RD21]	System Requirements Specification RO-EST-RS-2001
[RD22]	Avionics Requirements Specification RO-DSS-RS-2001
[RD23]	System Interface Requirements Specification RO-DSS-IS-1001
[RD24]	CDMS Requirements Specification RO-MMT-RS-2029
[RD25]	AOCMS FDIR technical note RO-MMT-TN-2008
[RD26]	Evaluation of ESA FDIR Working Group Report RO-DSS-TN-1067
[RD27]	On-board Software Requirement Specification RO-DSS-RS-1004
[RD28]	ESA Software Engineering Standard SA PSS-05-0
[RD29]	Avionics ICD RO-MMT-IF-2002

1.4. Acronyms and Abbreviations

ACM	Active Cruise Mode
ACS	Avionics Computer System
AD	Applicable Document
AFM	Asteroid Fly-by Mode
AIU	AOCMS Interface Unit
AIV	Activity of Integration and Validation
AM	Activation Mode
AOCMS	Attitude and Orbit Control and Measurement Subsystem
AOCS	Attitude and Orbit Control Subsystem
APM	Antenna Pointing Mechanism
ATP	Approach Transition Point
AU	Astronomical Units
BCP	Broadcast Pulse
BCU	Battery Charge Unit
BDR	Battery Discharge Regulator
BDU	Battery Discharge Unit
BER	Bit Error Rate
BIT	Built-in Test
BRU	Battery Recharge Unit
BSM	Bus Support Module
CAP	Comet Acquisition Point
CC	Commonly Controlled
CCD	Charged Coupled Device
CCS	Central Check-out System
CCSDS	Consultative Committee for Space Data Systems
CDMS	Control and Data Management Sub-assembly
CDMU	Control and Data Management Unit
CFRP	Carbon Fibre Reinforced Plastic
CIA	Communication Interface Adapter
CLCW	Command Link Control Word
CPDU	Command Pulse Distribution Unit
CPU	Central Processing Unit
CSM	Communication Switching Matrix

CSME	Communication Switching Matrix Element
DL	Down Link
DMS	Data Management System
DOF	Degree of Freedom
DS	Digital Serial acquisition
DSHM	Deep Space Hibernation Mode
DSN	Deep Space Network
DSP	Digital Signal Processor
DST	Deep Space Transponder
EDAC	Error Detection and Correction
EEPROM	Electrically Erasable PROM
EGSE	Electrical Ground Support Equipment
EMC	Electromagnetic Compatibility
EOP	End of Packet
EPC	Electrical Power Conditioner
EQM	Engineering Qualification Model
FAU	File Assembly Unit
FCL	Fold-back Current Limiter
FCV	Flow Control Valve
FDIR	Failure Detection Isolation and Recovery
FE	Front End
FMECA	Failure Mode Effect Analysis
FMS	File Management System
FOP	Flight Operation Procedure
GaAs	Gallium Arsenide
GMI	Global Mapping Insertion
GSE	Ground Support Equipment
GTD	General Theory of Diffraction
HDR	Hardware Design Review
HGA	High Gain Antenna
HGAMA	High Gain Antenna Major Assembly
HGAPM	High Gain Antenna Pointing Mechanism
HIB	Hibernation
HK	Housekeeping

HM	Hibernation Mode
HPC	High Power Command
HPCM	High Power Command Module
HRM	Holddown & Release Mechanism
HW	Hardware
IC	Internally Controlled
I/O	Input / Output
ICD	Interface Control Document
ID	Identifier
IFOV	Instantaneous Field of View
IOT	In Orbit Testing
KAL	Keep Alive Line
LCB	Last Chance Bit
LCL	Latch Current Limiter
LEOP	Launch and Early Orbit Phase
LET	Linear Energy Transfer
LGA	Low Gain Antenna
LGA	Low Gain Antenna
LILT	Low Intensity Low Temperature
LM	Launch Mode
LNA	Low Noise Amplifier
LOS	Line Of Sight
LSB	Least Significant Bit
LV	Latch Valve
MACS	Modular Attitude Control System
MAP	Multiplexing Access Point
MGA	Medium Gain Antenna
ML	Memory Load
MLI	Multi Layer Insulation
MMH-LTO	Fuel
MMS	Matra Marconi Space
MMU	Memory Management Unit
MPPT	Maximum Power Point Tracker
MSB	Most Significant Bit

MTL	Mission Time Line
MUX	Multiplexer
NAV Cam	Navigation Camera
NCM	Near Comet Mode
NM	Normal Mode
NSHM	Near Sun Hibernation Mode
OBCP	On-board Control Procedure
OBDH	On-board Data Handling
OBT	On-board Time
OCM	Orbit Control Mode
OCXO	Oven Controlled Crystal Oscillator
OIP	Orbit Insertion Point
PCA	Pressure Controlled Assembly
PCU	Power Control Unit
PDR	Preliminary Design Review
PDU	Power Distribution Unit
PFM	Proto Flight Model
PM	Processor Module
PMD	Propellant Management Device
PRNU	Pixel Response Non Uniformity
PROM	Programmable ROM
PRR	Propellant Refillable Reservoir
PSM	Payload Support Module
PVNC	Pyro Valve Normally Closed
PVNO	Pyro Valve Normally Open
RAM	Random Access Memory
RCS	Reaction Control System
RD	Reference Document
RVM	Rendezvous Manoeuvres
RFDU	Radio Frequency Distribution Unit
RFMU	Radio Frequency Mock-Up
RLG	Ring Laser Gyro
RM	Reconfiguration Module
ROM	Read Only Memory

RRP	Rate Reduction Phase
RTU	Remote Terminal Unit
RWA	Reaction Wheel Assembly
RWL	Reaction Wheel
RX	Receiver channel
S/HM	Safe / Hold Mode
S/W	Software
SA	Solar Array
SADM	Solar Array Drive Mechanism
SAM	Sun Acquisition Mode
SAP	Sun Acquisition Phase
SAS	Sun Acquisition Sensor
SCET	Spacecraft Elapsed Time
SCL	Spacecraft Control Language
SCOE	Specific Check-out Equipment
SCP	Sun Capture Phase
SEU	Single Event Upset
SGM	Safeguard Memory
SI	Silicon
SKM	Sun Keeping Mode
SMCS	Scaleable Multi-Channel Communication Subsystem
SOC	State of Charge
SpM	Spin-up Mode
SPP	Sun Pointing Phase
SSMM	Solid State Mass Memory
SSP	Science Surface Package
STM	Structural Thermal Model
STP	System Interface Temperature Points
SuM	Survival Mode
SVF	Software Validation Facility
TBC	To Be Confirmed
TBD	To Be Defined
TC	Telecommand
TC S/S	Thermal Control Subsystem

TCM	Trajectory Correction Manoeuvre
TCS	Test Control System
TFG	Transfer Frame Generator
TM	Telemetry
TRP	Temperature Reference Points
TT&C S/S	Telemetry, Telecommand and Communication Subsystem
TTC	Telemetry Tracking and Commanding
TWTA	Travelling Wave Tube Assembly
TWTL	Two Way Travelling Lighttime
TX	Transmitter channel
URD	User Requirement Document
USO	Ultra-Stable Oscillator
UTC	Universal Time Code
UVD	Under-Voltage Detector
VCA	Virtual Channel Assembler
VCM	Virtual Channel Multiplexer
WD	Watch-Dog
WDE	Wheel Drive Electronics
WIU	Wave Guide Interface Unit

1.5. Mission Definition

1.5.1. ROSETTA Mission Overview

The ROSETTA mission is an interplanetary mission whose main objectives are the rendezvous and in-situ measurements of the comet 67P/Churyumov-Gerasimenko, scheduled for 2014/2015. The spacecraft will also carry a Surface Science Package to the nucleus and deploy it onto its surface. A German-led consortium of European institutes will provide the so-called ROSETTA Lander.

On its long way to the comet nucleus after a Launch by Ariane 5 P1+ in February 2004, the ROSETTA spacecraft will orbit the Sun during one year until it returns to Earth for the first fly-by. The planet Mars will be reached in February 2007, about 3 years after launch. In November 2007 a second Earth fly-by will take place and a third one in November 2009. One or two asteroid fly-bys will be performed on the way to the comet; which ones will be visited is going to be decided after launch depending on the available propellant after the launcher correction manoeuvre. Around the aphelion of its orbit, which is 5.3 AU from the Sun, the spacecraft will be in a spinning hibernation mode for about 2.5 years.

The comet 67P/Churyumov-Gerasimenko will be reached about 10.5 years after launch, in August 2014. After a comet mapping phase the Surface Science Package, carried piggyback on the spacecraft will be released for landing on the comet's surface for in-situ measurements. The ROSETTA mission will then make a detailed study of the comet and its environment until a Sun distance of 2 AU is reached again after comet perihelion, end of the year 2015.

1.5.2. ROSETTA Mission Objectives

The scientific objectives of the ROSETTA mission can be considered from three main viewpoints:

First of all, comets and asteroids are fully-fledged members of our solar system, which means, that they are objects of intrinsic interest to planetary scientists. Up to now, only fast comet fly-bys have been achieved, and one of these comets, P/Halley, has been imaged at a close range. There have been only few fly-bys of small main-belt asteroids. The level of investigations conducted on these bodies is therefore far below that, achieved for the other objects of the solar system. The study of the small solar-system bodies arguably represents the last major gap in the tremendous worldwide effort that has been made to reveal our planetary neighbours to us.

The most important scientific rationale for studying small solar-system bodies is the key role-play in helping us to understand the formation of the solar system. Comets and asteroids have a close genetic relationship with the planetesimals, which formed from the solar nebula 4.57 billion years ago. Most of our present understanding of these processes has been obtained by studying meteorites, which constitute a biased sample of asteroidal material, and micrometeoroids, which may represent cometary grains processed by solar radiation and atmospheric entry. There is therefore a strong scientific case of studying cometary material in-situ, as it is surely more primitive than extraterrestrial samples.

A third scientific aspect is the study of the physio-chemical processes, which are specific to comets and asteroids. In this respect, asteroids can provide information on impact phenomena, particularly on very large scale. However, the increase in cometary activity as these bodies approach the Sun undoubtedly represents one of the most complex and fascinating processes to be observed in the solar system.

1.5.3. Mission Profile

The ROSETTA mission profile results from the orbit of the target comet 67P/Churyumov-Gerasimenko, which has a perihelion close to 1.2 AU and an aphelion of about 5.7 AU, resulting in a period of about 6.5 years.

The injection of the spacecraft by a single Ariane 5 Launch with the so-called “delayed ignition“ of the upper stage, is not directly into the trajectory to the comet, because of the high spacecraft wet mass. Therefore the spacecraft has to be accelerated by a sequence of gravity assist manoeuvres at Mars and the Earth, in order to catch up with the comet’s velocity at perihelion. However, this increases the mission duration to a total of nearly 12 years.

The initially large distance to the comet at the perihelion of its trajectory is slowly decreasing after the third Earth swing-by. At the intersection of both orbits, the difference in orbit inclination and the residual relative velocity are diminished by the comet orbit matching manoeuvre at around 4.0 AU Sun distance.

The range of the spacecraft-to-Sun distance is between 0.88 and 5.33 AU, defined by the minimum Sun distance during the first five years of the mission with the swing-bys at Earth, and the maximum Sun distance close to the aphelion of the comet’s orbit. The evolution of the spacecraft distance to Earth over the mission time follows the profile of the Sun distance superimposed by an oscillation with an amplitude of 1 AU and a period of about one year due to the Earth’s motion around the Sun. This results in a range from 0 AU (Earth Departure and Swing-by) to 6.3 AU during the superior solar conjunction close to the spacecraft’s aphelion.

After the second and third Earth swing-by ROSETTA will cross the asteroid main belt, which gives the opportunity of two asteroid fly-bys. Table 1-1 below lists the available candidate asteroids. Because of their different propellant needs it can be decided only after launch, which asteroids will be visited, depending on the size of the required launcher correction manoeuvre.

Name	Diam	Delta-V (m/s) for launch on			Extra Delta-V	Arc	Fly-by date	Relat Veloc	Sun S/C Asteroid angle at approach	Sun S/C Earth angle	Sun Ear S/C angle	Sun Dist	Earth Dist
		Feb 26	Mar 07	Mar 17									
	km				m/s		yymmdd	km/s	deg	deg	deg	AU	AU
None		1681	1664	1686	0								
Lutetia	99.5	1782	1786	1817	131	E-C	10/07/10	14.997	168.8	19.29	62.16	2.72	3.04
Rhodia	14.3	1773	1739	1763	87	E-E	08/09/17	11.255	138.7	21.15	50.20	2.13	2.63
Sofala	??.?	1799	1752	1774	113	E-E	08/09/11	6.912	122.3	24.87	65.43	2.17	2.39
Sy	19.2	1682	1672	1697	11	E-E	09/03/06	8.208	53.4	14.28	33.58	2.22	2.98
Fogelin	??.?	1691	1680	1705	19	E-C	10/05/25	13.556	158.5	25.32	92.79	2.36	2.08
Baetsle	??.?	1689	1677	1702	16	E-E	08/10/05	8.555	145.3	20.84	52.04	2.21	2.68

Name	Diam	Delta-V (m/s) for launch on			Extra Delta-V	Arc	Fly-by date	Relat Veloc	Sun S/C Asteroid angle at approach	Sun S/C Earth angle	Sun Ear S/C angle	Sun Dist	Earth Dist
		Feb 26	Mar 07	Mar 17									
	km				m/s		yymmdd	km/s	deg	deg	deg	AU	AU
Steins	??.?	1747	1722	1744	61	E-E	08/09/06	8.565	141.4	24.56	61.70	2.13	2.41
Carrera	??.?	1760	1729	1751	74	E-E	08/07/31	11.248	153.7	29.77	91.68	2.04	1.74
Izvekov	21.1	1683	1674	1700	14	E-C	10/12/04	11.288	159.9	8.54	33.65	3.67	4.45
Luichewoo	??.?	1704	1695	1721	35	E-E	09/04/08	5.594	74.4	21.70	52.30	2.14	2.60

Table 1-1: Asteroid Fly-by Candidates

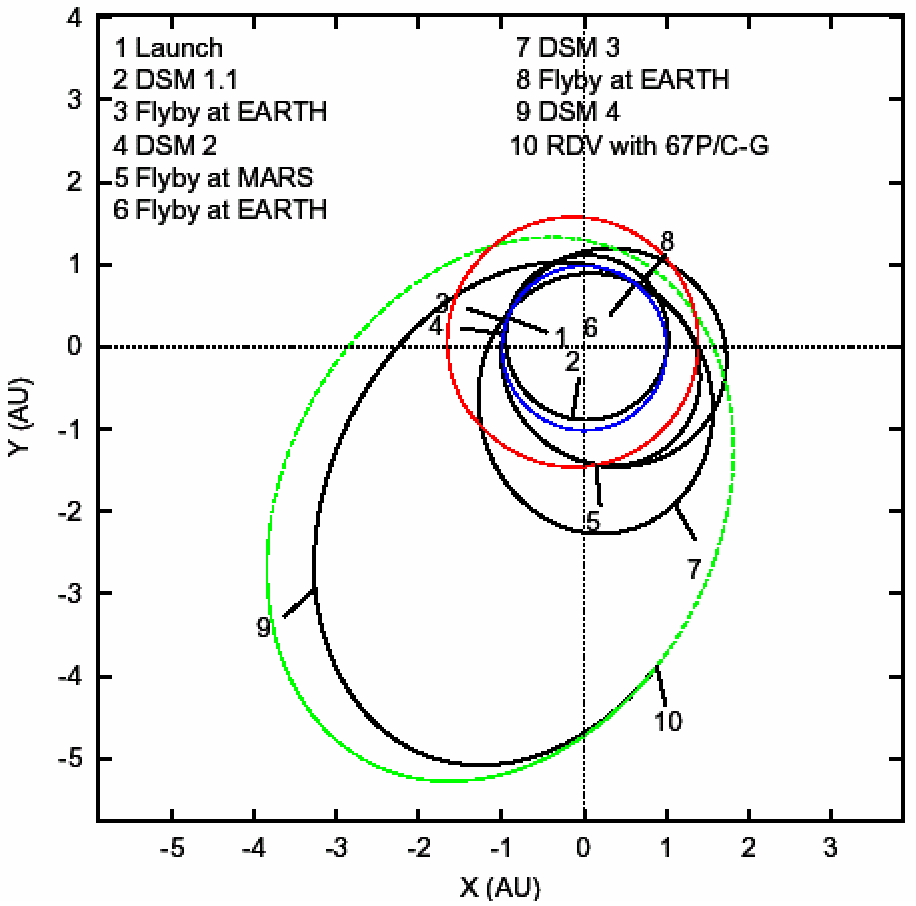


Figure 1-1: ROSETTA Mission Profile

Between the major mission events, up to the comet rendezvous manoeuvre, the spacecraft performs long interplanetary cruise phases (up to 2.5 years) with several solar conjunctions and the power critical aphelion passage (last cruise phase). In order to reduce the ground segment costs and the wear and tear of spacecraft equipment during these phases, the spacecraft will be put in "Hibernation Mode".

Two types of hibernation modes are planned to be used:

- "Deep Space Hibernation Mode" above 4.5 AU: Inertial spin mode with a spin rate of 4 deg/sec. The spacecraft is almost entirely passive, except of receivers/ decoders, power supply, heaters and two Processor Modules with one RTU.

- "Near Sun Hibernation Mode" below 4.5 AU: 3-axes stabilised mode with the solar arrays Sun-pointing and the +X-axis Earth-pointing. Attitude control is performed with thrusters and STR, based on ephemerides; control deadband typically 5 deg; occasional solar array adjustments and ground contacts via MGA.

The final approach to the comet into its sphere of influence is prepared by the rendezvous manoeuvre (RVM-2), that matches the spacecraft orbit with the comet orbit.

A subsequent sequence of approach manoeuvres, supported by optical navigation, takes the spacecraft closer and closer to the comet. After determination of the physical model of the comet by Doppler and optical measurements, the spacecraft will be inserted into a global mapping orbit around the comet.

The global mapping starts from orbital heights of 5 to 25 comet radii, depending on the actual size, shape and mass of the comet. Close observation of specific landmarks from altitudes down to one comet radius is planned. At least 80% of the illuminated surface shall be mapped. The very low velocity of the spacecraft in the comet orbit (few cm/s) requires a high performance accuracy of the propulsion system.

The delivery of the Surface Science Package (SSP) is achieved from an eccentric orbit, which takes the spacecraft to a low altitude above the selected landing site. The SSP release is fully automatic according to a predefined schedule, and shall lead to touch down with minimum vertical and horizontal velocities relative to the local rotating surface. Upon the landing of the SSP, the spacecraft provides up- and downlink data relay between the Lander and the Earth.

After the SSP delivery the ROSETTA spacecraft will escort the comet until the perihelion passage and outwards again, until a Sun distance of 2 AU is reached end of the year 2015. The main scientific objective during this phase is the monitoring of the features of the active comet.

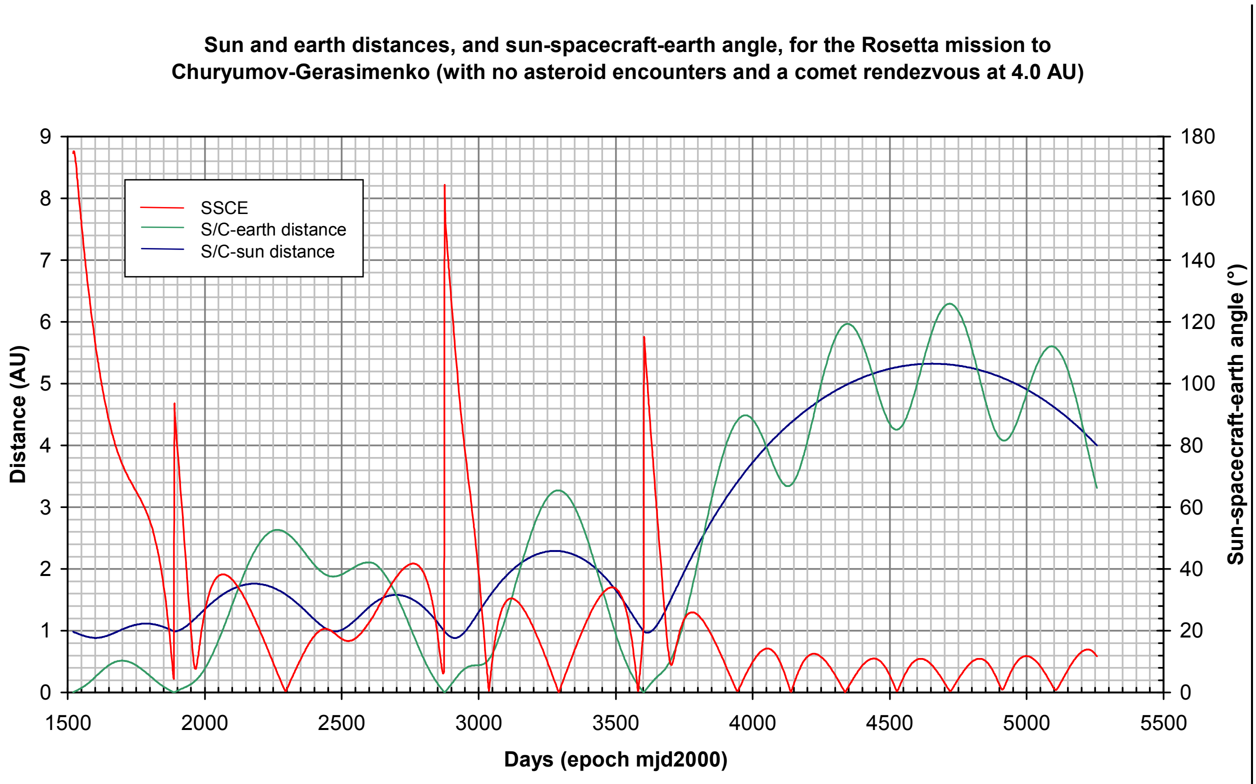


Figure 1-2: Spacecraft to Sun/Earth Distance Profiles and SSCE

1.6. Mission Requirements and Constraints

In the following, the stringent mission requirements are summarised and related to their consequences on the spacecraft system design.

The ambitious scientific goals of the ROSETTA mission require:

- a large number of complex scientific instruments, to be accommodated on one side of the spacecraft, that shall, in the operational phase, permanently face the comet. During cruise the instruments shall be served for survival.
- one Surface Science Package (SSP), to be accommodated, suitable for cruise survival and proper, independent ejection from the orbiter (spacecraft). In addition, the orbiter shall provide the capability for SSP data relay to Earth.
- a complex spacecraft navigation at low altitude orbits around an irregular celestial body with weak, asymmetric, rotating gravity field, rendered by dust and gas jets.

These primary mission requirements are design driving for most of the spacecraft layout and performance features, as:

- data rate (DMS, TTC)
- pointing accuracy (AOCMS, Structure)

- thermal layout
- closed loop target tracking (AOCMS, NAV Camera), derived requirements from asteroid fly-by
- small-delta-v manoeuvre accuracy (RCS)

Other mission requirements, that relate to the interplanetary cruise phases rather than to the scientific objectives, drive mainly the power supply, propulsion, autonomy, reliability and telecommunication:

For achieving the escape energy (C3=11.8 km²/s²) to the interplanetary injection, an Ariane 5 Launch (delayed ignition) is required, that constrains the maximum S/C wet mass and defines the available S/C envelope in Launch configuration.

The total mission delta-v of more than 2100 m/s requires a propulsion system with over 1700 kg - bi-propellant.

The environmental loads (radiation, micro meteoroids impacts) over the mission duration of nearly 12 years is very demanding w.r.t. shielding, reliability and life time of the S/C components.

The large S/C to Earth distance throughout most mission phases makes a communication link via an on-board high gain antenna (HGA) mandatory. The spacecraft must provide an autonomous HGA Earth-pointing capability using star sensor attitude information and on-board stored ephemeris table. TC link via spherical LGA coverage, and TC/TM links via an MGA shall be possible as backup for a loss of the HGA link.

The wide range of S/C to Sun distances (0.88 to 5.33 AU) drive the thermal control and the size of the solar generator.

The long signal propagation time (TWLT up to 100 minutes), ~~and~~ the extended hibernation phases (2.5 years the longest one), and the many solar conjunctions/oppositions (the longest in active phases is 7 weeks) require a high degree of on-board autonomy, with corresponding FDIR concepts.

1.7. Mission Phases

This section identifies 26 major mission phases as summarised in Table 1-2.

These phases can be grouped in seven types:

- Pre-launch phase and LEOP phase, where the spacecraft is launched and the first trajectory manoeuvres are prepared.
- Spacecraft commissioning phase for system activation and checkout.
- Active cruise phases around the fly-by of a third planetary body (key events as planet gravity assists and asteroid fly-bys).
- Active cruise phases around the deep space manoeuvres and comet detection phase (key events).

- Passive cruise phases between these key events (Near Sun Hibernation and Deep Space Hibernation).
- Active comet approach phases (between comet detection and the comet orbit insertion manoeuvre).
- Comet observation phases, where the spacecraft is orbiting the comet (global mapping, close observation, SSP delivery/data relay and extended comet monitoring until the end of mission)

The begin of all mission phases and main event times in Table 1-2 are related to a spacecraft launch at the begin of the 21 days launch window (26 February 2004). Later launch dates within the launch window result in rather small variations of a few days for some of the major mission events.

The start and duration of the comet approach phase depends on the actual time of comet detection, while the begin and duration of the observation phases depend also on the comet mass, size and rotation period, as well as on the period of the selected observation orbits.

The times as outlined in Table 1-2 for these phases are therefore to be considered as typical only.

Name of Phase	Phase Begin / Main Event (Mission Day)	Phase Duration (Days)	Applicable System Mode [1])
LEOP	1	3	LM
Commissioning Phase 1	4	99	AM/ACM
Cruise 1: Earth to Earth 1	103	105	ACM
Commissioning Phase 2	208	45	ACM
Earth Swing-by 1 Phase	253/372	151	ACM
Cruise 2: Earth to Mars	404	520	ACM/NSHM
Mars Swing-by Phase	924/1098	203	ACM
Cruise 3: Mars to Earth 2	1127	172	NSHM
Earth Swing-by 2 Phase	1299/1359	91	ACM
Cruise 4: Earth 2 to Earth 3	1390	636	ACM/NSHM
Earth Swing-by 3 Phase	2026/2086	91	ACM
Cruise 5: Earth 3 to RVM1	2117	395	ACM/NSHM
Asteroid Fly-by tbd	tbd		AFM
RVM-1 Phase	2512/2631	181	ACM
Cruise 6: Deep Space Hibernation	2693	927	DSHM
RVM-2 and Comet Approach Phase	3620/3739	211	ACM
Global Mapping and Close Observation	3831	58	NCM
SSP Delivery and Relay Phase	3889	27	NCM
Comet Escorting Phase	3916	411	NCM

Legend:

LM = Launch Mode
AM = Activation Mode
ACM = Active Cruise Mode
NSHM = Near Sun Hibernation Mode
DSHM = Deep Space Hibernation Mode
AFM = Asteroid Fly-by Mode
NCM = Near Comet Mode

SSP = Surface Science Package (Lander)

Table 1-2: Sequence of Major Operational Mission Phases

[1] Mode description see Section 3.1

Operational Mission Phases

The **LEOP Phase** (3 days) comprises final pre-launch preparations, the Ariane 5 ascent, the coast orbit and the escape injection burn of the Ariane upper stage (L9.7) and the first three days in solar orbit until the first TCM is performed. The burn-out of the L9.7 stage occurs after the end of the eclipse phase. The upper stage will acquire the desired separation attitude and separate the spacecraft. At spacecraft separation the “Separation Sequence Program“ will activate the AOCMS, and initiate RCS priming; also the downlink will be initiated via LGA. This is followed by the initial Sun acquisition, the solar array deployment and the final Sun re-acquisition. Fine 3-axis attitude stabilisation in Safe Mode will be achieved under ground control. Due to the Sun-S/C-Earth geometry in this phase, the Safe Mode attitude has to be different from the usual X-axis to Sun or Earth pointing. It has to be such that the X-axis is biassed away from the Sun, in order to avoid blinding of the star trackers on the opposite side by the Earth. This phase includes deployment of the HGA, and the preparation for and the execution of the 1st TCM on day 3.

The **Commissioning Phase 1** (99 days) starts after the end of the 1st TCM. A complete subsystems and payload check-out is performed as well as calibration of AOCMS sensors and SA/HGA mechanisms. At the end of this phase the first deep space manoeuvre DSM1 is performed, the size of which highly depends on the day of launch.

The **Cruise Phase 1** will be relatively short (about 3.5 months), and the spacecraft will remain in Active Cruise Mode. In the first month SW Maintenance is planned, with the major part related to loading of the deep space hibernation application software (DSHAP). Afterwards, contact will be maintained only on a weekly basis.

In the **Commissioning Phase 2** (about 1.5 months) the spacecraft and payload check-out activities will be completed.

The **Earth Swing-by 1 Phase** starts about 4 months before the encounter, because at 3 months before the swing-by the second deep space manoeuvre DSM2 shall be performed. Its size depends on the launch day. The fly-by distance will be 4290 km for launch at begin of the launch window, but can be as low as 1240 km towards the end of the launch window.

About 1 month after the Earth swing-by the **Cruise Phase 2** towards Mars begins, which is nearly 1.5 years long. It is divided in several phases, where the S/C is put in Earth-pointing Near Sun Hibernation Mode (NSHM), and where contact is established via MGA X-Band only once per month. Between the NSHM periods there will be the regular half-yearly payload and AOCMS checkouts and maintenance activities. In addition, a test of the Sun-pointing NSHM is performed, which may be used in the deep space phase as back-up to the spinning mode DSHM. A seven weeks solar conjunction phase takes place in March/April 2006, during which the S/C stays in normal operational mode.

The **Mars Swing-by Phase** (7 months) begins some six months prior to the swing-by, with the preparation for the first Deep Space Manoeuvre 1 month later. The swing-by altitude will be 200 km. A 14 min RF black-out and a 24 min eclipse will occur. This requires special preparations of the S/C to avoid that normally active surveillances, which are related to the presence of the Sun, trigger transition to back-up mode.

During the **Cruise Phase 3** (Mars to Earth 3, about 1/2 year) the spacecraft will be set in Earth-pointing NSHM, with ground contacts on a monthly basis.

The **Earth Swing-by 2 Phase** (3 months) begins with AOCMS and payload checkout and maintenance activities. The Earth fly-by distance will be about 14000 km.

At the begin of **Cruise Phase 4** (Earth 2 to Earth 3, 21 months) the smallest Sun distance is encountered with 0.88 AU. Due to the high solar array temperatures the output voltage may become critically low, therefore the MPPT will be disabled for a short period as a precautionary measure. Only 2 NSHM phases of around 5 months duration are planned in this cruise phase. In between there will be the regular half-yearly payload and AOCMS checkouts and maintenance activities and a 6 weeks solar conjunction period. In addition the DSM4 manoeuvre is prepared and executed.

The **Earth Swing-by 3 Phase** (3 months) begins two months before the swing-by with payload and AOCMS checkouts and maintenance activities. The Earth fly-by altitude is only 300 km, so that the air-drag will not be negligible.

In the **Cruise Phase 5** (13 months) only one NSHM phase of about 5 months is planned in the middle, which is surrounded by payload and AOCMS checkouts and maintenance activities. A solar conjunction phase of seven weeks duration ends about 2 months before the end of the cruise phase.

The **RVM-1 Phase** (6 months) begins 4 month before the first rendezvous manoeuvre (RVM1) with spacecraft check-out and ground based navigation. The spacecraft is now more than 4 AU away from the Sun, and the available solar array power has to be used economically. This means, that power sharing strategies have to be applied (e.g. tank heaters shall be switched off while the downlink is switched on), certain equipment has to be operated in a reduced power mode (e.g. SSMM, reaction wheels), and other equipment shall not be operated simultaneously (HGA and solar array pointing mechanisms). To determine the really available power margins, and thereby the necessary power saving strategies, a test of the available solar array output power needs to be performed in this phase (by increasing the spacecraft loads until the batteries fall into discharge mode). The deterministic deep space delta-v manoeuvre is performed at 4.4 AU, and shall aim the spacecraft to the desired point of the comet orbit matching manoeuvre (RVM2) after the deep space hibernation. Before the RVM1, which is a very large manoeuvre with over 500 m/s delta-V, the second RCS pressurisation has to be performed. The phase ends with post manoeuvre trajectory determination on ground and a subsequent trajectory trim manoeuvre, if required. The preparations for the Deep Space Hibernation Phase start at about 4.5 AU from the Sun, in order to have some operational margin for the latest entry at 4.6 AU. The spacecraft will be spin-stabilised at 4°/s so that the AOCMS can be switched off. Correct attitude and spin-rate set-up can be verified on ground by the HGA carrier downlink signal strobing over the Earth. Then ground can send the final authorisation to proceed into the hibernation mode, otherwise the S/C would return automatically to Safe Mode.

During the **Cruise Phase 6** (2.5 years) the spacecraft passes the aphelion of its orbit at 5.33 AU Sun distance. During this phase the spacecraft is almost entirely passive except of receivers/ decoders, power supply, heaters and two Processor Modules with one RTU. The AOCMS processor is in stand-by mode and all AOCMS equipment is off. The DMS processor runs the Deep Space Hibernation Application Program (DSHAP), which performs a cyclic refreshing of the hibernation heater configuration, a protection against an undetected mainbus undervoltage causing heater LCLs to trip off. It also watches for the pre-programmed hibernation end time, when it initiates and controls the hibernation exit operations up to thruster based Safe Mode. The reaction wheels have to be re-commissioned after this long phase, which they had to survive without heater power. This will be performed under ground control as well as the subsequent operations to return to normal operational mode.

The **RVM-2 and Comet Approach Phase** (7 months) starts after the wake-up from Deep Space Hibernation at about 4.5 AU Sun distance. An earlier wake-up is not possible because of a solar conjunction just before. Comet detection activities can be performed with the navigation cameras and with the P/L Osiris camera, but probably the comet will be detected only after RVM-2 which is determined based on astrometric measurements. The RVM-2 manoeuvre, executed after 4 months at 4.0 AU, is very large (over 730 m/sec) and will therefore be performed in four steps to reduce the relative velocity to the comet to about 50 m/s. It is expected that the comet will be detected at a distance of 100000 km (the Comet Acquisition Point, CAP). During the following comet Far Approach Phase the relative velocity is reduced further by a sequence of manoeuvres with decreasing magnitude, down to about 3 m/s at a distance of 1000 comet radii (the Approach Transition Point, ATP). In the Close Approach Phase the velocity is further reduced to below 1 m/s and the distance to 40 nucleus radii, which is the Orbit Insertion Point (OIP). The transition to the global mapping phase is achieved by a series of further small manoeuvres, in total about 1 m/s, to reduce the distance down to that required for global mapping (10 - 25 comet radii) and to circularise the orbit. This Global Mapping Insertion point (GMI) is reached about 3 months after start of RVM-2.

The **Global Mapping and Close Observation Phase** (58 days) starts at the GMI. The comet mapping will be performed from an elliptical orbit around the comet with altitudes between 5 and 25 comet radii (depending on mass, shape and size of the comet). The phase shall achieve a mapping of at least 80% of the illuminated surface. The mapping allows the determination of the size, shape, rotation axis and period of the comet. Finally images of selected points from low altitudes (below 1 comet radius) are taken. The orbit planning must ensure, that there is no risk of a collision of the spacecraft with the comet, in case of an anomaly (e.g. loss of communication).

The **Surface Science Package Delivery and Relay Phase** (27 days) is characterised by complex spacecraft navigation and manoeuvring. The landing site has been selected during the previous close observation phase. From this the ejection conditions, namely the delivery orbit, attitude, and separation velocity can be defined. The delivery orbit is reached in two steps: first a change of the orbit plane from the close observation orbit plane to the delivery orbit plane, then an injection into the delivery orbit. The orbit plane change is carried out with use of an intermediate circular orbit with a radius big enough to save propellant and to allow synchronisation with the comet rotation phase, such that the target landing site can be reached. After the successful landing of the SSP the spacecraft receives the scientific data from the comet surface and transmits it to Earth. The operational phase of the SSP is foreseen to be 5 days, during which the visibility between orbiter and SSP shall be maximised by appropriate manoeuvring. The landing of the SSP on the comet takes place at a Sun distance of 3 AU.

Comet Escorting Phase: After the comet mapping and SSP activities, the spacecraft will spend more than one year in orbit around the comet, until the perihelion passage at around 1.24 AU and back out again, until 2 AU Sun distance is reached. The major scientific goals during this phase are to monitor the nucleus, and its dust and gas jets, and to analyse dust, gas and plasma in the inner coma. End of the year 2015 is the planned end of the mission.

The Run-down Phase does not belong to the nominal part of the mission. The mission objectives have been achieved and ESOC may want to make some spectacular or risky operations, which might be of scientific or technological interest, like going deep into the dust of the comet or even landing on it (our favourite!).

Solar Conjunction Phases

Other mission phases, which result from the orbit geometry and interfere with the above operational phases, are the solar conjunctions. Two types of conjunctions occur throughout the mission:

- Solar Oppositions: The Earth is between spacecraft and Sun, resulting in a degradation of the command link to the spacecraft.
- Superior Solar Conjunctions: Sun is between spacecraft and Earth, resulting in a degradation of the command and telemetry link to/from the spacecraft.

Table 1-3 shows the 13 solar conjunction phases throughout the mission with type, begin and duration of the conjunction, as well as the concerned mission phase. The phases are defined as the periods, during which the Sun-spacecraft-Earth (SSCE) angle is below 5°.

No.	Type of Conjunction	Begin (Mission Day)	Duration (Days)	Mission Phase
1	Conjunction 1	755	48	Cruise 2
2	Opposition 1	1515	11	Cruise 4
3	Conjunction 2	1755	41	Cruise 4
4	Opposition 2	2059	11	Earth Swing-by 3
5	Conjunction 3	2403	50	Cruise 5
6	Opposition 3	2604	39	RVM1
7	Conjunction 4	2789	64	Cruise 6, DSHM
8	Opposition 4	2986	49	Cruise 6, DSHM
9	Conjunction 5	3169	69	Cruise 6, DSHM
10	Opposition 5	3371	46	Cruise 6, DSHM
11	Conjunction 6	3619	60	Cruise 6, DSHM
12	Opposition 6	3801	28	RVM2
13	Conjunction 7	3940	40?	Comet Escort

Table 1-3: Solar Conjunction/Opposition Phases

1.8. Mission Control Concept

The ROSETTA mission represents a great challenge for spacecraft design and operation. During the mission several busy periods with manoeuvring and operations around planets, asteroids, and the comet alternate with long quiet cruise phases, where the spacecraft will be left in a hibernation mode without ground support. Beside the envisaged complex science operations the wide range of Earth and Sun distances, stringent pointing and navigation requirements, and last not least the anticipated reliability and safety for this long duration mission have driven design and operational concept. From this scenario a spacecraft design has evolved, which may best be designated as a 'three axis stabilised spinner', and which exhibits operational capabilities, flexibility and on-board autonomy features particularly suited for this interplanetary mission in order to maximise the science return.

The operations of the ROSETTA spacecraft and its payload and Surface Science Packages will be conducted under control of the ROSETTA Mission Operations Centre (RMOC) at ESOC, which also provides facilities and services to the scientific community for activity planning and provision of the scientific data. The ground station network consists of the New Norcia 35m station, to support all phases of the mission, the Kourou 15m station for the early phases and NASA/DSN stations (34m/70m) for support during critical operations, e.g. Lander delivery and relay phase as well as for emergency support.

Communications with the spacecraft are primarily performed via X-Band telecommand uplink and telemetry downlink through the HGA, which satisfies the high data rate requirements. The X-Band up- and downlink at any distance is also possible through a MGA as a back-up. At small Earth distances two S-Band LGAs provide omni directional coverage and serve also for emergency commanding up to maximum distance. For recovery operations S-Band up- and downlink is also possible through the HGA and a second MGA.

The general concept for operating the spacecraft is that all activities will be performed according to an on-board master schedule, which will be kept updated from ground. This on-board master schedule executes the mission timeline by performing direct commanding or initialising On-Board Control Procedures (OBCPs). In addition to this nominal Mission Timeline (MTL) a Backup MTL is now available which allows to execute preloaded commands also after the occurrence of a Safe Mode.

The OBCPs perform on-board control functions and are written in a dedicated spacecraft control language. Procedures, which are essential for mission success, will be resident as part of the software code in PROM. The procedures can be modified on-board or uploaded from ground into an SSMM file, EEPROM, or working RAM, and may be defined to execute any command or control and monitoring function. For maximum operational flexibility and compensation of anomalous performance the on-board software is also accessible for modification, loading and dumping of memories, and it is possible to combine software stored in PROM, EEPROM, RAM, and SSMM for execution in RAM.

For direct commanding of the spacecraft (instead of command insertion into the on-board Mission Time Line for later verification before execution) it must always be taken into account that the spacecraft status, on which the new commands have been based, may be no longer valid when the commands arrive on-board. This means that meanwhile the spacecraft may have autonomously changed the switching status or mode following an on-board event, and the new commands are not suitable any more. The proposed solution is that any such direct commanding is performed by using OBCPs, which as the first step verify their applicability before starting commanding.

The on-board autonomy and operational capabilities are designed such that no telecommands from ground are required within a response time of less than 3 hours. After an anomaly, detected by the On-board Monitor or the AOCMS internal FDIR functions, the spacecraft will always first attempt to recover from the failure(s) and continue the planned operations. Only if this is not possible, the spacecraft will be configured to Safe Mode (X-axis Sun or Earth pointing), which includes payload switch off, HGA or HGA/MGA Earth pointing, and SA Sun pointing. This mode provides essential autonomy and fault management functions and is designed to ensure spacecraft and payload safety w.r.t. power and thermal requirements over nearly unlimited time, and guarantees command accessibility.

As a last emergency countermeasure, protecting against multiple failures already, independent hardwired detectors are implemented, which trigger a system alarm in case of solar array power shortage (discharge of batteries for a period longer than appr. 5 minutes). This will cause a reconfiguration of both, DMS and AOCMS, processors and other essential equipment, and finally Safe Mode will be established.

In case of a major anomaly on-board such that the Safe Mode cannot be established successfully, the spacecraft will enter the Survival Mode, in which the SAs are kept Sun pointing based on Sun sensor and thruster control with use of gyros for rate estimation and control. At AOCMS level this means the MGA Strobing Mode, as a sub-mode of SKM. In this mode the solar arrays will be driven to an offset angle from the +X-axis, which corresponds to the current Sun-S/C-Earth angle (SSCE), taken from a table stored on-board. During this rotation of the solar arrays the Sun will be maintained within a few degrees of the solar array perpendicular. Finally, the MGA bore-sight will be pointing at an offset from the Sun direction, where the Earth can be found. The AOCMS then performs a small rate (0.017°/sec) around the Sun line. The OBCP "Survival Mode" will initiate S-band carrier downlink via the MGA, which can be picked up on ground once per revolution (may need DSN 70m station). Recovery from this mode is in principle performed by a command to start an OBCP which will stop the rotation at the right point and switch to X-band downlink for TM data transmission to ground.

Sufficient telemetry is transmitted to ground, or stored in the SSMM for later transmission, to allow verification of all mission operations, performance and trend evaluations, and investigations of on-board anomalies, for which event logs with relevant data are stored additionally in non-volatile memory.

During the interplanetary phases outside hibernation the spacecraft is, beside a few exceptions, always capable of keeping the HGA automatically pointed towards Earth for optimum communications, and simultaneously the solar arrays to the Sun and the instruments, if operational, to the target. The exceptions are the Earth fly-bys (HGA tracking not feasible, but link can be maintained via LGAs), and the close asteroid fly-bys (for a few minutes around closest approach the HGA tracking has to be suspended, while the instruments are kept pointing to the target). Shadowing of the solar arrays by the HGA or spacecraft body does normally never happen, but it cannot be excluded for the exceptional case of the SSP separation attitude and for attitude failure cases. As a consequence the solar generator is designed to cope with potential shadowing effects.

2. SYSTEM DEFINITION

Please note: The ROSETTA spacecraft was originally designed for a mission to the comet Wirtanen. Due to a delay of the launch a new comet (Churyumow-Gerasimenko) had been selected. The compliance of the design was checked and where necessary adapted for this new mission. Therefore in the following all the figures and characteristics for this new mission are used (like min and max distance to Sun).

The ROSETTA spacecraft consists of a box-type central structure, on which all subsystems and payload equipment are mounted, and two solar panels, which extend out both sides to a total span of about 32.7m tip to tip.

The spacecraft can be physically separated into two main modules, a Payload Support Module (**PSM**) and a Bus Support Module, (**BSM**). The Lander is attached to the rear face (-X) and a two-axes steerable HGA is mounted on the front (+X) face. The 2 solar wings extend from the side (+/-Y) faces.

The top of the spacecraft accommodates the payload instruments and the base of the spacecraft the subsystems.

The payload composition is specified in Table 2-1

Name	Instrument Description
Remote Sensing Instruments	
ALICE	ALICE is a classical grating spectrograph, incorporating a 40-mm telescope, an ellipsoidal holographic diffraction grating, and a two-dimensional imaging photo-counting micro-channel plate detector on a Rowland circle.
MIRO	The MIRO Instrument for ROSETTA is a dual-frequency heterodyne spectrometer, operating at millimeter (230-242 GHz) and sub-millimeter (547-577 GHz) wavelengths.
VIRTIS	VIRTIS is a Visible and Infrared Thermal Imaging Spectrometer which houses two quasi-independent instruments: VIRTIS-M (Mapping), a visible and infrared imaging spectrometer and VIRTIS-H (High-resolution), an Echelle spectrometer.
OSIRIS	OSIRIS consists of a Wide Angle Camera (WAC), with a 12 deg field of view and a scale of 100 mrad/px, and a Narrow Angle Camera, with a 2.35 deg FoV and a scale of 20 mrad/px.
Composite Analysis Instruments	
Cosima	The COSIMA sensor is a time-of-flight secondary ion mass spectrometer (TOF-SIMS) equipped with a dust collector, a primary ion gun, and an optical microscope for target characterisation. The instrument has a mass resolution greater than 2000.
MIDAS	The MIDAS collects dust on targets that are presented through an aperture to free space. MIDAS will be able to measure the size and texture of individual cometary particles and their building blocks in the range of 4 nanometre to 5 micrometer.
ROSINA	The ROSINA experiment is a combination of three sensors, optimised for different targets while providing overall redundancy: DFMS, RTOF and COPS.
Cometary Dust & Nucleus Structure Analysing Instruments	
Consert	CONSERT is an electrical wave propagation experiment through the comet to gather information about the geometrical structure and electrical properties of the deep interior of the comet nucleus.

Name	Instrument Description
GIADA	The GIADA consists of two sensors: the grain velocity and momentum measurement system (GDS + IS) and the deposition system (MBS).
Plasma Analysing Instruments (Plasma Package, RPC)	
LAP	The LAP is a pair of classic LANGMUIR probes that can be operated in three modes: the electron collection mode, positive ion collection mode, and cross-correlation mode.
IES	The IES consists of two electrostatic analysers, one each for electrons and ions. It counts the charged particles as a function of energy, time, and angle of arrival.
MAG	The MAG is comprised of two ultra-light tri-axial fluxgate magnetometers, mounted about 0.25 m apart on the spacecraft boom pointing away from the comet nucleus. They will measure the magnetic field in both nominal and high-resolution.
ICA	The ICA uses the same type of elevation analyser as the IES. It analyses the ions in both direction and mass per charge simultaneously.
MIP	The MIP measures the electrical coupling of a transmitting antenna and a receiving antenna, and identifies the plasma density, temperature and drift velocity from the features of the frequency response.
Special Payload	
SREM	SREM is a radiation monitoring instrument
RSI	Radio Science Investigation of the gravity fields and dynamics and of the cometary nucleus and coma using the S/C TT&C subsystem.

Table 2-1: Rosetta Payload

A coarse overview on the ~~T~~he spacecraft main characteristics is ~~summarised~~ given hereafter:

Total launch mass requirement	30654~~,0~~ kg
Propellant mass:	1718~~644,13~~ kg
Overall size (xyz) Launch configuration SA deployed	 225x256x318 cm 32.7 m tip-to-tip
power provided by SA	at max dist from sun ~~(5.3 AU)~~: 440 W ~~at min dist from sun (1 AU): 7400 W~~
energy provided by 3 Batteries (EOL)	500 Wh
data management	operation of s/c according to an on-board master schedule and in real-time via ground-link

The summary of the payload mass allocation is taken from the Experiment IDs, the power values have been extracted from theDetails can be found in the corresponding budget tables

2.1. System Description

An overview of the design of the ROSETTA spacecraft is given in Figure 2-1:...Figure 2-4.

Figure 2-1 and Figure 2-2 shows the spacecraft in launch configuration and Figure as well as Figure 2-4 in flight configuration. Notable for the flight configuration are the huge solar arrays, which extends to a total width of approximately 32m in y-direction. The solar arrays can be rotated about the y-axis to provide optimal orientation w.r.t. the sun. A further highlight is the High Gain Antenna (HGA) with a dish diameter of 2.2 m. The HGA can be rotated in two axes to allow for a large pointing range.

Most of the payload is mounted on the PSM, with instruments sensors boresight aligned with the spacecraft +z direction, which will be pointing towards the comet nucleus during the approach phase.

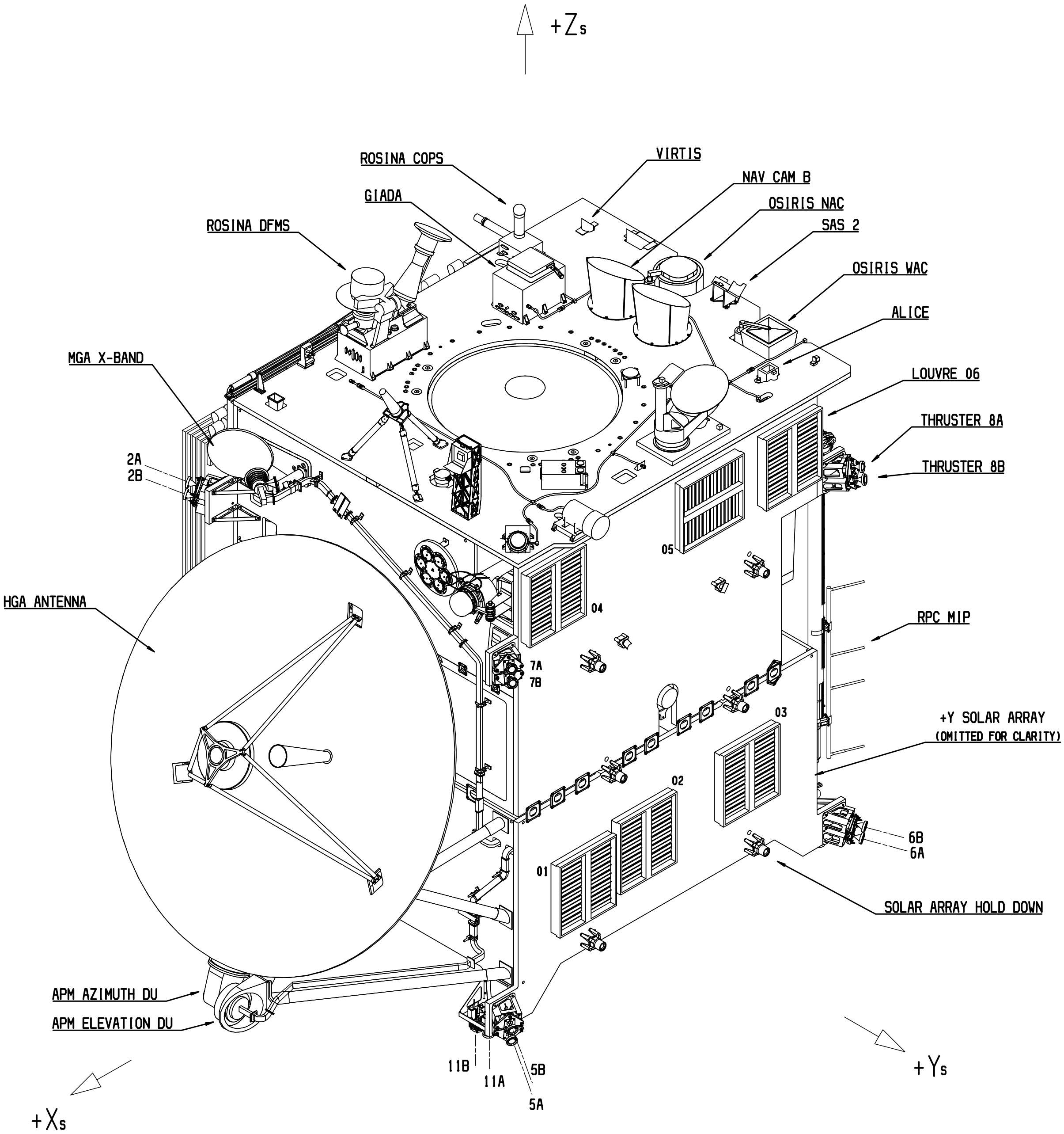


Figure 2-1: ROSETTA in Launch Configuration (+X face)

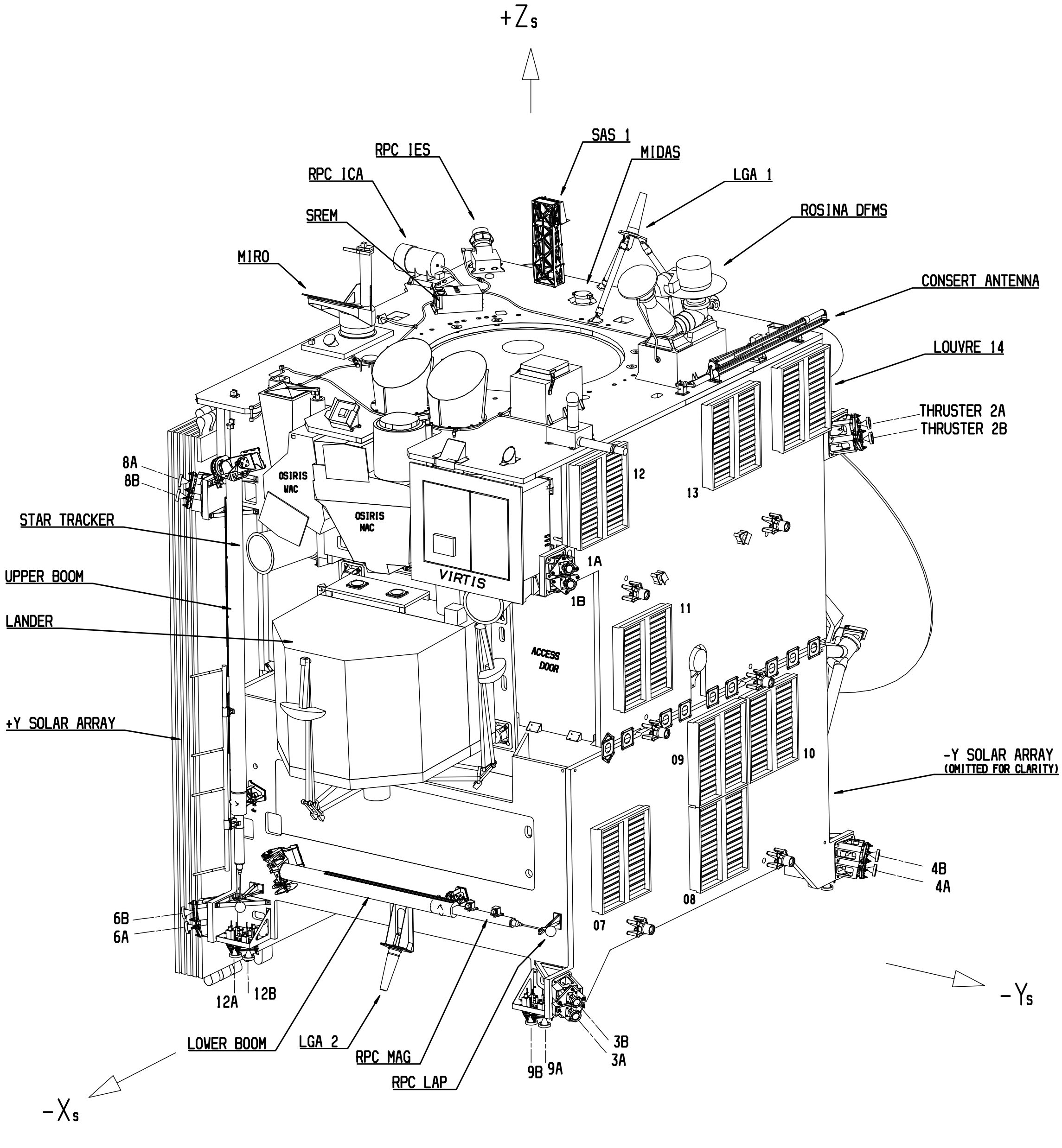


Figure 2-2: ROSETTA in Launch Configuration (-X face)

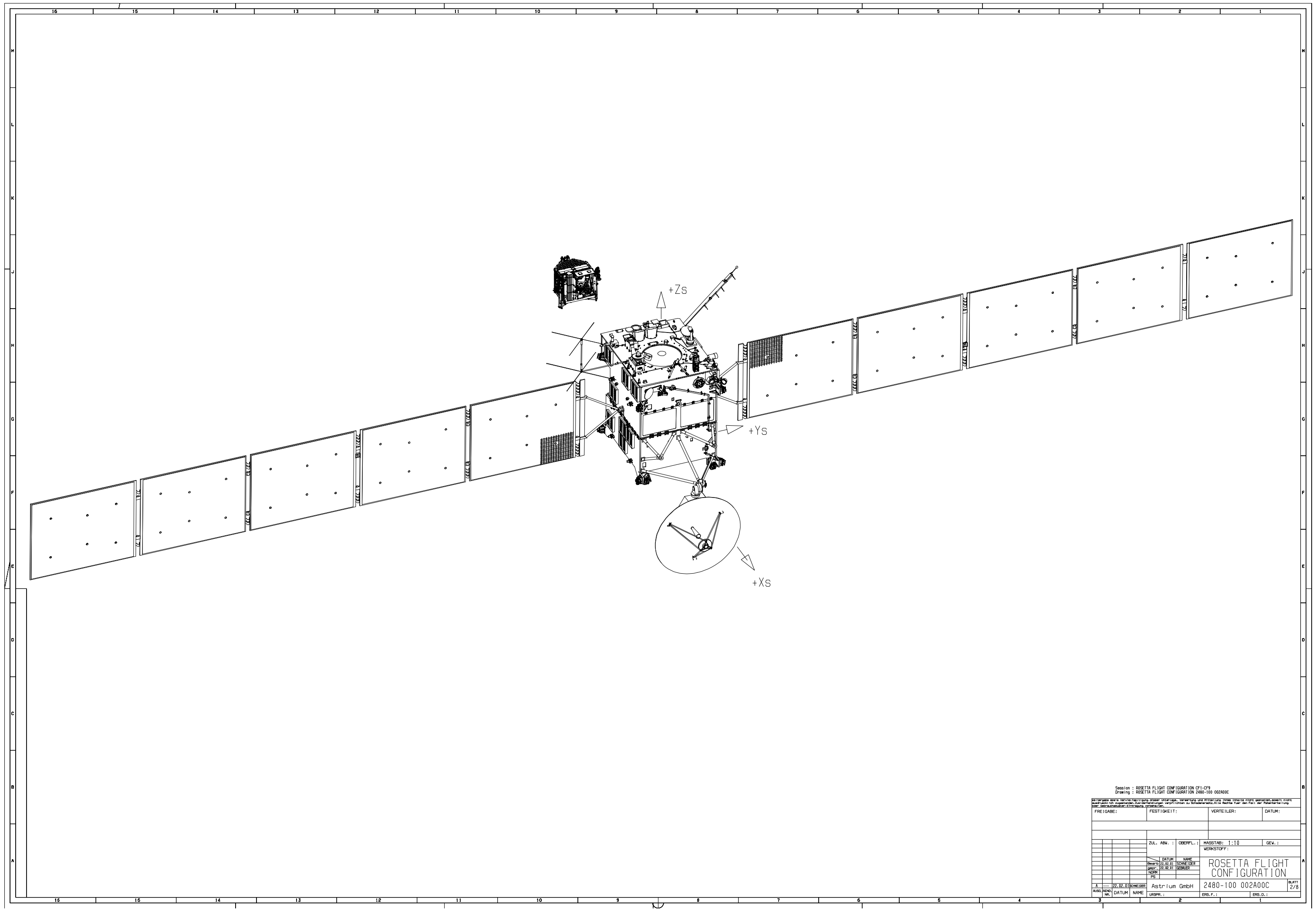


Figure 2-3: Front View, Deployed Configurations

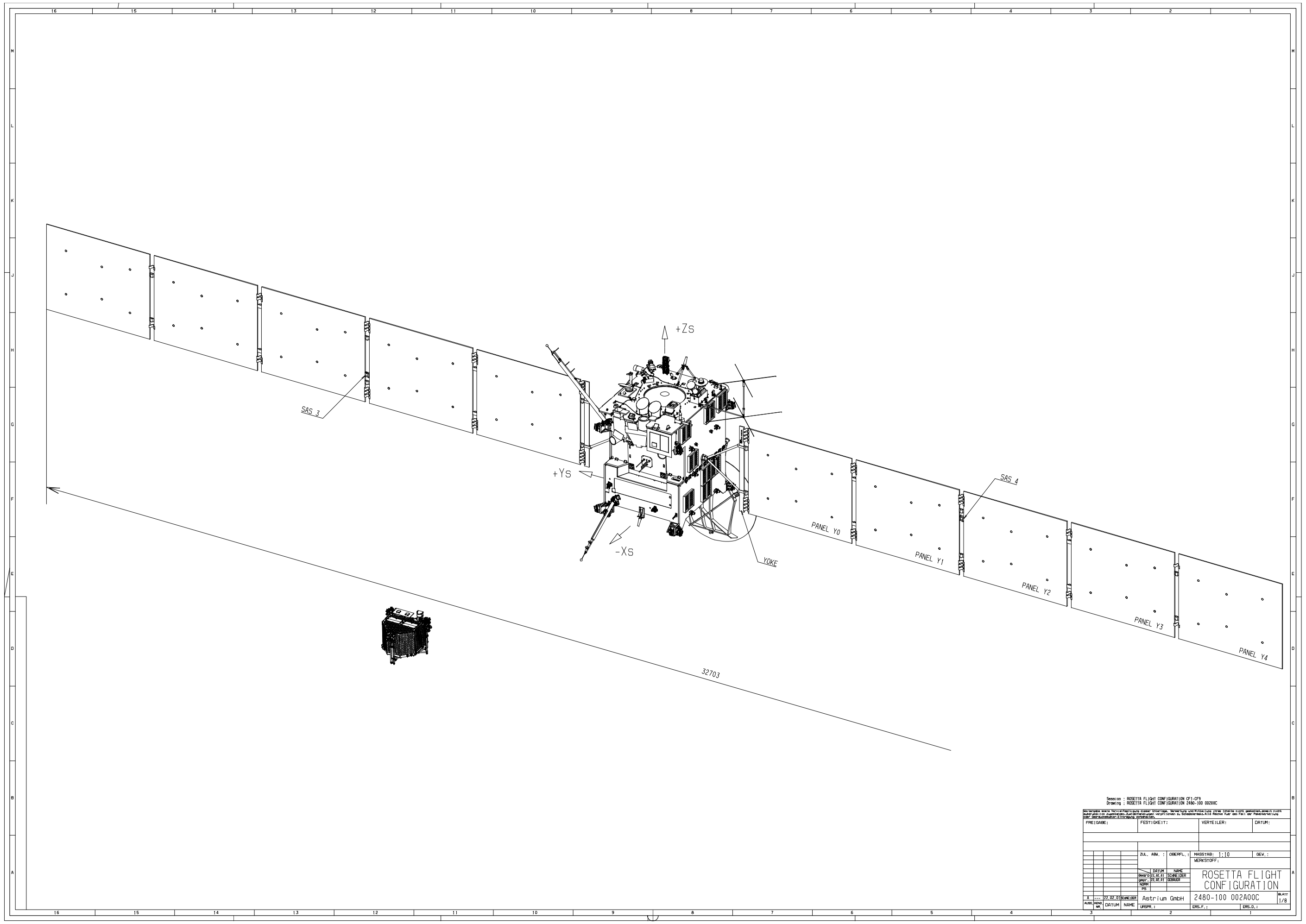


Figure 2-4: Rear View Deployed Configurations

2.1.1. Subsystem Accommodation

As already described, the majority of the subsystem equipments are accommodated together within the BSM. The electronic units are located mostly on the Y panels so that their thermal dissipations are closely coupled to the louvred radiators on the sidewalls. So far as practical, functionally related groups are located close together for harness, integration and testability reasons. Where possible, equipments are positioned towards the +X half of the S/C to counterbalance the mass of the Lander on the opposite side.

Some subsystem equipments are deliberately located on the PSM. These include the PDU and RTU for the payload, the NAVCAMS, two of the SAS units and the +Z LGA. The PDU and RTU are located closer to the payload instruments to reduce harness complexity and mass, and the NAVCAMs and SASs and +Z LGA are located on the PSM for field of view reasons. Other subsystem equipments have been located on the PSM sidewalls as a result of BSM equipment/harness growth, or thermal limitations. These comprise the STR electronics and SSMM as well as the USO.

The subsystem accommodation is presented in Figure 2-5 to Figure 2-9.

The RCS subsystem comprises tanks, thrusters and the associated valves and pipework. The main tanks are accommodated within the central tube while the helium pressurisation tanks are mounted on the internal deck. Most of the valves and pipework are located on the +X BSM, panel which becomes permanently attached to the BSM once RCS assembly is completed. Sixteen of the twenty-four thrusters are located at the four lower corners of the BSM. The remaining thrusters are located in 4 groups near the top corners of the S/C. They are installed as part of the BSM, but are attached to the PSM after PSM/BSM mating.

The Star Trackers are mounted on the –X shearwalls. The STR B is rotated by additional 10 degrees towards the -Z direction compared to STR A to avoid the VIRTIS radiator rim to be seen in its FOV. This location of the STRs is both thermally stable and mechanically close to the –X PSM panel which accommodates the instruments requiring high pointing accuracy. The reaction wheels are located on the internal deck which provides them with a thermo-elastically stable location.

A 2.2m diameter HGA is stowed face-outwards for launch against the S/C +X face (so it would be partially usable even in the event of a deployment failure). After deployment, the HGA can be rotated in two axes around a pivot point on a tripod assembly some distance clear of the lower corner of the S/C. This provides the HGA with greater than hemispherical pointing range. The two MGAs are fixed mounted on the S/C +X face, oriented in the +Xsc direction, as this is the most useful direction for a fixed MGA. The LGAs are located at the +Z and –Z ends of the S/C but angled at 30 degs to the Z axis. This accommodation provides spherical coverage with minimum need for switching.

The solar array comprises two 5-panel wings folded against the Ysc faces of the S/C for launch. Because the arrays are sized to operate at aphelion, the outwards facing outer panel can also generate useful power before array deployment.

Two Sun Acquisition Sensors are located on the solar arrays and another two on the S/C body. Their design and location of these also allow them to serve as fine Sun sensors.

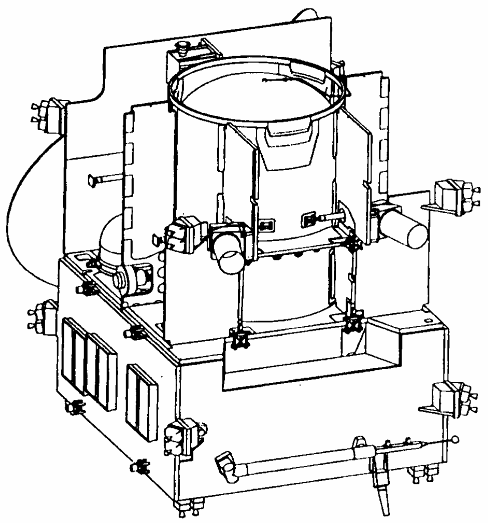


Figure 2-5: BSM Overview[1]

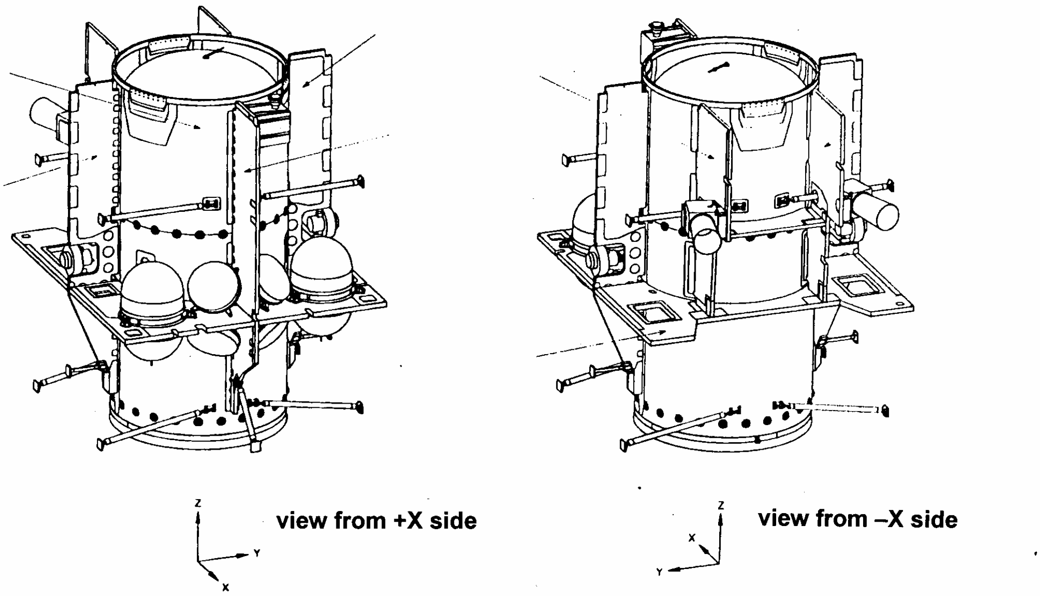


Figure 2-6: BSM Internal View[1]

[1] depicted is the StM. Note, that the lower thrusters have been relocated to the lower s/c corners in the PFM (see drawing 2480-100 001A00-4).

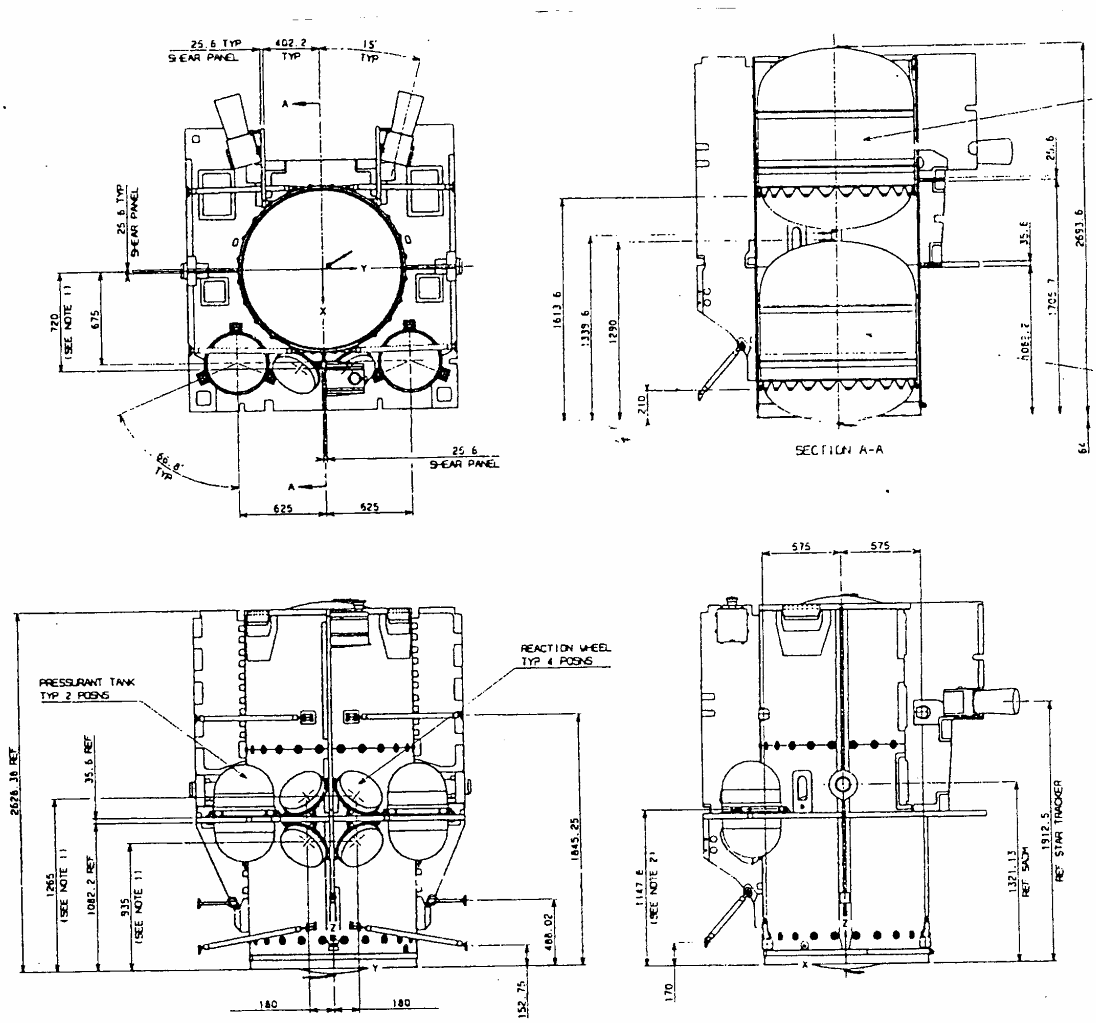


Figure 2-7: BSM Internal Layout[1]

"

[1] depicted is the StM

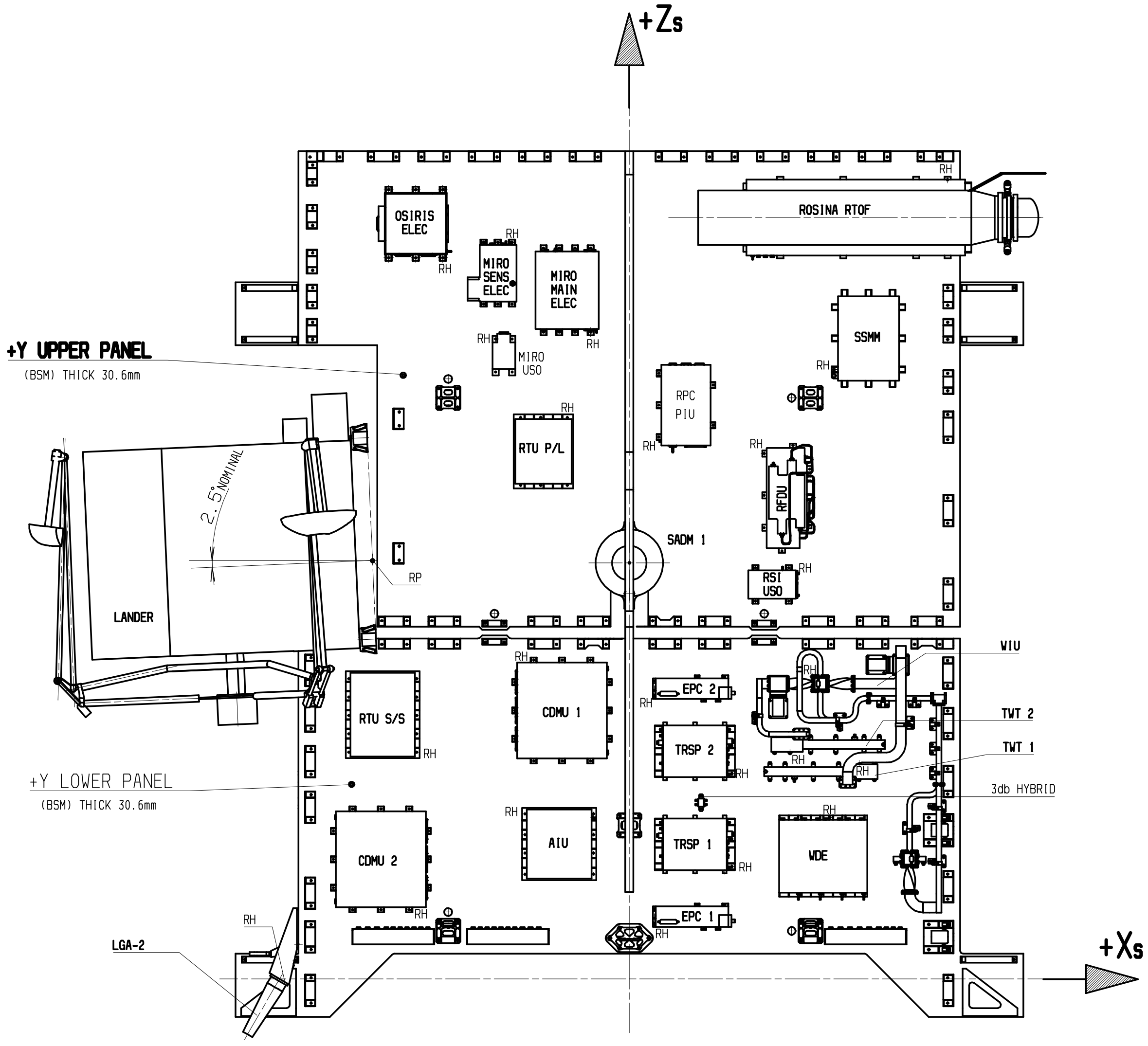


Figure 2-8: +Y Panel Layout

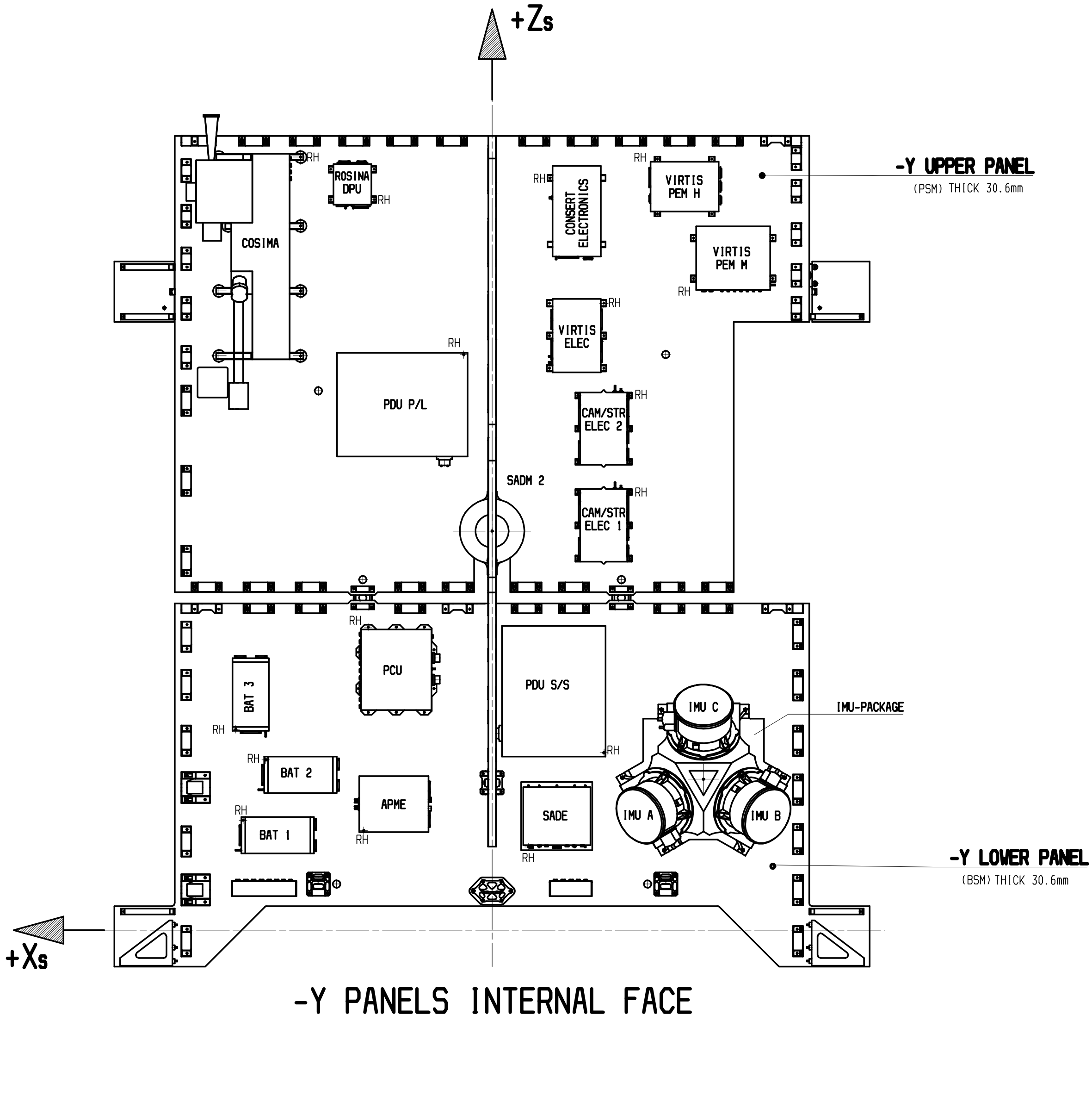


Figure 2-9: –Y Panel Layout

2.1.2. Structure Design

The ROSETTA platform structure consists of two modules, the Bus Support Module and the Payload Support Module (BSM and PSM) which can be handled independently. Mounted to the BSM is the Lander Interface Panel (LIP), which can be handled separately for the Lander integration. The overall configuration is illustrated in Figure 2-10.

The spacecraft structural design is based on a version with a central cylinder accommodating the two propellant tanks. The general dimensions are dictated on one hand by the need to accommodate the two large tanks, to provide sufficient mounting area for the payload and subsystems and the Lander, as well as being able

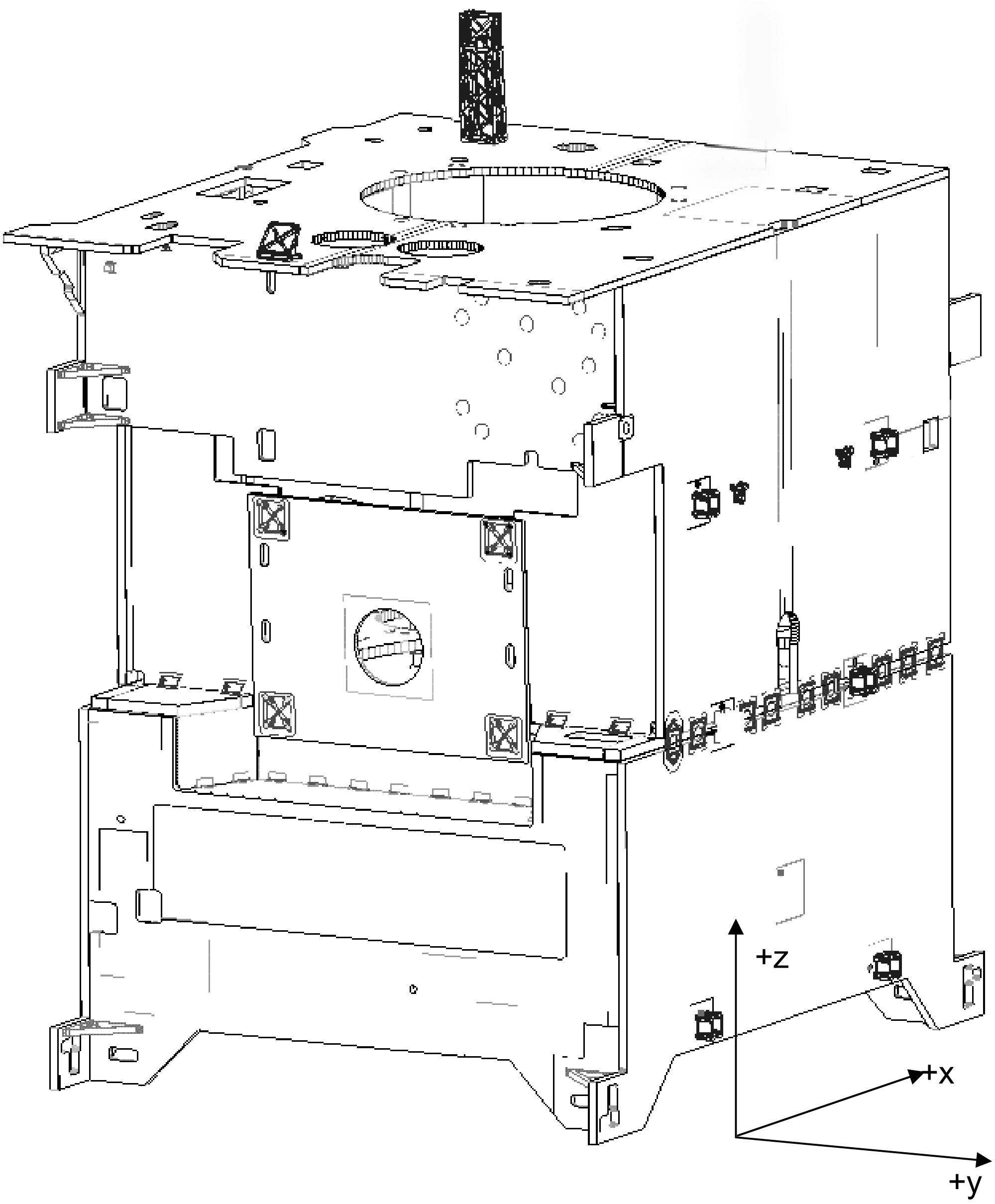


Figure 2-10: Overall Configuration

to accommodate two large solar arrays, and on the other hand by the requirement to fit within the Ariane 5 fairing.

The spine of the structure is the central tube, to which the honeycomb panels are mounted. The spacecraft box is closed by lateral panels, which are connected to the central tube by load carrying vertical shear webs and an internal deck.

The structure two main modules are shown below:

The Bus Support Module **(BSM)** accommodates most of the platform and Avionic equipment (see Figure 2-11).

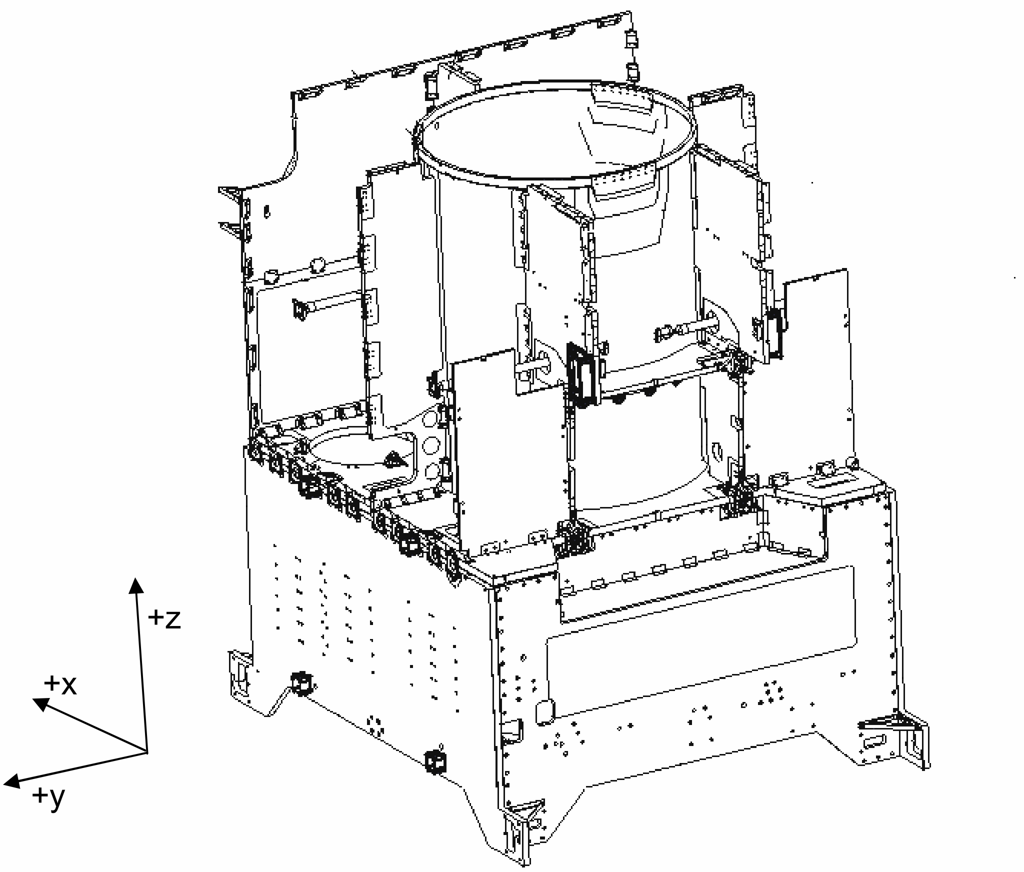


Figure 2-11: Bus Support Module Structure

The Payload Support Module (PSM) is accommodating all science equipment.

The PSM structure consists of the PSM +z-panel, the PSM –x panel, the PSM +y/-y panels and the Lander Interface Panel (LIP) as described in Figure 2-12.

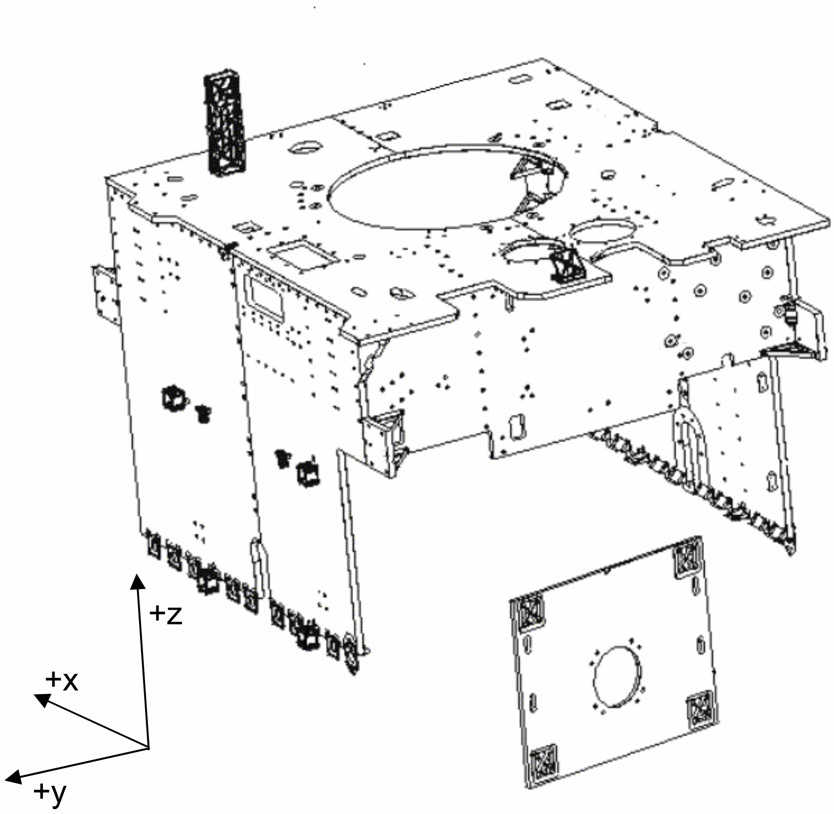


Figure 2-12: Payload Support Module Structure

Most instrument sensors are located on a single face, the +Z-panel, with the exception of VIRTIS and OSIRIS mounted on the -X panel to allow for the accommodation of their cold radiators, Alice mounted on PSM -X and COSIMA mounted on the PSM -Y panel. The P/L electronics are mounted on the +Y and -Y side of this module for heat radiation via Louvers.

Special supports are provided by the structure for:

Solar Array

They provide stiff and accurately positioned points for the solar array hold down points and for solar arrays drive mechanisms.

Reaction Wheels

The brackets provide stiff wheel support with alignment capability. All 4 RW brackets are mounted together between the +X shear wall and the central deck building one compact bracket unit which provides high stiffness and stability.

Propellant Tanks

The two tanks are mounted via a circumferential ring of flanges to a reinforced adapter ring on the tube with titanium screws.

Helium Tanks

The two helium tanks are mounted on the main deck of the BSM. They are attached by an equatorial fixation in the middle of the tank through internal deck holes.

Thrusters

Thrusters on the side of the spacecraft are mounted on lateral panel extensions with aluminium machined brackets ensuring the angular position of the thrusters. Thrusters underneath the spacecraft (-Z pointing thrusters) are mounted on brackets on the corners of the +/-Y panels.

High Gain Antenna

The HGA is stowed against the +X panel, in areas stiffened by the +/-Y panels and the HGA support tripod. After launch, the HGA is deployed and is connected to the S/C by the support tripod only. The axis Antenna Pointing Mechanisms, fixed on the tripod, are located close to the edge of the HGA.

Gyros

A single bracket provides stiff gyro support and alignment capability and orientates the 3 IMUs in the requested angular orientation The bracket is mounted on the -Y BSM panel for thermal dissipation reasons.

2.1.3. Mechanisms Design

The ROSETTA mechanisms comprise the following major equipments:

- Solar Array Drive Mechanism (SADM)
- HGA Antenna Pointing Mechanism (APM)
- HGA Holddown & Release Mechanism (HRM)
- Experiment Booms & HRMs
- Louvres (mechanical elements)
- Solar Array Deployment Mechanisms

Solar Array Drive Mechanism (SADM)

The SADM performs the positioning of the Solar Array w.r.t. the Sun by rotation of the panels around the spacecraft Y-axis. There are two identical SADMs on both sides of the spacecraft, which can be individually controlled. The control authority rests with the AOCMS subsystem, which always 'knows' the actual attitude and Sun direction and is therefore in the position to determine the required orientation of the solar panels. The positioning commands are routed from the AOCMS I/F Unit via the SADE (SADM-Electronics) to the SADM.

The Solar Array rotation is limited to plus and minus 180 degrees to the reference position.

The array zero position is as defined in Figure 2-13. At zero (reference) position the array wing is aligned such that the array surface is in the spacecraft Y-Z plane, with the face (cells) aligned such that the array normal is parallel to the +X axis of the spacecraft.

This means that in stowed configuration (i.e. launch configuration) the array position of the array on the +Y panel is -90 degrees and on the -Y panel +90 degrees.

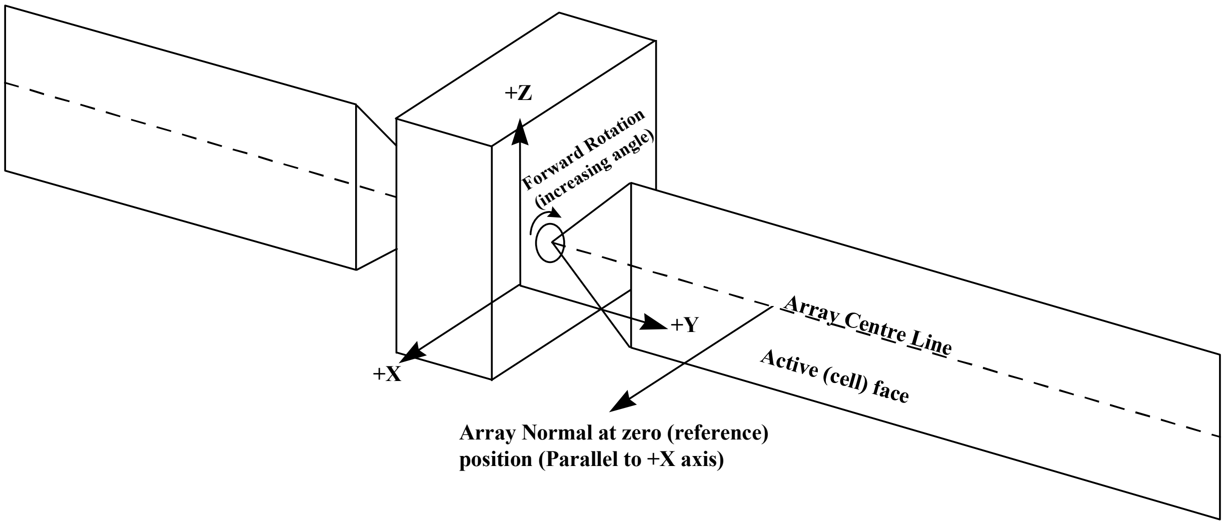


Figure 2-13: + Y Solar Array Drive Reference Axis

The Solar Array Drive Mechanism baseline design comprises the following major components:

- Housing structure from aluminium alloy
- Main bearing, pre-loaded angular contact roller bearing
- Drive unit consisting of a redundantly wound stepper motor, gear-reduction unit, anti-backlash pinion, and final stage gear ring
- Redundant position transducer and electronics, harness and connectors.
- Mechanical end-stop for ±180° travel limit with redundant micro-switches (4 in all)
- Redundant electrical power and signal harnesses, and connectors
- Twist capsule unit, allowing ±180° electrical circuit transfer
- Thermistor for temperature reading, with harness.

The SADM drive unit employs a "pancake" configuration with one single X-type ball-bearing to provide high moment stiffness and strength within a compact axial envelope. The central output shaft is of hollow construction, providing sufficient space to accommodate the power and signal transfer harness and a twist capsule allowing ±180° rotation of the harness. The drive unit contains a position transducer and a drive train.

The Solar Arrays Drive Electronic is intended to manage two Solar Array Drives that can be rotated so as to get the maximum energy from the solar cell panels-.

HGA Antenna Pointing Mechanism (APM)

The APM is a two-axes mechanism which allows motion of the HGA in both azimuth and elevation. The control authority rests with the AOCMS subsystem, which always ‘knows’ the actual attitude and Earth direction and is therefore in the position to determine the required orientation of the antenna. The positioning commands are routed from the AOCMS I/F Unit via the APM-E (APM-Electronics) to the APMM.

HGA elevation rotation is physically– limited to +30° / -165° from the reference position (after deployment). Before and during deployment the range is -207° and +30°.

HGA azimuth rotation is physically limited to +80° / -260° from the reference position. Operational constraints taking into account plume impingement are discussed in section §3.5.5.

The main functions of the APM are:

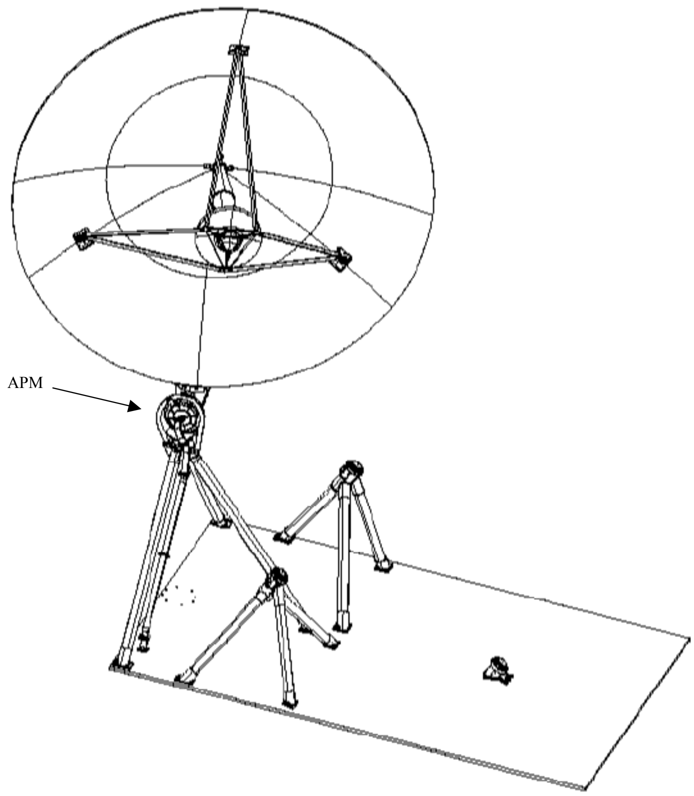
- Allow accurate and stable pointing of the antenna dish through controlled rotation about azimuth and elevation axes.
- Minimise stresses on the waveguides by acting as load transfer path between the HGA and the spacecraft.

It consists of three main components:

- The motor drive units (APM-M) and RF Ancillary Equipment (Rotary Joint)
- The support structure (APM-SS).
- The electronic control of these units (APM-E).

The APM-M is– mounted between the antenna dish and the APM-SS as shown in Figure 2-14.

For thermal reasons the elements of the APM-M and APM-SS and the Antenna HDRMs are covered with MLI.



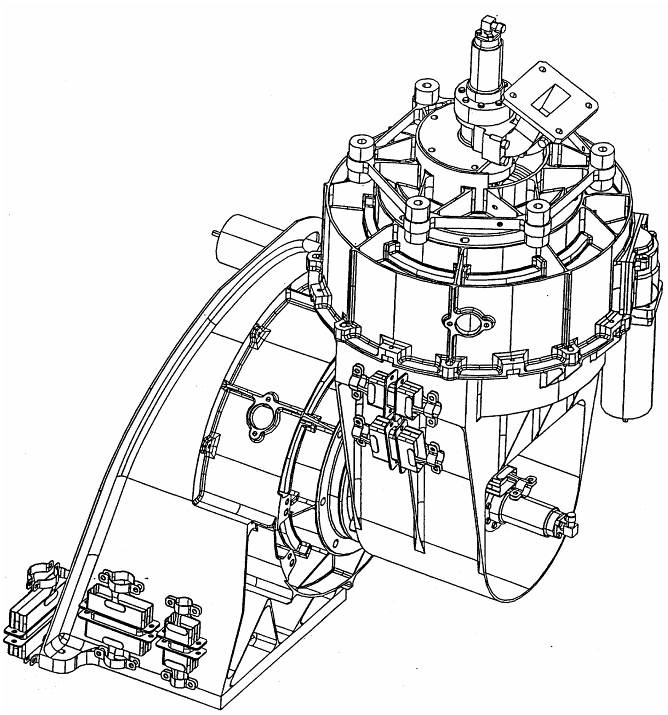


Figure 2-14: HGA in deployed configuration showing the complete HGA Assembly and the APM-M

Experiment Boom Deployment plus Hold-down and Release Mechanisms

Two deployable experiment booms support a number of different lightweight sensors from the plasma package which need to be deployed clear of the S/C body. These booms are deployed at ~~the~~ begin of the mission after Launch.

Each boom consists of a 76 mm dia CFRP tube. The lower boom is approximately 1.3 m long and the upper boom 2m.

The boom deployment is performed by means of a motor driven unit. The deployment mechanism consists of:

- Hinge, Motor Gear Unit, Coupling system, Latching system and Position switches.

The Hold down and release mechanisms, one per boom, has the following characteristics:

- Three Titanium blades to allow relative displacement in the boom centreline direction. This reduces the mechanical and thermo-elastic I/F forces.
- The separation device is the Hi-Shear low shock Separation Nut SN9422-M8

Louvres

The Rosetta Thermal Control Subsystem contains 14 louvers with 2 different set points which are located on the S/C Y walls in front of white painted radiators. The louvers are designed, manufactured and qualified by SENER.

The mechanisms of the 16 blade louver are the 8 temperature dependent bi-metal springs (actuators), which supply the fundamental function of the louver. The actuators are driving the louver blades to its end stops for the defined fully open / fully closed temperature set points.

More details about the louver design are described in [RD1]

Solar Array Deployment Mechanisms

Refer to chapter 2.1.9 .

2.1.4. Thermal Control Design

Thermal Control Concept

The thermal control design is driven on one side by the low heater power availability together with the low solar intensity in the cold case, and on the other side by the hot cases characterised by high dissipation of the operational units and high external heat loads.

The thermal control concept mainly utilises conventional passive components supported by active units like heaters and controlled radiative areas, using well proven methods and classical elements. An overview of the concept is shown in Figure 2-15.

This concept can be characterised as follows :

- Heat flows from and to the external environment are minimised using high performance Multi-Layer Insulation (MLI).
- Most unit heat is rejected through dedicated white paint radiator, actively controlled by louvers, located on very low Sun-illuminated +/-Y panels.
- High internal emissivity compartments reduce structural temperature gradients.
- Individually controlled instruments and appendages (booms, antennas,...) are mounted thermally decoupled from the structure.
- High temperature MLI is used in the vicinity of thrusters.
- Optimised heaters, dedicated to operational, and hibernation modes, are monitored and controlled to judiciously compensate the heat deficit during cold environment phases.

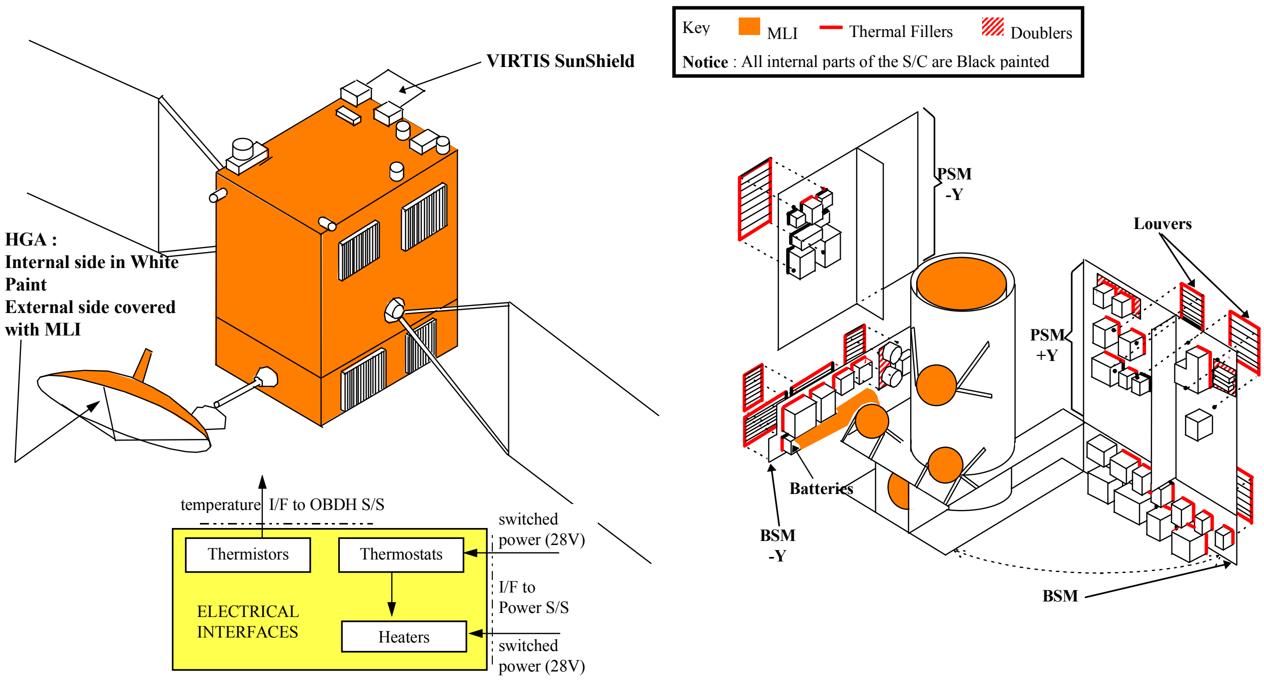


Figure 2-15: Thermal Control Configuration Exploded View

Thermal control design

The thermal control subsystem (TCS) design is optimised for the enveloping design cases of the end of life comet operations and the aphelion hibernation. From the overall mission point of view the deep space hibernation heater power request is the most critical thermal design case. This heater power request is dependent on the radiator sizing which need to be performed for worst case end of mission conditions. The very strong heater power limitation implies that to a certain extent constraints in the operation and/or attitude need to be accepted for hot case.

The TCS uses a combination of selected surface finishes, heaters, multi-layer insulation (MLI) and louvres to control the units in the allowable temperature ranges. The units are mostly mounted on the main ± Y panels of the spacecraft (and +Z for experiments), with interface fillers to enhance the conductive link to the panel for the collectively controlled units. The individually controlled experiments are thermally decoupled from the structure.

Generated heat by the collectively controlled units is then rejected via conduction into the panel and subsequent radiation from the external surface of the panel to space. These surfaces are covered with louvers over white painted radiators minimising any absorbed heat inputs and heat losses in cold mission phases. The louvers are selected as baseline being the best solution (investigated during phase B) for flexibility, qualification status and reliability.

VIRTIS and OSIRIS cameras are located at the top of the -X (anti-sun face) so that their radiator may view deep space. The top floor is extended over the top as a sunshield to prevent any direct solar illumination of these instruments, while the sun angle on the –Z side has to be limited to 80° for the same reason.

Any external structural surface not required as a radiator, (or experiment aperture) is covered with a high performance MLI blanket. The bottom of the bus module, which is not enclosed with a structural panel, is covered with a high performance MLI blanket used also as an EMC screen. In the areas around thrusters, a high temperature version of the MLI are implemented. All blankets are adequately grounded and vented.

The bi-propellant propulsion subsystem needs to be maintained between 0º to +45º throughout the mission. This is far warmer than some units, particularly when the spacecraft is in deep space hibernation mode. The tanks and RCS are therefore well isolated from the rest of the spacecraft to allow their specific thermal control.

The antennae and experiment booms are passively thermally controlled by the use of appropriate thermo-optical surface finishes and MLI. The mechanism for the HGA has similar appropriate passive control but also needs heaters to prevent the mechanism from freezing. It is thermally decoupled from the rest of the spacecraft to allow its dedicated thermal control.

The chosen solution for thermal control subsystem design uses well known and proven technologies and concepts. More details about the present TCS design are described in [RD1].

General Heater Control Concept

The operation of the TCS shall enable to maintain all spacecraft units within the required temperature range throughout the entire mission coping with all possible spacecraft orientations and unit mode operations.

The thermal heater concept uses the following major control features:

- Thermistor controlled (software) heater circuits, which are used to maintain platform, avionics and payload units within operating limits when these units are operating.
- The S/W heater design includes 3 control thermistors sited next to each other and uses the middle temperature reading to control the heater switching. This method is used in order to maximise the reliability of thermistor controlling temperature.
- Thermistors will be also used to monitor the temperature at each unit's temperature reference point (TRP) and at the System Interface Temperature Points (STP).
- Thermostat controlled (hardware) heater circuits, which are used to maintain platform, avionics and payload units within their non-operating (or switch-on) limits when these units are non-operating. These operate autonomously during satellite hibernation and Safe modes to ensure thermal control.
- The hardware heater circuits will be controlled by one thermostat (cold guard) connected in redundant circuit. The prime circuits without any thermostat will be powered as long as the relevant LCL is defined to be enabled. In the prime circuit a thermostat (hot guard) is included to prevent from overheating. In the event of a failure in the prime circuit the redundant circuit is automatically switched on when the temperature falls because it is permanently enabled.
- The lower set points for the thermostats (cold guard) are at the lower non-operating limits of units. The hysteresis of the thermostats is chosen to 35°C to limit the number of switching cycles for the long Rosetta mission. The higher set points of the prime thermostats (hot guard) is oriented to the upper operational temperature limit, but will still have an appropriate margin to that limit.
- Main and redundant heaters will be in separate foil heaters. It is necessary to define reserved unpainted areas on all units, which would nominally be black painted, specifically for the mounting of heaters.

All software and hardware heaters circuits will comprise a simple series connection of heaters with no parallel connections. The heater concept assumes prime and redundant heater elements in different mats. The heaters will be mounted directly onto units as this maximises the efficiency of the heating.

The sizing of the autonomous H/W heater circuits are based upon the following criteria:

- Payload heaters shall be designed to maintain non-operating temperature limits at 5.~~25AU~~ 33AU or switch-on limits at 3.25AU, whichever gives the greater heater power requirement,
- Platform and Avionics units OFF in hibernation have heaters designed to maintain non-operating temperature limits at 5.~~25AU~~ 33AU or switch-on limits at 4.~~70AU~~5AU, whichever is the greater power requirement,
- Platform and Avionics units ON during hibernation have heaters designed to maintain operating temperature limits at 5.~~25~~ 33 AU.

The suppliers of individually controlled (I/C) units ~~suppliers~~ shall size their S/W and H/W heaters by themselves and may install them where they wish in order to control their unit temperatures.

Micrometeoroid and Cometary Dust Protection

The micrometeoroid protection used for Rosetta is composed of 2 layers of betacloth and a spacer. This protection is only applied to the exposed +Z and -Z central tube areas of the propellant tanks as the spacecraft honeycomb structure will form an effective shield elsewhere.

The first betacloth layer is underneath the outermost layer of the S/C MLI acting as a bumper. To reach the agreed probability of no impact of 0.998 a separation of 50mm to the second betacloth layer (on top of the tank MLI) is needed. The micrometeoroid protection is part of the overall MLI design.

The cometary dust will have a velocity similar to that of Rosetta and so hypervelocity impacts are not an issue. Of more concern is the coating of the spacecraft surfaces by the cometary dust. Grounding of the external surfaces prevents differential charging but the whole spacecraft may be charged to some potential.

2.1.5. Propulsion Design

The propulsion subsystem is based on a pressure fed bipropellant type using MMH and NTO . It is capable to operate in both regulated and in blow-down mode and provides a delta v of ~~1990~~ more than 2100 m/s plus attitude control. It is able to operate in three axis and in spin stabilised mode (about the x-axis) provided that the spin rate does not exceed 1 rpm. The subsystem provides a high degree of redundancy in order to cope with the special requirements of the ROSETTA mission. The schematic is shown in Figure 5-92: RCS Subsystem Schematic. For explanation of the symbols in this figure see the more extensive description of the Propulsion subsystem in §5.4.2.

The materials used in the propulsion subsystem are proven to be compatible with the propellants– and their vapours the wetted area being mainly made of titanium or suitable stainless steel alloys.

The components and most of the pipework are installed on the spacecraft -X -panel by means of supporting brackets made of material with low thermal conductance. The lay-out is shown in Figure 5-94: Component accommodation on –x-X panel.

The subsystem has 24 10 N thruster for attitude and orbit control-. They are located such that they can provide pure forces and pure torques to the spacecraft. The 24 thrusters are grouped in pairs on the brackets, one of each pair being the main and one the redundant thruster. The subsystem allows the operation of 8 thrusters simultaneously.

The subsystem will be maintained within the temperature limits of the components. The mixture ratio- may be adjusted by tank temperature (i.e. pressure) manipulation in order to enhance thruster performance.

2.1.5.1. Operation

The propulsion subsystem will be operated in regulated mode as well as in blow down mode. The pressurisation strategy must take into account various constraints as the available propellant, the minimum inlet pressures for the thrusters, the maximum allowable pressures in the propellant tanks etc.

Calculations have been performed to demonstrate the capability of the subsystem to fulfil the mission requirements in terms of delta-v provision under the various constraints and also with respect to the requirement for additional 20% fuel.

2.1.6. Electrical & Functional System Design

2.1.6.1. Electrical Design Overview

The electrical concept of ROSETTA is shown in the block diagram Figure 2-16 and the detailed drawing Figure 2-17.

The system electrical and functional architecture is composed of 3 major blocks:

- the Avionics, including the DMS and AOCMS functions,
- the Platform including the power, TT&C, thermal control, mechanisms and propulsion functions,
- the payload and lander.

The external interfaces of this system are driven by the 3 main phases of its life cycle

- during AIT with the EGSE+
- during the count down and launch with the launcher
- in orbit with the Rosetta ground segment

The data management system is based on a standard OBDH bus architecture enhanced by high rate IEEE 1355 serial data link between the different Avionics processors and the SSMM. The OBDH bus is the data route for transmission of status telemetry, the acquisition of data and distribution of commands or command packets via the RTUs. A clear separation is made with regard to data acquisition between Instruments and subsystems. Instruments are accessed via a dedicated Payload RTU which is located on the Payload Support Module (PSM), subsystems are accessed via a dedicated Subsystem RTU which is located on the Bus Support Module (BSM).

On ROSETTA the design of AOCMS and DMS subsystems is merged in the Avionics system, which includes 4 identical Processor Modules (PM) located in 2 CDMUs. Any of the processor modules can perform either the DMS or the AOCMS task and has its own EEPROM where both S/W images (i.e. DMS and AOCMS) are stored. The one selected for the DMS function acts as the bus master. The one selected as the AOCMS computer is in charge of all sensors, actuators and HGA/SA drive electronics, which are accessed via serial links (MACS bus, RS 422, IEEE 1355) through the AOCMS I/F Unit (AIU). As in classical OBDH configurations the TC-decoder and Transfer Frame Generator (TFG) are included in each CDMU.

Each CDMU also includes a Reconfiguration Module and a Centralised Memory Module.

- Each Reconfiguration Module (RM) includes an oscillator used to generate clocks. The quadruple redundancy allows a “majority voting” (at least 2 out of 4) decision for reconfiguration requests or hibernation entry and exit.
- Each Centralised Memory Module (CMM) includes
  - a Safeguard Memory (SGM) for the storage of the context data and
  - a PROM for the storage of the nominal DMS and AOCMS SW.

The internally redundant Solid State Mass Memory (SSMM) includes 25 Gbit of memory (EoL). It is coupled to :

- the 4 processors via an IEEE 1355 link,
- the TFGs of the 2 CDMUs via a serial link,
- VIRTIS, OSIRIS and the Navigation Camera via a high data rate serial link (IEEE 1355)
- the High Power Command Module (HPCM) selecting the valid PM

The SSMM will store images, science and telemetry packets as well as Software for the AOCMS and DMS computer. The SSMM is usable like a "Hard Disk Storage" and contains a data compression module which allows lossy and loss-less compression of data to be stored.

The lossy compression method (WAVELET) will be used for image data compression of the NAVCAM or STR. The degree of compression can be set by filter parameters from ground. The compression of OSIRIS and VIRTIS image data could also be performed inside the SSMM. Present baseline however is that these two instruments do not request data compression from the system.

The loss less compression method (RICE) will mainly be used for the compression of all HK and science data with exception of images prior to their downlink via VC1.

One special responsibility of the avionics subsystem is the distribution of special synchronization signals to units which need them. On-board time distribution and Broadcast Pulse Protocol are provided as well.

The AOCMS is built around the AOCMS Interface Unit (AIU) which is used by the CDMU (including the current AOCMS processor) to exchange functional data with:

- the AOCMS sensors: 2 Navigation Cameras (CAM) and 2 Star Trackers (STR) having a common electronics unit, 4 Sun Acquisition Sensors (SAS) and 3 Inertial Measurement Packages (3 IMP, each incl. 3 gyros + 3 acceleros),
- the AOCMS actuators: the Reaction Wheel Assembly (RWA), and belonging to the Platform the Reaction Control System (RCS), the High Gain Antenna Pointing Mechanism (HGAPM), and the 2 Solar Array Drive Mechanisms (SADM).

The AIU is the central data acquisition and distribution unit which allows access to the sensors and actuators with different type of interfaces. It includes RS 422, IEEE 1355 and MACS Bus interfaces as well as analog and discrete digital interfaces for commanding and data acquisition.

The AIU includes furthermore a 12 bit A/D converter in order to convert analog signals from the pressure transducers (temperature and pressure) precise enough for the fuel level prediction on-board of Rosetta late in the mission, when the fuel level is critical.

Telecommunications are suited for the deep space application. It uses a redundant S/X-band deep space transponder able to receive and transmit data in S- and X-band. The X-band downlink signal is boosted via TWTAs. A HGA with 2.2 m diameter is used, which can be pointed in all directions of the +X hemisphere plus 30 deg. A fixed mounted S- and X- band medium gain antenna (MGA) serves as backup for the HGA. Both antennas can be used for S/X-band up- and down-link. Furthermore there are 2 S-band low gain antennas (LGAs) providing full spherical coverage for up-link during all mission phases and hemispherical coverage for down-link, depending on the attitude of the spacecraft.

The power generation is performed in the solar generator wings of roughly 62 m² covered with LILT silicon solar cells. Each wing is connected to a redundant power control unit (PCU), which is designed in accordance with the maximum power point tracker (MPPT). The PCU includes the charge/discharge regulators (BRUs) for the Lithium-Ion batteries. The PDUs are in charge of power distribution to subsystems and payload, one serves the payload, the other the subsystems. The PDUs include overload protection without using fuses. Fusing is implemented by electronics. The pyro firing functions are included in both PDUs and additionally thermal knife functions are in the S/S PDU for deployment of the solar arrays. Heater switching and control is also performed via dedicated PDU LCLs. Heater branches are connected via LCLs. The PL-PDU additionally provides keep alive lines (KAL) to power the experiment memories in case the experiments are switched off (exception: Deep Space Hibernation Mode).

The heater control is based on-:

- a software temperature control loop outside the deep space hibernation phases,
- thermostat control during the deep space hibernation phases and Safe Mode

The three harness EMC classes (power, pyro, and signal) are routed separately. All harnesses are electrically overall shielded. Test connections for TC/TM video interfaces, umbilical interface, Safe Arm Plugs, auxiliary SSMM data interface, and special signal interfaces for test purposes are provided.

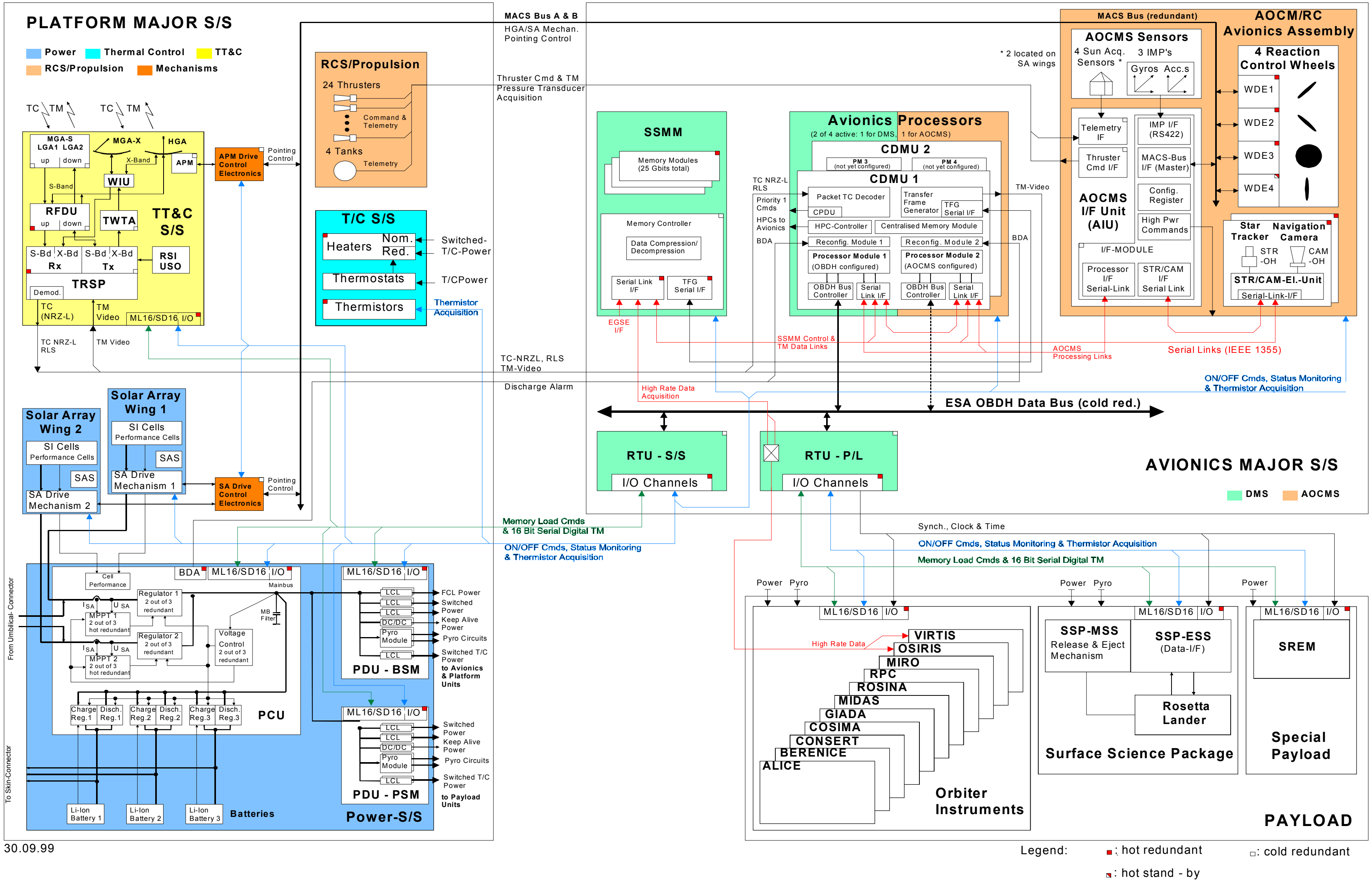


Figure 2-16: ROSETTA Block Diagram

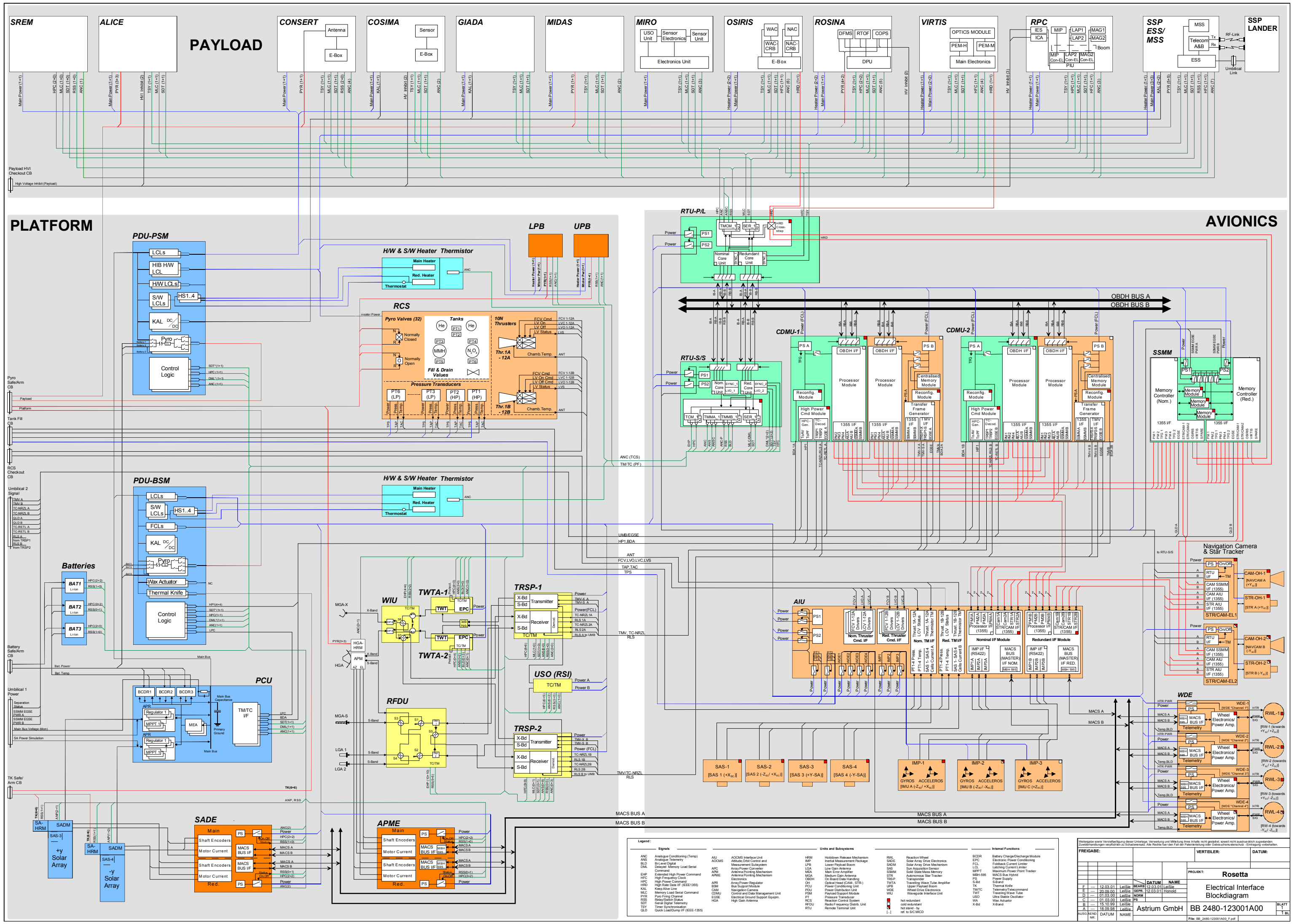


Figure 2-17: Electrical Interface Diagram

2.1.7. Avionics Design

2.1.7.1. Avionics General O~~o~~verview

The ROSETTA Avionics consists of the Data Management Subsystem (DMS) and the Attitude and Orbit Control and Measurement Subsystem (AOCMS) functions.

Data Management Subsystem

The data management subsystem is in charge of telecommand distribution to other spacecraft subsystems and payload, of telemetry data collection from spacecraft subsystems and payload and formatting, and of overall supervision of spacecraft and payload functions and health.

The DMS is based on a standard OBDH bus architecture enhanced by high rate IEEE 1355 serial data link between the different Avionics processors and the SSMM, STR and CAM. The OBDH bus is the data route for data acquisition and commands distribution via the RTUs. Payload Instruments are accessed via a dedicated Payload RTU. Subsystems are accessed via a dedicated Subsystem RTU.

DMS includes 4 identical Processor Modules (PM) located in 2 CDMUs. Any of the processor modules can perform either the DMS or the AOCMS processing. The PM selected for the DMS function acts as the bus master. It is also in charge of Platform subsystem management (TT&C, Power, Thermal). The one selected as the AOCMS computer is in charge of all sensors, actuators, HGA & SA drive electronics. TC-decoder and Transfer Frame Generator (TFG) are included in each CDMU. Telemetry can be downlinked via the TFG using the real time channel (VC0) or in form of retrievals from the SSMM (VC1).

The Solid State Mass Memory (SSMM) is used for data storage including 25 Gbit of memory. It is able of file management capability. It is coupled to the 4 processors, the TFG, VIRTIS, OSIRIS and the Navigation Camera. It stores CAM images, science and telemetry packets as well as software data. It is able of data compression allowing lossy (for CAM image) and lossless (for HK and science data) compression.

Attitude and Orbit Control Measurement System

The AOCMS is in charge of attitude and orbit measurement and control and is in charge with sensors and actuators for autonomous attitude determination and control as well as pre-programmed manoeuvring.

AOCMS subsystem is built around the AOCMS Interface Unit (AIU) which is used by the AOCMS-SW to exchange functional data with:

- the sensors: 2 Navigation Cameras (CAM) and 2 Star Trackers (STR), 4 Sun Acquisition Sensors (SAS) and 3 Inertial Measurement Packages (IMP), each IMP includes 3 gyros + 3 accelerometers,
- the actuators: the Reaction Wheel Assembly (RWA) belonging to the Avionics, and the Reaction Control System (RCS), the High Gain Antenna Pointing

Mechanism (HGAPM), and the 2 Solar Array Drive Mechanisms (SADM) belonging to the Platform.

Different type of interfaces ~~is~~ are used by AIU: RS422 for IMP, IEEE1355 for CAM and STR, MACS Bus for RWA, HGAPM and SADM, and analogue and discrete digital interfaces for SAS and RCS.

The overall layout of the Avionics is shown in Figure 2-18 below.

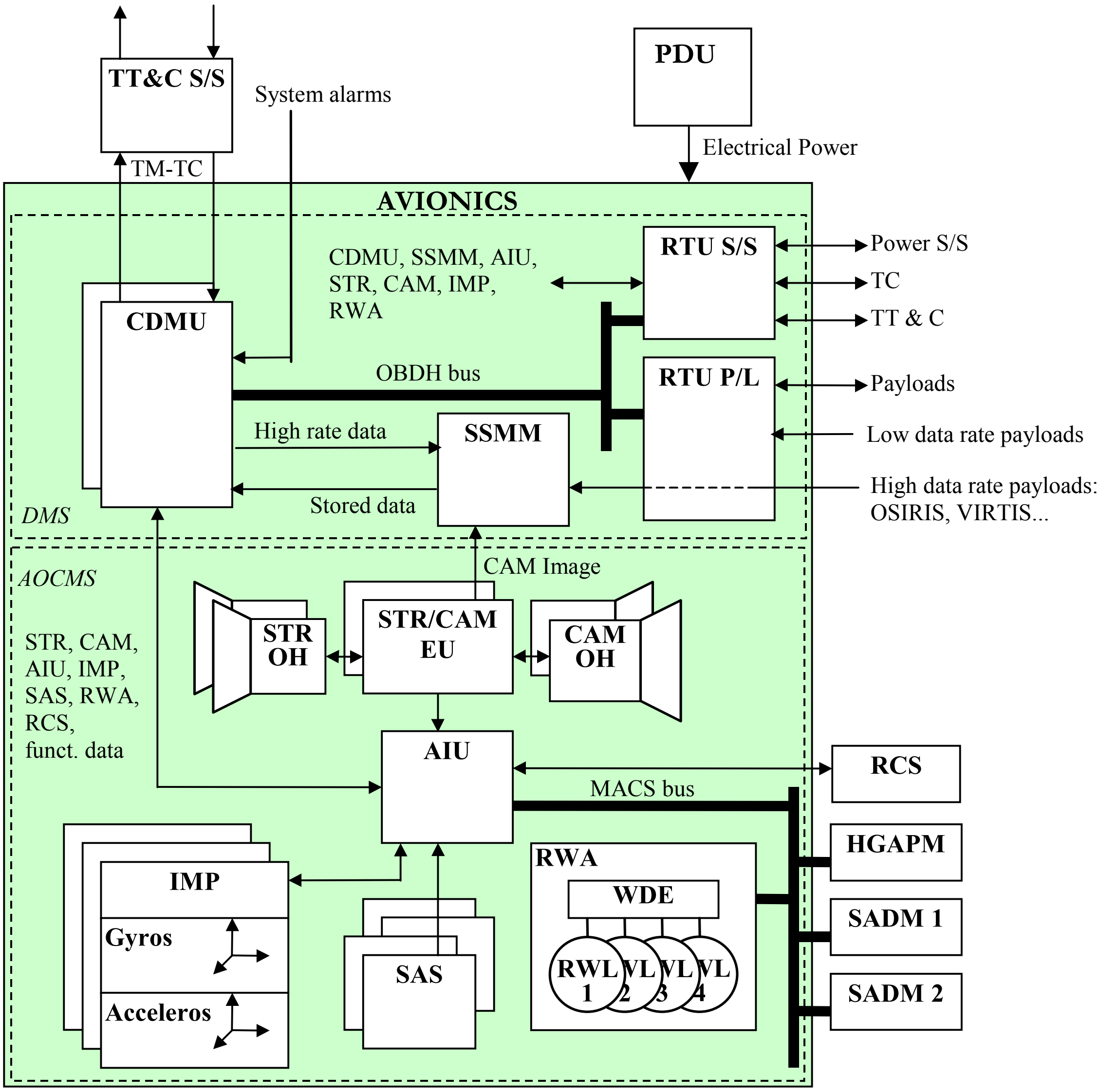


Figure 2-18: Avionics General Overview

Avionics external interface

The Avionics system has the following external interface to other subsystems of the Rosetta spacecraft:

- **interface with the Ground through TT&C Subsystem:**

  Ground Telecommands (TC) are checked, decoded and executed internally or sent to other subsystems, Telemetry (TM) data generated on-board are collected, formatted (if needed) and sent to Ground through TT&C S/S, either in real time or in play-back after storage in SSMM, on ground request.

- **interface with Platform and Payload**:

  The Avionics provides the experiments and Platform equipment with a hardware command capability (power On/Off commands, heater On/Off commands...),

  The Avionics provides experiments with a time synchronisation capability~~datation~~, so that the Ground can later on correlate results coming from different experiments,

  The Avionics uses for attitude and communication control purpose as well as for power generation Platform equipment: Reaction Control System (RCS), High Gain Antenna and Solar Array Pointing Mechanisms (HGAPM, SADM)

  Housekeeping data and experiment science data are collected on-board to be sent to Ground in real time TM, or to be stored for play-back downlink,

  The Avionics S/W provides experiments and Platform with a processing capability, ~~housing software packages~~in form of application programs (AP) or On-board Control Procedures (OBCP), coded and implemented by the Avionics/OBCP contractor, but specified by the users to allow montoring/surveillance, thermal control, experiment or mechanism management.

2.1.7.2. Architecture and Interface

A distribution of Avionics functions into the Avionics hardware is visualised in Figure 2-19, a short description of the various functions is given below.

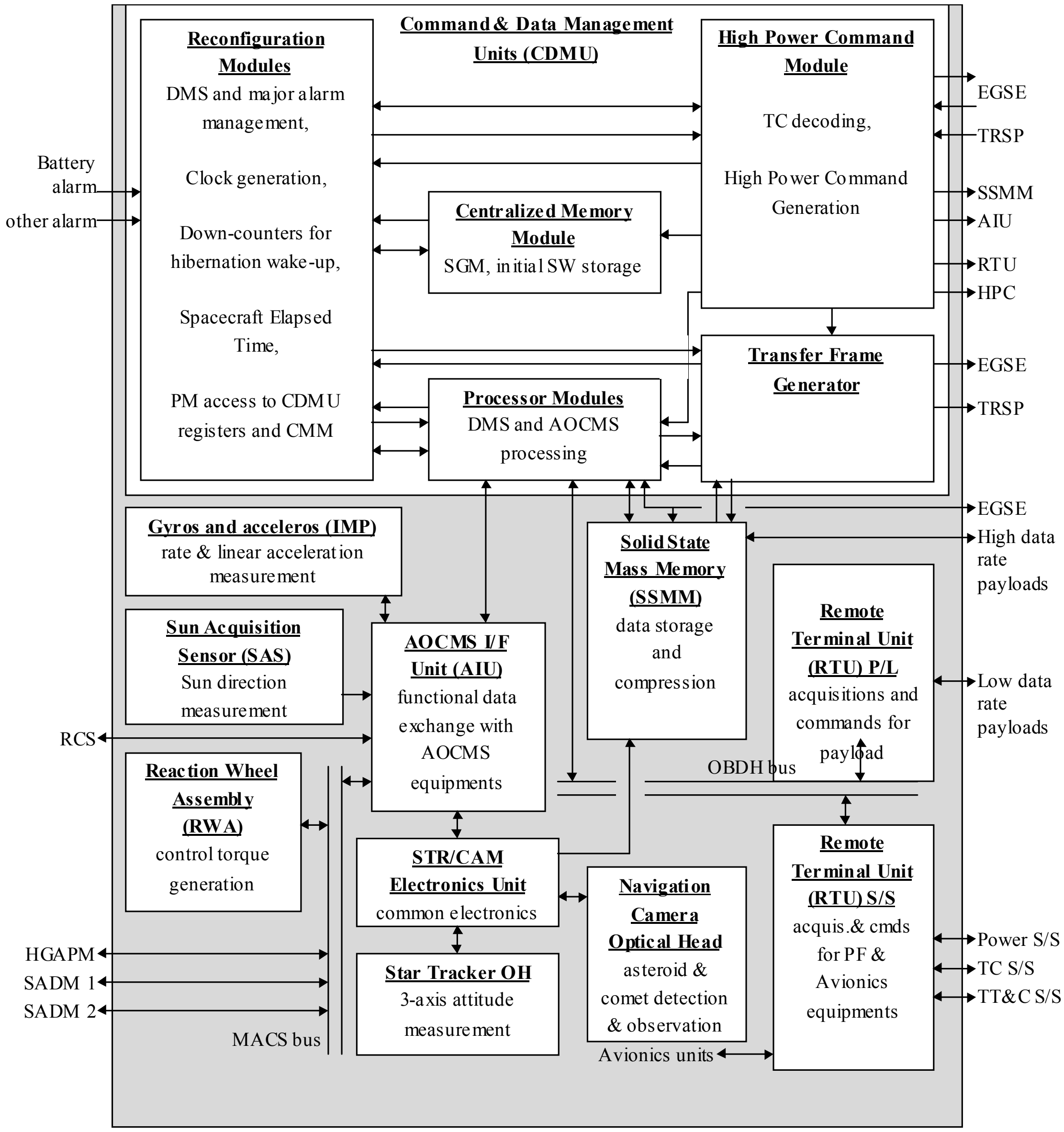


Figure 2-19: Avionics Function Distribution into Units

- **Telecommand and Telemetry management:**

  Ground telecommands are sent from TRSP receiver to HPCM where they are decoded and executed.

  A command can be directly executed in the HPCM by the Command Pulse Distribution Unit (CPDU) or routed to the DMS processor, which is responsible for the execution of the command (sending of commands towards the RTU, the SSMM or the AOCMS PM).

  Telemetry data dealing with DMS are collected

Functional telemetry data dealing with AOCMS are collected through the AIU by the AOCMS processor and then sent to the DMS processor (see further description of AOCMS management).

TM packets are sent by Processor Modules or by the SSMM through TFG to TRSP transmitter. The TFG provides processor modules and SSMM with feedback information allowing the regulation of TM data flow.

- **Hardware configuration:**

  The Hardware configuration is controlled:

  - by the ground through telecommands,
  - by the DMS processor
  - by the Reconfiguration Modules
  - The selection of DMS and AOCMS Processor Modules is performed by high power commands controlling HPCM relays.

- **High level monitoring and reconfiguration:**

  The Reconfiguration Module processes alarm signals coming from Power sub-system (battery discharge alarm).

  After receipt of 2 among 4 reconfiguration requests, the HPCM sends a Reset to the Processor Modules and set a new Avionics Hardware configuration (PM, RM I/O and clock selection) based on the actual used reconfiguration register content.

  Thise reconfiguration information is stored in a HPCM PROM. Alltogether 65536 configuration settings/permutations are available The organisation of the HPCM PROM is such that it is possible to avoid to power ON a module already declared as “failed”.

  The Processor Modules send to the Reconfiguration Module an Alive signal. The one coming from the DMS processor rearms a RM watchdog, allowing DMS PM monitoring. The triggering of this watchdog leads to the same HPCM reconfiguration logic as described above. The DMS PM monitors the AOCMS PM through the exchanged data flow, and an Under Voltage (UVD) status.

- **Time and Hibernation management:**

  The Reconfiguration Module includes an oscillator used to generate clocks, on-board time and wake-up timers.

  On-board time (Spacecraft Elapsed Time: SCET) and settable down-counters for hibernation wake-up are accessible for the Processor Modules through I/O function of the RM.

As in the meantime for the hibernation phases an active S/C is the baseline the wake-up timers are no longer used.

- **AOCMS management:**

  AOCMS PM communication with AOCMS sensors (IMP, SAS, STR, CAM) and actuators (RWA, RCS), and with pointing mechanism electronics (SADE and HGAPE) is performed through the AIU. Functional AOCMS data which need to be put in the Telemetry and sent to the ground are ~~given~~ packetised by the AOCMS processor and sent to the DMS processor for futher downlink to ground and storage in the SSMM.

  The navigation camera can also directly send image data to the SSMM through a high data rate link.

  The DMS PM permanently checks the AOCMS health by monitoring that the AOCMS PM does not stop to communicate with DMS PM. This is done by checking the correct reception of the so-called 'essential' AOCMS HK packet every one second.

2.1.7.3. Avionics Hardware Architecture and Redundancy

The Data Management System is based on an OBDH bus architecture enhanced by IEEE 1355 serial links between units which need high data rate or in order to standardise point to point links with new equipment.

The OBDH bus is the data route for transmission of telemetry status, low data rate acquisition, commands or command packets distribution via the Remote Terminal Units (RTU).

The high data rate link is fully required by a few instruments like OSIRIS, VIRTIS, or by Navigation Camera to the Solid State Mass Memory (SSMM).

Specific standardised serial links are necessary between AIU and existing equipment like RS422 link for the gyros and accelerometers, or like MACS bus for the Reaction Wheel Assembly (RWA) and the pointing mechanism electronics (SADE~~M~~, ~~HG~~APME).

2 Avionics PMs are used simultaneously, one as DMS PM and the other one as AOCMS PM. The DMS PM acts as the OBDH bus master. The AOCMS PM is not using the OBDH bus but communicates with the DMS PM via the IEEE 1355 serial link and is in charge of all sensors, actuators, Solar Array Drive mechanism (SADM) and High Gain Antenna Mechanism through AIU. Each one of the 4 Avionics PM can be configured either as DMS PM or as AOCMS PM.

For the other Avionics units and modules, the redundancy scheme is related to the criticality of their function. As shown next page, the most common situation is the cold redundancy, but some important particular cases are to be noted:

- the Reconfiguration Module of the CDMU is quadruple redundant and permanently ON because of its criticality. The quadruple redundancy allows a "majority voting" (at least 2 out of 4) decision for reconfiguration requests ~~or hibernation entry and exit~~,
- the High Power Command Module of the CDMU is hot redundant and permanently ON
- some modules are in hot stand-by redundancy, meaning that the redundant module is nominally cold redundant, but can be used in hot redundancy for critical phases. This is the case for the Inertial Measurement Unit, the Navigation Camera, the Star Tracker and the fourth Reaction Wheel.

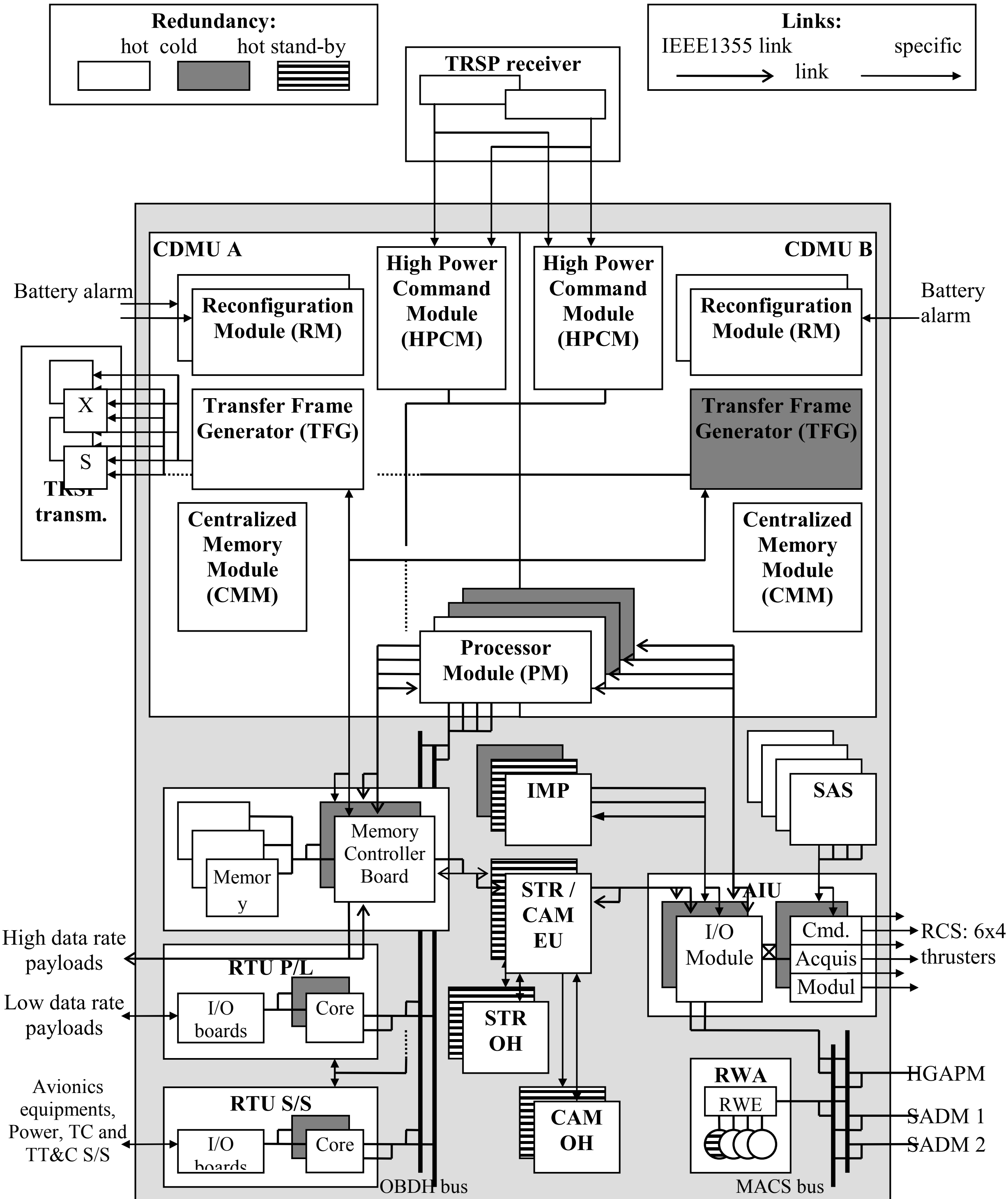


Figure 2-20: Avionics Hardware Architecture and Redundancy

2.1.7.4. Avionics modes

2.1.7.4.1. Avionics Modes versus System Modes

The Avionics modes derived from the AOCMS modes are the following:

Stand-By Mode

The SBM is used in Pre-launch and Launch Modes for general check supervision. Only DMS functions are activated. It is possible to command thrusters through AIU for RCS Priming.

Sun Acquisition Mode

This mode is used during Separation Sequence to perform rate reduction (if necessary), Sun acquisition and Sun pointing.

SAM is also used as second level back-up mode to recover Sun pointing attitude in case of an unsuccessful ~~back-up to~~ Sun Keeping Mode.

Safe/Hold Mode

The SHM follows the Sun Acquisition Mode / Sun Keeping Mode to achieve a 3-axis ~~stabilisation~~ attitude based on star trackers, gyros and reaction wheels, with solar arrays pointing towards the Sun and Medium and High Gain Antennae (i.e. S/C X-axis) pointing towards the Earth and the Y-axis normally pointing to the noth of the ecliptic plane.

~~It is used at the end of the Launch Modes and, in case of reconfiguration, at the end of the system Safe Mode.~~

In some mission phases (i.e. defined by the minimum earth distance), S/C X-axis pointing towards the Earth is forbidden because of thermal constraints. Then, +X axis is pointed towards the Sun, and the High Gain Antenna is pointed towards the Earth.

Normal Mode

The NM is used in Active Cruise and Near Comet ~~Modes~~ phases for nominal long-term operations, for comet observation and SSP delivery. Reaction wheel off-loading is a function of the Normal Mode.

Thruster Transition Mode

The TTM is used for transition from Normal Mode to operational thruster Modes, and vice-versa, for control tranquillisation.

Orbit Control Mode

The OCM is used in Active Cruise Mode for trajectory and orbit corrections.

Asteroid Fly-By Mode

The AFB mode is dedicated to asteroid observation.

Near Sun Hibernation Mode

The NSHM is a 3-axis controlled mode (with the attitude estimation based on the use of STR only, and no gyro), with a dedicated thruster control (i.e. single sided) to minimise the fuel consumption. ~~The attitude control concept is a completely passive inertial spin during this mission phase.~~

~~There is no AOCMS Deep Space Hibernation Mode.~~

Spin-up Mode

The SpM is necessary to spin up the spacecraft at hibernation entry (spin down at hibernation exit is achieved by Sun Keeping Mode). The attitude control concept is a completely passive inertial spin during the deep space hibernation phase.

There is no AOCMS Deep Space Hibernation Mode.

Sun Keeping Mode

The Sun Keeping Mode is used nominally at wake-up after Deep Space hibernation, and as first level back-up mode to recover Sun pointing attitude in case of a failure involving the Avionics and for which a local reconfiguration on redundant units is not efficient. In case the autonomous entry to Safe / Hold Mode is disabled or not successful Earth Strobing Mode is established leading to ~~A~~a slow spin motion around the Sun direction ~~is achieved~~. ~~The High Gain Antenna Pointing Mechanism is commanded such that the antenna~~Then the + X-axis is pointed towards the expected earth direction (i.e. using the actual Sun/spacecraft/Earth angle). The rotation along the Sun line is maintained therefore ~~crosses~~ the Earth crosses once per revolution the + X-axis which will allow communication with the MGA ~~(Earth strobbing mode function used in case of STR failures). Then Safe / hold Mode is entered.~~

An overview of the Avionics/System modes is shown in the following table.

System Modes	Functions	Avionics Modes
Pre-launch Mode	General health supervision	Stand-by Mode
Launch Mode	Separation check, initial RCS priming, SA deployment	Stand-by Mode

System Modes	Functions	Avionics Modes
	Sun acquisition	Sun Acquisition Mode
	Safe Sun and Earth pointing	Safe / Hold Mode
Activation Mode	Spacecraft check-out (incl. Hibernation) and payload commissioning	Normal Mode + all Avionics Modes
Active Cruise Mode	Waiting phase between major mission events	Normal Mode
	Trajectory corrections	Orbit Control Mode (+ Thruster Transition Mode)
Deep-space Hibernation Mode	Passive spin, however active Data Handling	Spin-up Mode, Hibernation Mode, (+ Thruster Transition Mode)
Near-Sun Hibernation Mode	Autonomous Sun pointing	Near Sun Hibernation Mode (+ Thruster Transition Mode)
Asteroid Fly-by Mode	Asteroid observation	Asteroid Fly-by Mode
Near Comet Mode	Comet observation, SSP delivery	Normal Mode + Orbit Control Mode (+ Thruster Transition Mode)
Safe Mode	(When established) 3-axis stabilisation with reaction wheels, solar arrays pointing towards the Sun, HGA & MGA pointing towards the Earth	Sun Keeping Mode with autonomous entry to Safe/Hold Mode
Survival Mode	Back-up when Safe Mode is not successful	~~Sun Acquisition Mode (Sun Pointing Phase),~~ Sun Keeping Mode (Solar Arrays Sun Pointing ~~Phase~~and + X-axis Earth Strobing)

Table 2-2: Avionics Modes

2.1.7.4.2. AOCMS Modes and Transitions

There are as many AOCMS modes as Avionics Modes, some of them being broken down into phases:

- Attitude acquisition :

  for initial acquisition or back-up re-acquisition, the performed sequence is: Sun Acquisition Mode - Safe/Hold Mode, or Sun Keeping Mode – Safe/Hold Mode, including the following phases:

- Sun Acquisition Mode : Rate Reduction - Sun Capture - Sun Acquisition - Sun Pointing – Biased Pointing (or Star Acquisition),
- Sun Keeping Mode : Rate Reduction - Sun Acquisition - Star Acquisition,
- Safe/Hold Mode: Earth Acquisition Initialisation – Earth Acquisition – Hold - Earth Pointing Initialisation - Earth Pointing.

- Operational mission phases:

  In addition to the Normal Mode including reaction wheel off-loading, specific mission phases are supported by the Orbit Control Mode and, Asteroid Fly-by Mode and Spin-up Mode for hibernation entry.

- Hibernation phases :

  Near Sun Hibernation Mode and Spin-up Mode for deep space hibernation entry. During deep-space hibernation, the AOCMS is fully passive (i.e.in Standby Mode) with active DMS.

- Back-up modes :

  The Sun Keeping Mode is used as a first back up keeping the solar arrays facing the Sun, the acquisition sequence Sun Acquisition Mode - Safe / Hold Mode is used as a second level back up.

- Transition mode:

  The Thruster Transition Mode is used as a tranquillisation phase between the Normal Mode (where the control is based on wheels only) and the other nominal Modes where the control relies on use of thrusters

A block diagram of the AOCMS modes and possible transitions are presented in Figure 2-21.

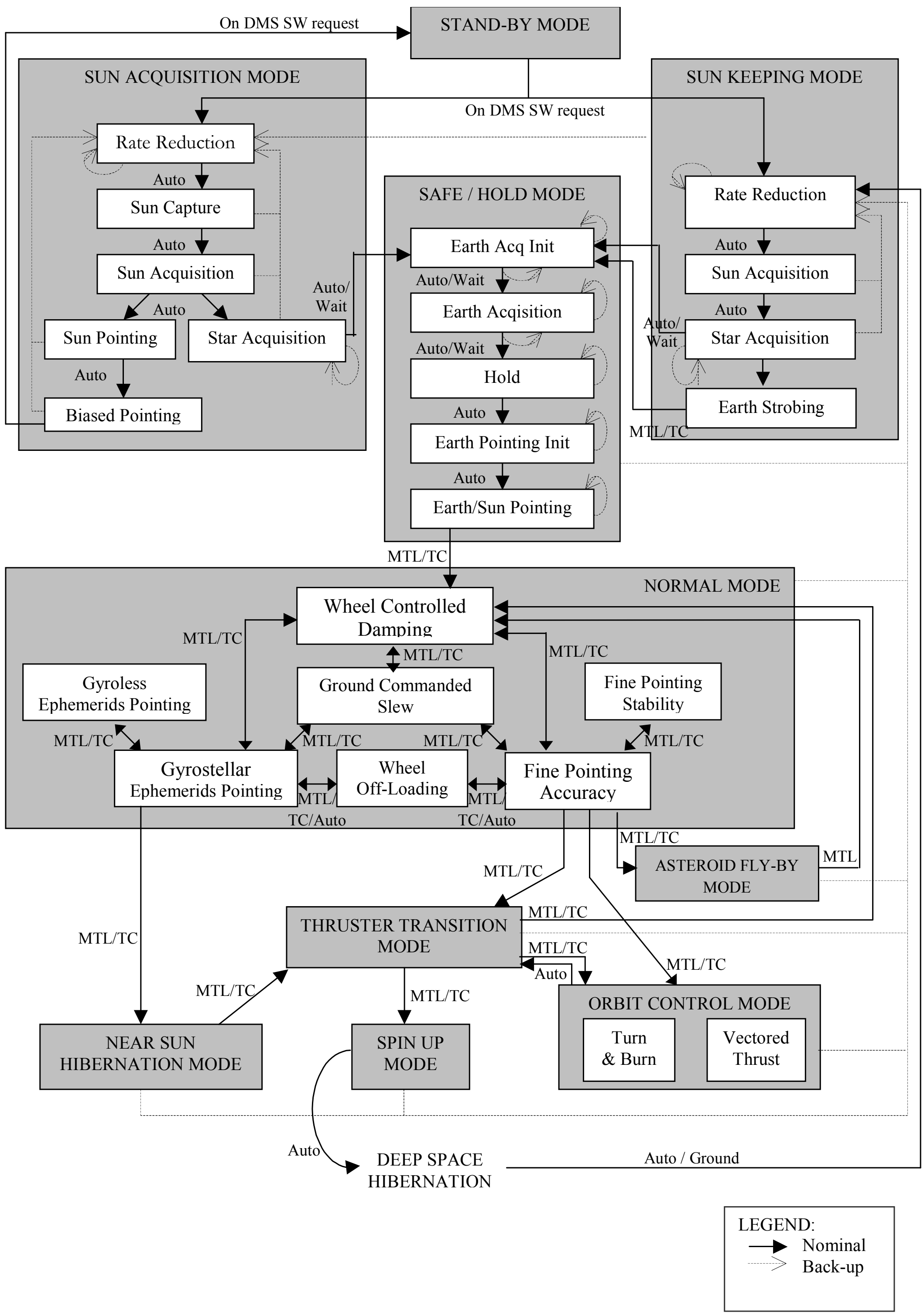


Figure 2-21: AOCMS Mode Transitions

2.1.7.5. Avionics Equipment Design

2.1.7.5.1. Control and Data Management Subassembly (CDMS)

The CDMS main functions are:

- the processing capability : the processing capability is located in the processor modules, a total of 4 PMs exists for the Rosetta mission
- the interface with the ground segment (i.e. decoder and TFG) through the TTC subsystem
- an upper level monitoring ~~and~~ surveying system alarms and other subsystems: this function includes the System Alarms processing and the reconfiguration processing
- the high ~~level~~ priority commands generation: this includes all commands ~~are all the commands that must be accessible from Ground even when the Processor Modules are OFF~~necessary to switch-on/reconfigure the avionics without using the S/W
- the clocks processing and distribution
- the centralised memory module (CMM containing the PROM and the Safe Guard Memory)
- the interface and storage function within the SSMM ~~and with the AIU~~
- the interface with the platform units and payload via the RTUs and the OBDH bus

2.1.7.5.2. AOCMS subsystem (AOCMS S/S)

The AOCMS uses a decentralised architecture built around the AOCMS Interface Unit (AIU) linked to all sensors / actuators and to the Processor Modules included in the CDMUs.

The major AOCMS components are the following, see also Figure 2-22:

- AOCMS Interface Unit (AIU): it interfaces to all AOCMS sensors and actuators
- The Sun Acquisition Sensors (SAS): they are internally redundant and are used for Sun Acquisition and pointing. They provide full sky coverage and ensure a permanent sensing of the Sun direction vector.
- The Inertial Measurement Packages (IMP): The IMP function provides roll rate and velocity measurements along 3 orthogonal axes.

- 4 Reaction Wheels: they are arranged in a tetrahedral configuration about the S/C Y-axis in order to enhance the torque and momentum capacity about that axis for the asteroid fly-by.
- 2 Autonomous Star Trackers: they contain an Autonomous Star Pattern Recognition function and provide autonomously to the AOCMS an estimated attitude quaternion and stellar measurements data.
- Other equipment interfacing with the AOCMS: the Navigation Camera is used in the AOCMS control loop only during the Asteroid Near Fly-by Phase. Pointing mechanisms (through target pointing angles) and propulsion thruster valves are commanded by the AOCMS through the AIU links.

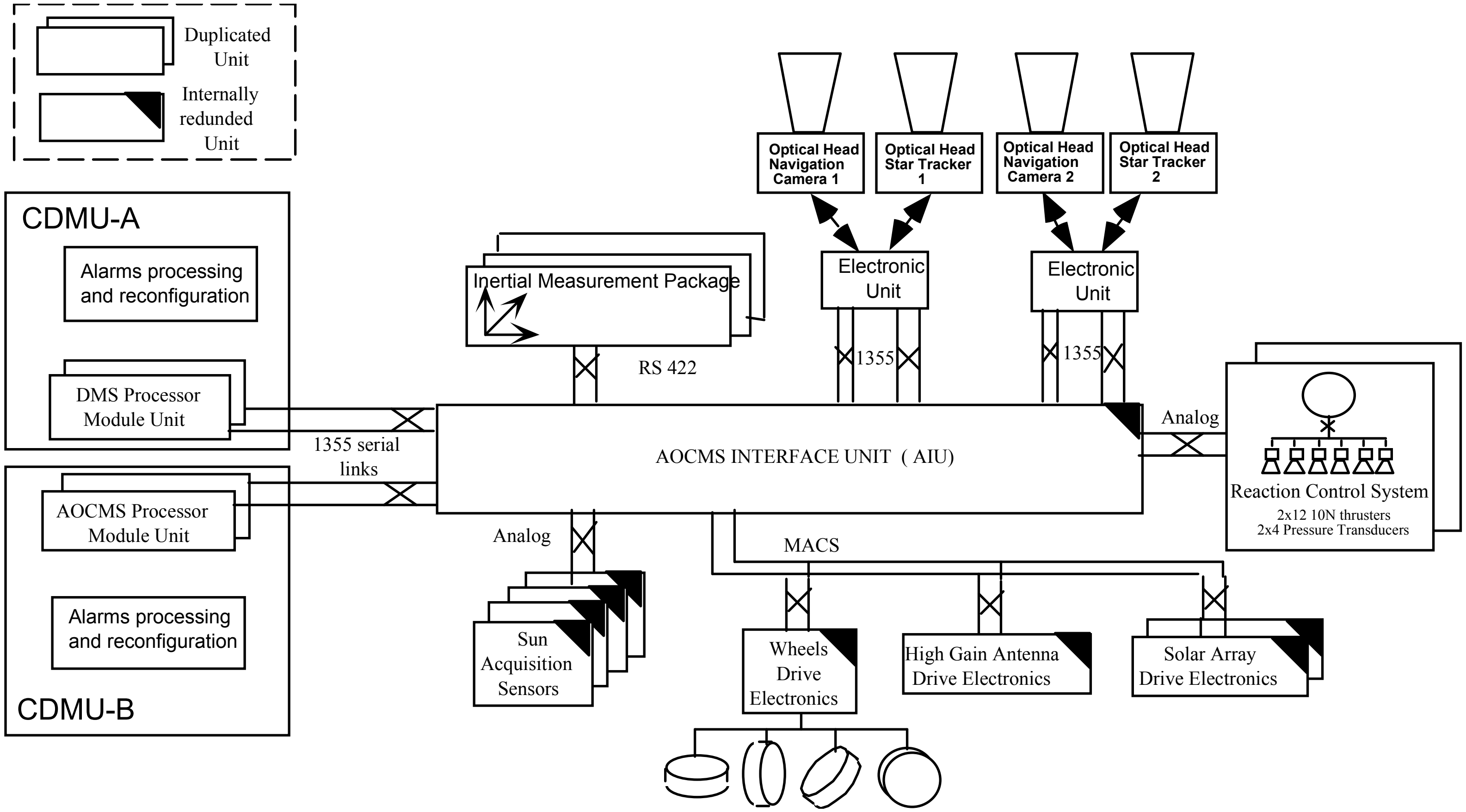


Figure 2-22: AOCMS general architecture

2.1.7.6. Avionics Software Design

2.1.7.6.1. Functional Breakdown

The Avionics system is composed of several software products. The software running in the processor module is composed of:

- PM Firmware

  The PM Firmware, stored in PROM, mainly runs in ~~P~~R~~O~~AM on each processor module (PM) as soon as the PM is powered ON (or reset).

- the DMS SW

  The DMS SW runs in RAM on a dedicated Processor Module. It is composed of four layers of software components: as shown in Figure 2-23.

- the AOCMS SW

  The AOCMS SW has its own processor resource on another PM. It runs in RAM and is composed of four layers of software components as shown in Figure 2-24

The SSMM and the AOCMS major equipment (STR, CAM and IMP) include also internal software.

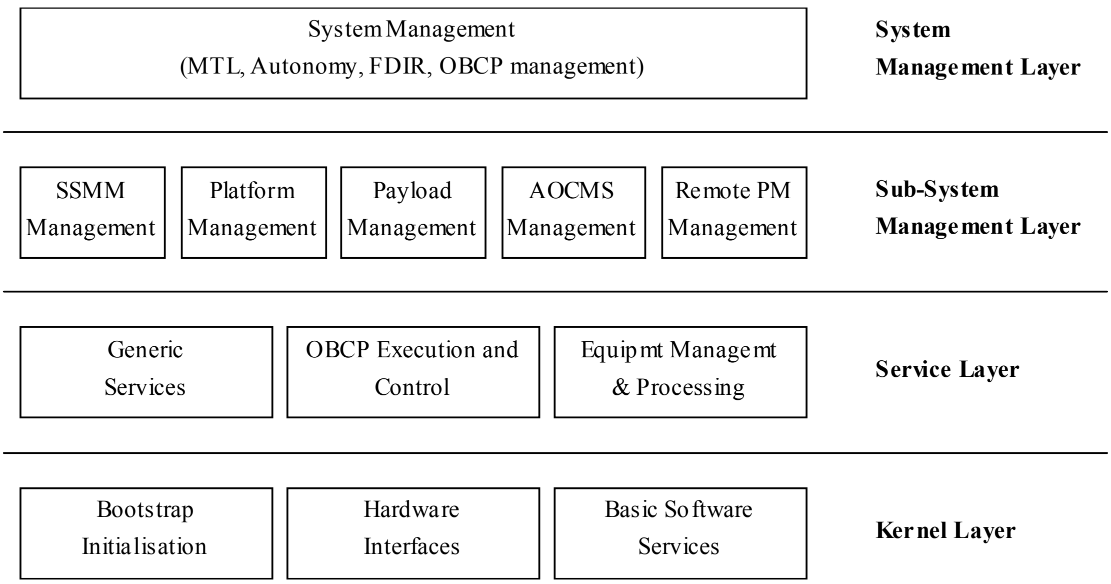


Figure 2-23: Definition of DMS Software Layer Main Elements

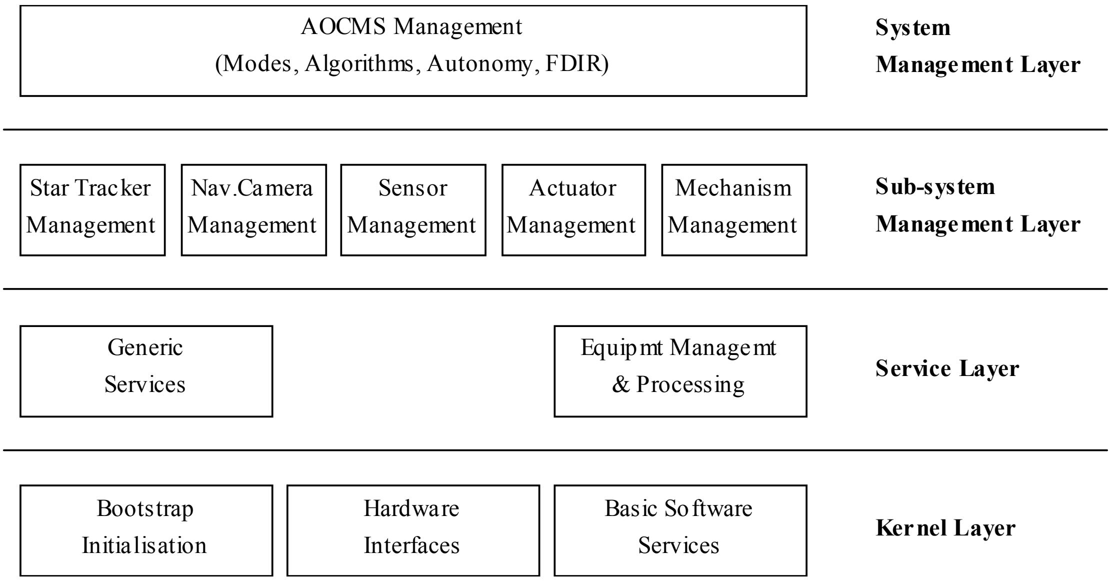


Figure 2-24: Definition of AOCMS Software Layer Main Elements

The SSMM SW runs on a Digital Signal Processor. The SSMM SW is made of:

- the init mode software

  The Init mode software ensures the boot up of the SSMM and the establishment of the communication with the DMS SW. It allows the loading of the operational SW from EEPROM to RAM, and its starting.

- the operational software

  The operational SW manages the files located in the Memory Modules of SSMM, and the Data Compression Function that performs Rice lossless and Wavelet lossy data compression.

The SW embedded within AOCMS major equipment comprises the STR SW, the CAM SW and the IMP SW.

- STR / CAM SW

  The STR and CAM software runs on its own processor at unit level and is in charge of the STR / CAM management. The STR SW mainly provides 3-axis autonomous attitude restitution to the AOCMS SW. The CAM SW mainly provides Line Of Sight information to the AOCMS SW and image data to the SSMM.

- IMP SW

  The IMP software runs in PROM on a processor at unit level and provides 3-axis angular and velocity increments to the AOCMS SW.

2.1.7.6.2. Software Flexibility

Default SW images of the DMS SW and AOCMS SW are located in the Centralised Memory Module PROM. Nominal version and upgrades can be stored in each PM EEPROM. The SSMM can also be used but only as a last backup for DMS SW. This means that at PM re-boot, the Firmware will load the SW either from the PM EEPROM, from the CMM PROM, or from the SSMM, depending on the context status pre-selected by Ground in the Safeguard Memory (SGM).

SSMM SW nominal version of the operational software is located in the SSMM EEPROM. Modifications can be loaded directly within this EEPROM. The Init mode SW loads the operational mode SW from SSMM EEPROM to RAM before starting the operational mode.

STR and CAM SW nominal version are located in STR and CAM EEPROM. Patches can be uploaded either directly by Ground, or they can be first stored in a SSMM file

2.1.7.7. Avionics FDIR concept general overview

The communication blackouts, hibernation periods and long distance between ROSETTA and the Earth do~~es~~ not allow to react on a failure in real-time by the ground~~ control~~. The Avionics failure management system (called FDIR: Failure Detection Isolation and Recovery) therefore ensures autonomous on-board robustness to any single failure. The Satellite can safely recover from any single failure, and ground has the possibility to restart the operations, once the failure is isolated. The on-board recovery can be:

- without mission interruption (i.e. on-going operations are restarted/continued without any ground intervention).
- with mission interruption (i.e. on-going operations are stopped) leading normally to Safe Mode.

Depending on the severity of the failure that triggers the Safe mode, this may be fully supervised by the DMS and AOCMS SW (this is the SW Safe Mode Sequence), or it may also be necessary to change the PM's currently selected as AOCMS and DMS PM's. In that case it is necessary that Safe Mode Entry and initial configurations is managed by HW means, before control is given back to the SW (this is the HW Safe Mode Sequence).

2.1.7.7.1. Avionics HW redundancy design

All resources on Rosetta can be used both in the nominal modes and in the back-up modes. The FDIR relies on redundancy concepts only for functions implemented in HW only and for functions controlled by SW.

Design rules are implemented into avionics design in order to avoid failure propagation and to reduce the risk of common cause failure.

2.1.7.7.2. Elements reconfigurable by HW

All Avionics units have (internal or external) redundancy available on-board. For almost all of them, reconfiguration to the redundant resource is fully controlled by SW (i.e. either the DMS SW or the AOCMS SW can fully manage the sequence of commands needed to switch on the redundant resource, and possibly to switch off the nominal one)

2.1.7.7.3. Avionics Safe Mode

The objective of the Avionics Safe Mode is to reach autonomously, without Ground intervention, a safe configuration of the Satellite. The Safe Mode must fulfil two major tasks:

- provide a correct attitude w.r.t Sun and w.r.t Earth. Fulfilment of this objective is under the responsibility of the AOCMS.
- provide correct Ground link capabilities (both up and down links). Fulfilment of this objective is under the responsibility of the DMS

The Avionics Safe Mode is not only a back-up mode entered whenever a major failure triggers, but also used as a nominal mode ~~before and during Separation Sequence and~~ at Deep Space Hibernation Mode DSHM exit.

2.1.8. Telecommunication Design

The Tracking, Telemetry and Command (TT & C) communications with the Earth over the complete Rosetta mission is ensured by three antenna concepts, operating at various stages throughout the overall programme, combined with a number of electrical units performing certain functions. The Telecommunication Subsystem is required to interface with the ESA ground segment in normal operational mode and with the NASA Deep Space Network during emergency mode.

The TT & C subsystem block diagram given in Figure 2-25 comprises~~-~~ a number of equipment's whose descriptions appear below:

- Two Transponders interfacing with the S-Band RF Distribution Unit (RFDU), with the High Power Amplifiers - in this case Travelling Wave Tube Amplifiers (TWTA's) -, and with the Data Management System (DMS). The Transponders modulate and transmit the Telemetry stream coming from both parts of the redundant Data Management System either in S or X-Band or both simultaneously without any interference and transpond the ranging signal in S and X-Band.
  The Transponders provide hot redundancy for the receiving functions and cold redundancy for transmitting functions.
  The receivers can receive t~~T~~elecommands in S-Band or X-Band (selectable per command) , but not simultaneously in both frequency bands.
  The configuration is such that both receivers can receive~~-~~, demodulate and send the t~~T~~elecommand signal to the DMS simultaneously. The transmitters are also

able to receive the telemetry stream from both parts of the redundant DMS. Each transponder is capable of operating in a coherent or non-coherent mode depending on the lock status of the receiver.

- An RF Distribution Unit (RFDU) providing an S-Band transmit/receive switching function between the antennas and the two Transponder units via two diplexers.

- Two TWTA's providing >28W of power at X-Band to the MGA or HGA via the Waveguide Interface Unit (WIU). The input to the TWTA HPA's is supplied by the Transponder X-Band modulators via a 3dB passive hybrid.

- A Waveguide Interface Unit (WIU) comprising of diplexers, two transfer switches and high power isolators so that it is possible to switch between antennas without turning off the TWTA.

- The transmit frequency (and receiver rest frequency) can also be derived from an external Ultra Stable Oscillator (USO) on request by Telecommand which may be used any time during the mission. This USO has a superior ~~specification~~ performance compared to the Transponder internal oscillator such that it is used for one-way ranging as part of the Radio Science Investigations (RSI).

- Two Low Gain Antennas (LGA) providing a quasi omni directional coverage for any attitude of the satellite which may be used for:

  the near earth mission phase at S-Band for uplink telecommand and downlink telemetry.

  the telecommand Up Link at S-Band during emergency and nominal communications over large ranges up to 6.25 AU.

- A 2.2m High Gain Antenna (HGA) providing the primary communication for Uplink at S/X-band and Downlink at S/X-Band.

- Two Medium Gain Antennas (MGA) providing emergency Up and Downlink default communication after sun pointing mode of the S/C is reached. The S-Band MGA ~~will be~~ is realised as a flat patch antenna whereas the X-Band MGA is a offset-type 0.31m reflector antenna. The MGAs also perform some mission communications functions at various phases throughout their lifetime due to their much larger coverage area.

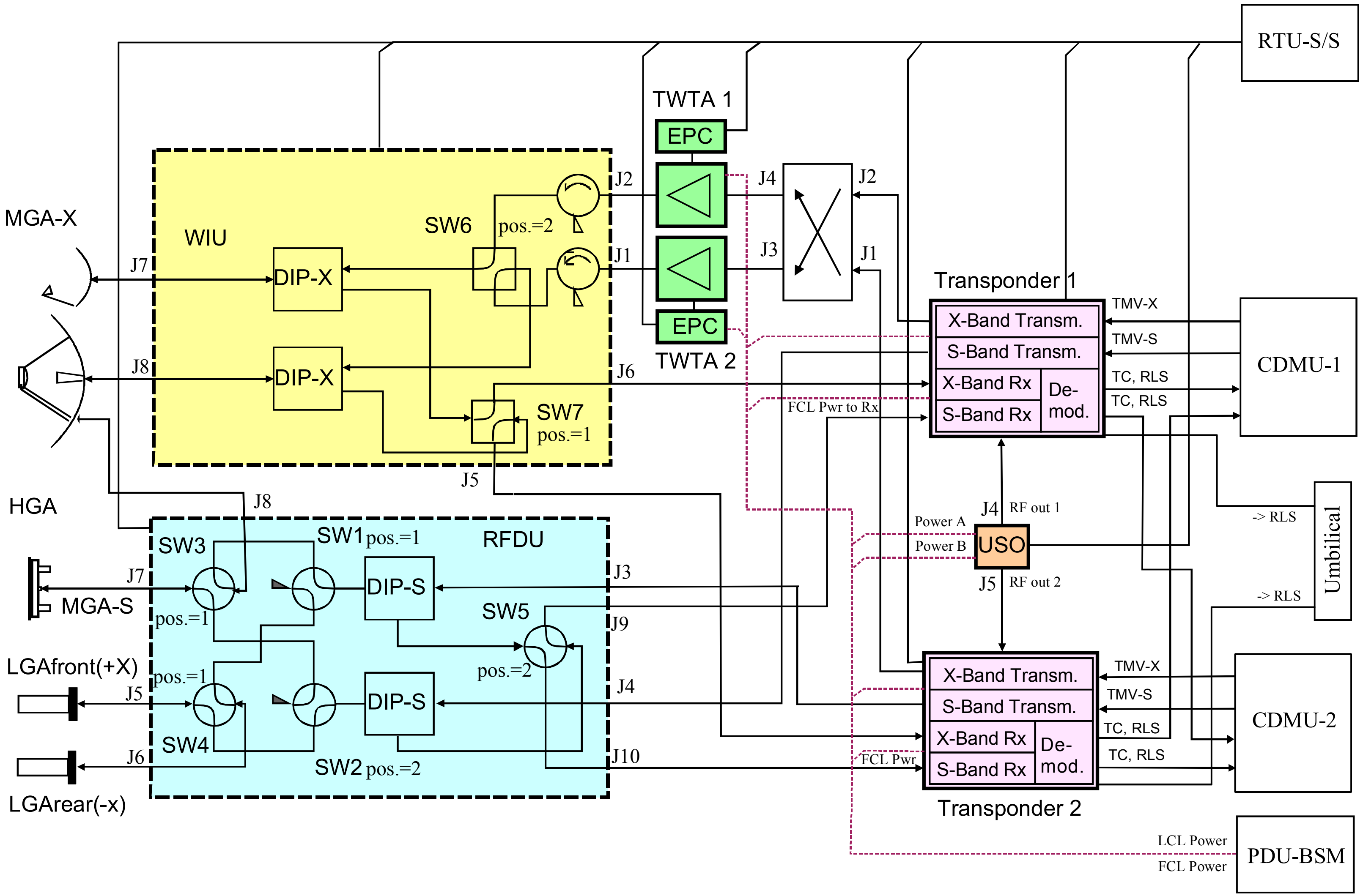


Figure 2-25: Telecommunication Block Diagram

High Gain Antenna Major Assembly

The transmission of the high rate scientific data of the ROSETTA spacecraft to earth is depending reliable operation of the High Gain Antenna major assembly, which is therefore a critical element for the mission success. The most important requirements for this assembly are:

- High reliability
- conform to specified pointing requirements
- minimize mechanical disturbances
- comply to antenna gain requirements

The HGA Major Assembly comprises:

- HRM Hold-down and Release Mechanism for the HGA dish during launch with three release points
- Two axes APM Antenna Pointing Mechanism (HGAPM) mounted on a tripoid to offset the antenna from the +X panel
- A Cassegrain (X-Band) quasiparaboloid highgain Antenna (HGA) with a dichoric subreflector and S-band primary feed
- Antenna Pointing Mechanism Electronics (APME)
- Waveguide (WG) and Rotary Joints (RJ) for the RF transmission

MGA

The MGA design has been split~~ted~~ into two physically separated antennae parts:

- the MGAS operating in -S-Band frequencies,
- the MGAX operating in -X-Band frequencies,

MGAS

The antenna design for the S-Band subsystem consists of an array of patch antenna elements providing a circularly symmetrical radiation pattern. The maximum gain obtainable for this array surface area (300mm x 300mm) ranges between 14.1 and 14.7 dBi in the receive and transmit frequency bandwidths.

The MGAS assembly can be sub-divided into two parts, the RF active part (radiators plus distribution network) and the support structure (platform plus stand-offs).

The array elements are arranged in a hexagonal lattice to provide the required symmetry to the antenna pattern. Six elements are used to meet the required specification.

MGAX

The configuration of the X-band MGA (MGAX) is a single offset parabolic reflector illuminated by a circular polarised conical horn. Reflector dimensions are selected to reach a desired minimum gain and to lead to a simple feeder design. This leads to an aperture diameter of about 310mm and a focal length of 186mm (F/D = 0.6). With these values a large reflector subtended angle is obtained which ensures small feeder dimensions and a compact antenna design.

The MGAX antenna assembly is composed of two sub-assemblies, a reflector and a feeder, and of a platform which supports both these sub-assemblies and provides the interface to the Rosetta spacecraft. The total envelope of the antenna is length=600mm, width=320mm, height=320mm.

The thermal protection for the antenna consists of:

- White paint on the radiant face, PYROLAC 120 FD + P128
- Thermal blankets on the rear face of reflector, feeder, supports and platform.

LGA

Two classical S-band Low Gain Antennae (LGA) of a conical quadrifilar helix antenna type are implemented on the satellite in opposite direction to achieve an omni-directional coverage. One is located at the +Z-panel in the near of the edge to the +X panel and thus is orientated towards the comet during the comet mission phase. The other one is mounted on the opposite face.

Ultra Stable Oscillator

An Ultra Stable Oscillator is implemented within the TT&C subsystem providing the required frequency stability (Allan Variance, 3s, 2×10^{-13} at 38.2808642MHz) for the RSI instrument. This USO will be used by the TT&C subsystem whenever needed and is available for RSI measurements as well. Should the USO fail, ~~the TT&C has a backup oscillator installed~~each transponder will use it's own oscillator (TCX0), but with less stability and not harming the performance.

2.1.9. Power Design

The Power Subsystem (PSS) conditions, regulates and distributes all the electrical power required by the spacecraft throughout all phases of the mission. Distribution involves the switching and protection of power lines to all users, including the Avionics units and the Payload instruments, and includes equipment power, thermal power and keep-alive-lines. The PSS also switches, protects and distributes power for the pyrotechnics and the thermal knives of the various release mechanisms of the spacecraft.

Main power source for Rosetta is provided by the Solar Array Subsystem from SI solar cells mounted on 2 identical solar array wings, which are deployed from the +Y and -Y faces of the spacecraft and can be rotated to track the sun. The solar cells on the outer panel of each wing are outward facing when in the launch (stowed) configuration in order to provide power input to the PSS for loads and battery recharge following separation from the launcher and prior to array deployment.

Batteries provide power for launch and post-separation support until the solar arrays are fully deployed and sun aligned, and thereafter will support the main power bus as necessary to supply peak loads and special situations during Safe Mode where the sun might not be fully oriented towards the sun.~~, although it is required that none of the mission essential operations after solar array deployment shall depend upon the availability of battery power.~~ One special feature of the power supply is the Maximum Power Point Tracker (MPPT), which will operate the solar array in its maximum power point in case of power shortage. During almost all time of the mission, except for short periods of peak power demands, the PCU will operate in nominal mode, i.e. the PCU takes only the power required by the satellite from the solar array. The delta power will remain in the solar array. Because of this feature the actual performance of the array can only be assessed by utilising “performance strings” which operate some cells in short circuit current mode and others in open circuit voltage mode. From the data obtained from these cells the performance of the solar generator can be determined.

Batteries are also the main power source for the pyrotechnics, although pyrotechnic power is also available from the main bus as a back-up in case there is no battery power.

The subsystem is designed in accordance to the ESA Power Standard PSS-02-10.

The PSS comprises 34 units (i.e. PCU and 2 PDUs) plus the batteries, but excludes the solar arrays which are part of the Solar Array Subsystem. The main functions of the PSS units are summarised below :

The Power Block Diagram is shown in Figure 2-26.

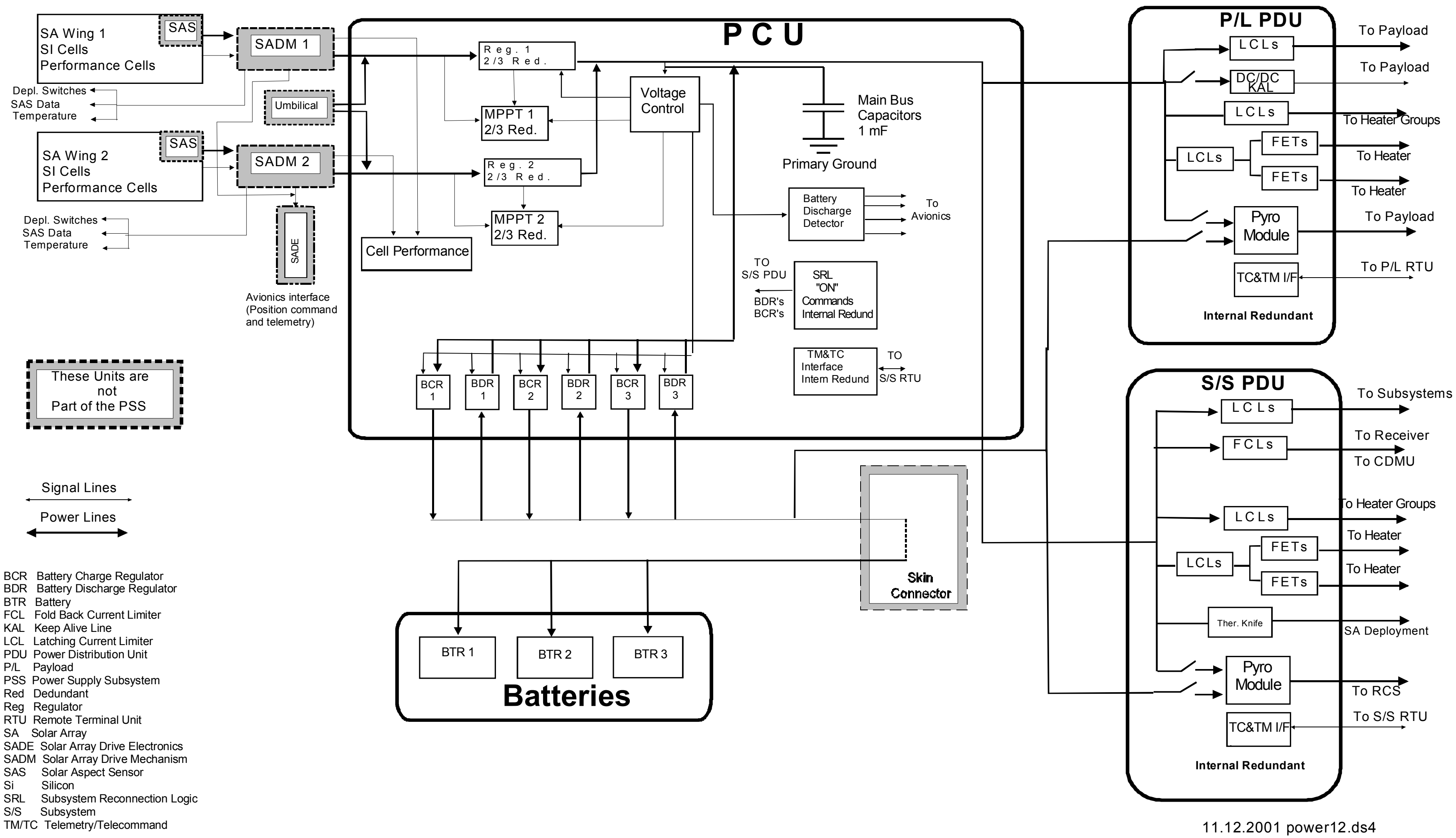


Figure 2-26: Power Supply Block Diagram

Power Conditioning Unit (PCU)

- Produces a fully regulated 28V single power bus from solar array and battery inputs.
- Main bus voltage control including triple redundant error amplifiers
- Separate hot redundant array power regulators for each array wing.
- Separate hot redundant Maximum Power Point Trackers (MPPT) for each array wing
- Separate Battery Discharge Regulator (BDR) for each battery.
- Separate Battery Charge Regulator (BCR) for each battery.
- Array performance monitor.
- TM/TC interface.
- Some automatic functions to support power bus management.

Payload Power Distribution Unit (PL-PDU)

- Dedicated to payload power distribution.
- Fully redundant unit.
- Main bus power outlets are all switched and protected by Latching Current Limiters (LCL).
- LCLs have current measurement and input under-voltage protection.
- 7 LCL power rating classes covering 5.5W to 135W (nominal load capability).
- Provision of Keep Alive Lines (KALs) for experiments
- Pyrotechnic power protection and distribution, including firing current measurement and storage.
- Distributes power to the Thermal Control Subsystem hardware and software controlled heaters.
- Individual on/off switching for each software controlled heater circuit.
- TM/TC interface.

Subsystems Power Distribution Unit (SS-PDU)

- Dedicated to Platform and Avionics power distribution.
- Fully redundant unit.
- Fold-back Current Limiters (FCL) for non-switchable loads (Receivers and CDMUs).
- All other main bus power outlets are switched and protected by Latching Current Limiters (LCL).
- FCLs and LCLs have current measurement and FCLs have input under-voltage protection.
- LCL classes and power ratings as for PL-PDU.
- Pyrotechnic power protection and distribution, including firing current measurement and storage.
- Thermal Knives (TKs) power distribution (for Solar Array panels release).
- Distributes power to the Thermal Control Subsystem combined hardware - software controlled heaters.
- Individual on/off switching for each software controlled heater circuit.
- TM/TC interface.

Batteries

- 3 batteries each comprising 6 series and 11 parallel connected Li-Ion 1.5 Ah cells (corresponds to 16.5 Ah per battery).
- Power and monitoring connections to PCU.
- Power connections also to the PDUs for the pyrotechnics.
- Cells arrangement and wiring to minimise magnetic moment.
- 1 thermistors per battery for battery charge/discharge control.
- A combination of relay/heater mat in order to discharge the batteries for capacitance verification.

Solar Array Generator

The orbit of the S/C has an extremely wide variation of Spacecraft-Earth-Sun angles and distances, hence it is mandatory to include an electrical design based on LILT (Low Intensity Low Temperature) solar cell technology.

The structural parts/units (deployment system, substrates, hold-down & release system) are identical to the qualified ARA ~~Mk3~~MK3 design of Fokker Space.

The geometry and mechanical interface definition of the Rosetta baseline Solar Array design is identical to the 5-panel qualification wing.

The electrical architecture (cells, strings, sections & harness lay-out) is uniquely designed for Rosetta. Electro static discharge (ESD) protection design is qualified for the ARA ~~Mk3~~MK3 type solar array.

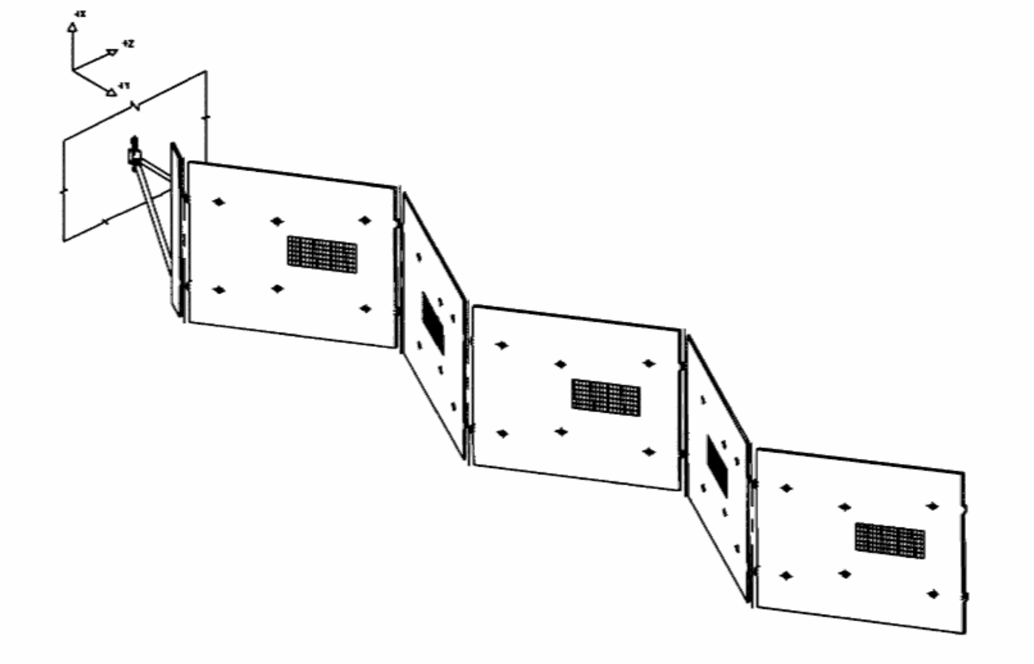


Figure 2-27: Solar array configuration

Baseline Concept Description

The baseline ~~is an~~are 2 solar arrays, each with ~~two~~ a full silicon 5-panel wing~~s~~, with panel sizes as used in the ARA ~~MK3~~MK3 5-panel qualification wing (about 5.3 m^2 per panel).

During launch the wings are stowed against the sidewalls of the satellite. They are kept in this position by means of 6 hold-down mechanisms per wing (see also Figure 2-29).

Approximately 3 hours after launch, the satellite is ~~brought in~~pointed towards the Sun ~~Acquisition Mode~~ and the wings are deployed to their fully deployed position. They are released for full deployment by 'cutting' Kevlar restraint cables by means of thermal knives (actually degrading of the Kevlar by heat).

The deployment system makes use of spring driven hinges and is equipped with a damper, that limits the deployment speed of the wing. Thus, the deployment shocks on SADM hinge and inter-panel hinges are kept relatively low.

The Rosetta wing is further equipped with:

- ESD protection on front and rear side,
- Solar Array sun acquisition sensor,
- Solar Array performance strings

Mechanical Design

The basic skin design of the panels of the solar arrays consists of two layers [0°/90°] M55J/950-1 CFRP prepreg (thickness per layer 0.06 mm) in closed lay-up. The panel substrate dimensions are 2.25 x 2.736 m^2. The front side skin will use a 50µm Kapton foil to isolate the solar cell network from the conductive CFRP layers. The Kapton foil is co-cured with the CFRP layers.

The panel core consists of Aluminium honeycomb with a core height of 22 mm. Local circular reinforcement plugs ('subassembly panels') are used to provide the hold-down areas with extra strength, stiffness and fatigue resistance.

The hold-down and release system uses a tie-down element (Kevlar cable) under high preload which will be degraded by heat of the thermal knife for release.

The hold-down, SADM and yoke snubber locations for Rosetta are fully identical to the ARA MK~~ark~~3 qualification hardware definition. The mechanical interfaces as they were defined for the ARA ~~Mk3~~MK3 5-panel qualification model, are given below in Figure 2-28.

The stowed wing has a height of <239 mm at the wing tips (the gap between inner panel and sidewall is increased from nominal 70 mm by about 30mm by means of a dedicated bracket, the inter panel gap is 12 mm, and the panel substrate thickness is 22 mm).

The deployment mechanism concept relies on spring-driven hinges. The spring characteristics are chosen such that the energy supply is enough for the full range up to 5 maximum sized panels, while maintaining the required deployment safety factors. In order to reduce the shock loads on the SADM and inter-panel hinges, a damper is introduced in the deployment system.

A stiff synchronisation system is applied to prevent a very non-synchronous deployment, resulting in unpredictable high deployment latch-up shocks at the inter-panel hinges.

The V-yoke length is 1103 mm when measured from SADM hinge-line to yoke/inner panel hinge-line. The yoke length used within the ARAFOM 5-panel QM wing programme is identical.

The arms of the V-shaped yoke consist of M46J CFRP filament wound with a circular cross section (inner diameter 43 mm; nominal wall thickness 0.9 mm) with reinforcements at the ends of the yoke tubes.

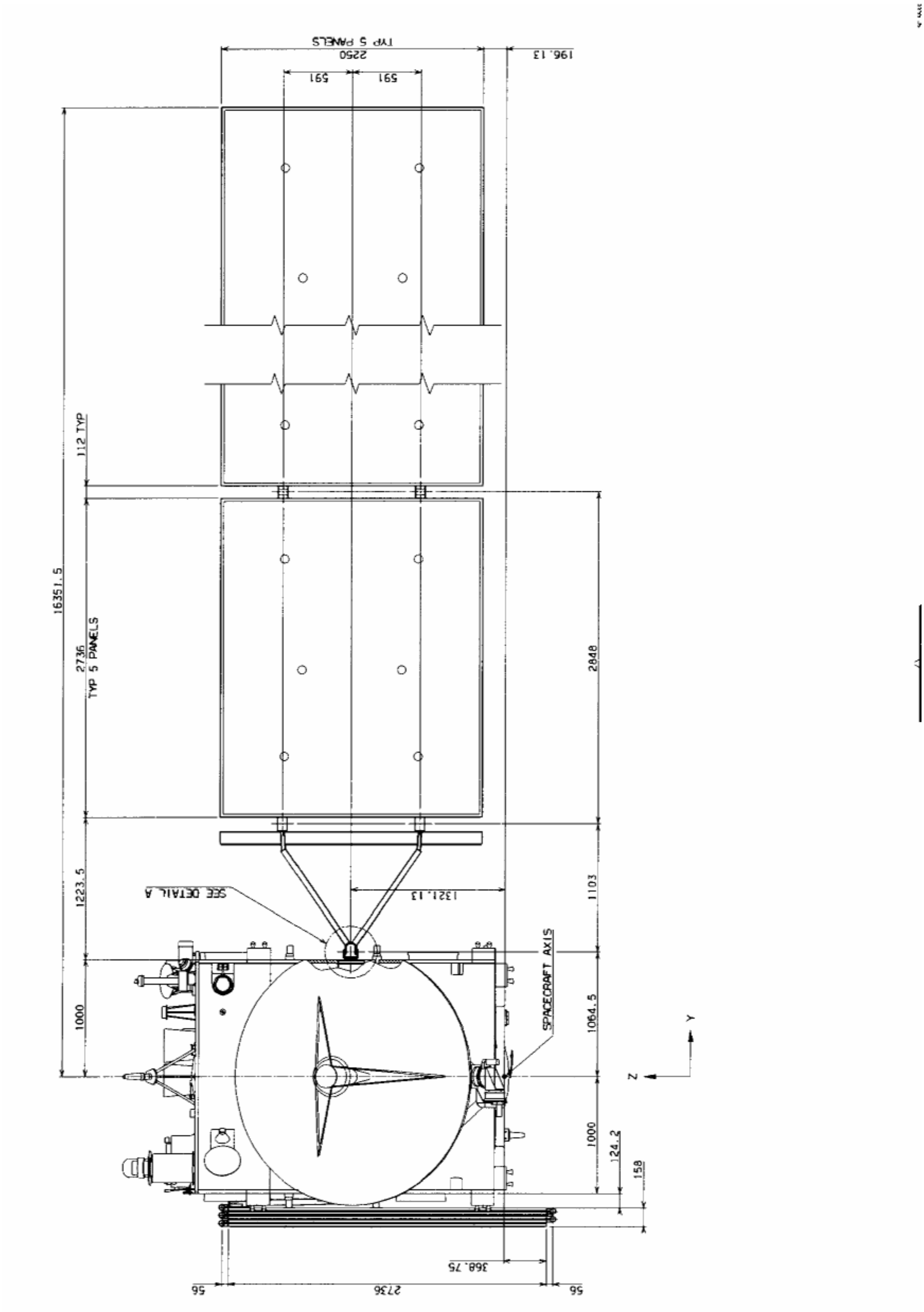


Figure 2-28: Solar array / S/C Interfaces Dimensions

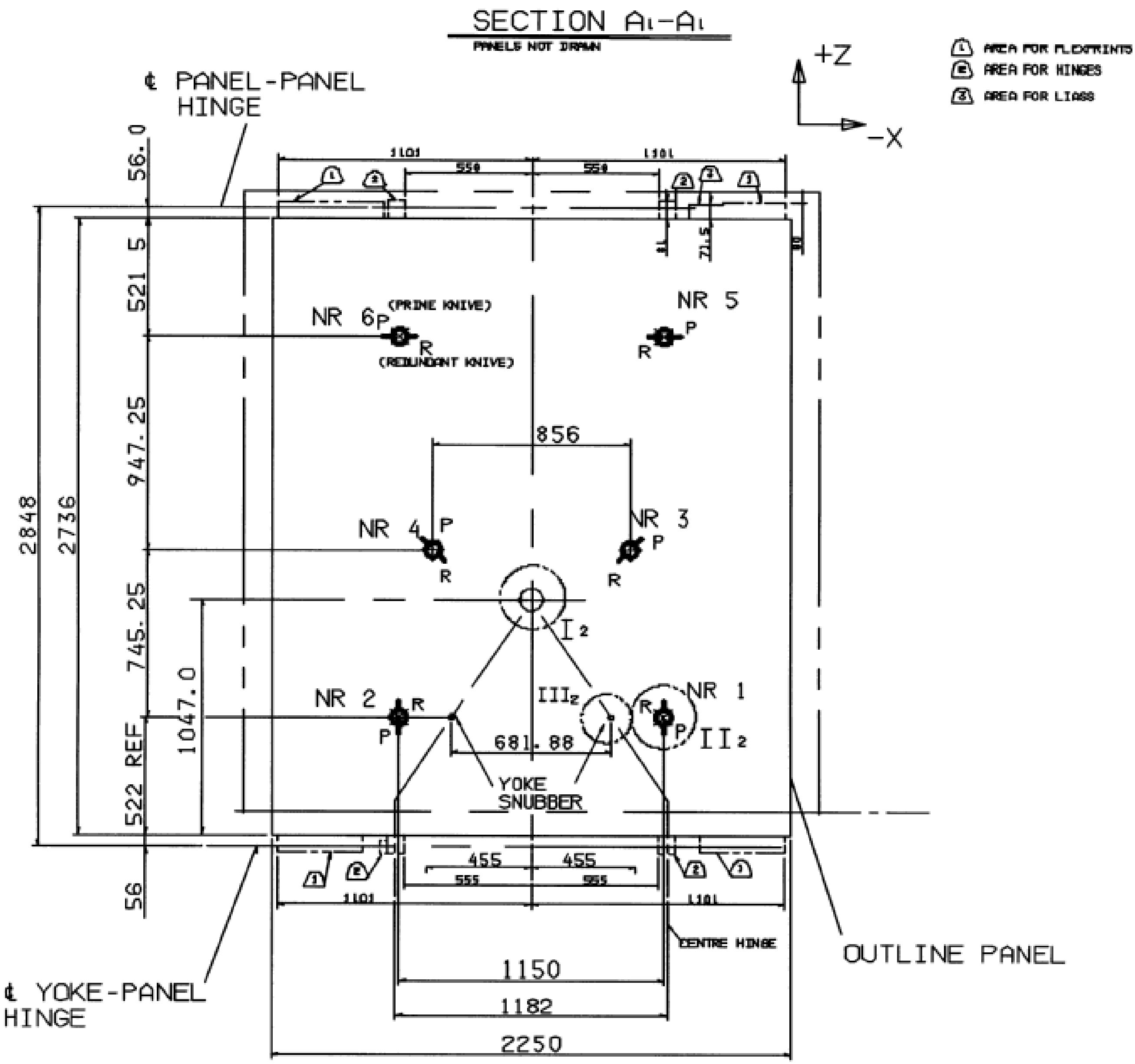


Figure 2-29: Solar array / S/C mechanical Interfaces

Electrical design

Silicon LILT cells are applied for the Rosetta mission. These have undergone advanced qualification. A formal delta ~~TAT~~ type approval test (TAT) was performed due to different technologies used in some area.

The solar cell employed is a 200 µm Si solar cell of LILT type sized 37.75 mm in width and 61.95 mm in length (note that the TAT approval cell size is identical to this). The cover-glass is 100 µm thick ceria doped micro-sheet designated CMG. The cover-glass covers the solar cell 100%.

Each panel is covered by 25 strings with 91 cells in series. The strings run parallel to the hinge-line direction. Thus, a maximum of 57 cells fit in series into the full panel width. The total cell quantity per panel is 2275 pcs. Each electrical string is equipped with blocking diodes.

The interconnection of the cell strings into circuits is done by stranded Ag wires. All electrical connections on the solar array (inter-connector to cell, cell to string terminal, terminal to terminal, terminal to wiring, wiring to diodes) are soldered.

Each cell string is terminated by an Ag-ribbon collection bus that is connected by redundant wiring to the panel interface connector for its negative end and to the diode boards for its positive end. All positive and negative power lines are routed together in parallel as far as possible to meet EMC requirements.

The blocking diodes are mounted on the rear side and connected to the cell sub-strings on the panel front side via harness.

The routing of the strings and circuits is designed in such a way that nearly complete compensation of the electromagnetic moments is achieved.

Due to the large difference in sun intensity at various mission stages, the solar cell temperature and therefore the voltage at the maximum power ~~maximum~~ point varies a lot. For the PVA (Photo Voltaic Assembly) cell string length design, the requirement for maximum allowed voltage of 70 Volt could not been reached due to power optimisation. The open circuit voltage will be around ~~7~~08 V. (EOL, sun distance 5.~~25~~ 33 AU, incident angle 0 degrees).

At all other times the spacecraft operates at far less power than Pmax (1kW per wing is the overall upper power limit), so V-operating will be closer to Voc (this is then at or close to a minimum voltage of ≈32V).

The total amount of lines at the SADM interface is 82. This amount is within the qualified ARA ~~Mk3~~MK3 range.

The transfer harness is modular. It is routed as close as possible along the holddown points from hingeline to hingeline. This is done to minimise the adverse effects on the dynamic behaviour of the panels. It is fixed to the panel rear side by means of cable clamps and/or adhesive fixation spots. Thermal expansion and repair provisions are taken into account.

The hingelines are crossed by inner and outer flexprints, with male connector parts attached to them. The flexprint consists of 12 etched copper tracks in-between two thin Kapton foils.

Shielding against ESD is provided by means of a metal mash over the transfer harness. It is attached to the rear side of the panel substrate by electrically conductive bonding.

Double insulation is included in the design, by adding an additional layer of Kapton underneath the harness over the rear side of the panel or by using wires with double isolation.

The power and signal wires are connected to the SADM harness by connectors.

Thermistors

3 thermistors are attached at each wing :

- One non-redundant thermistor with single wiring is placed on the outer panel. Its purpose is mainly to give a temperature indication shortly after solar array release to detect any deployment anomaly and to provide a reference for the Power monitoring string thermistors
- One thermistor is located under the Power Monitoring String on the inner panel, monitoring the short circuit string
- One thermistor is located under the Power Monitoring String on the next-to-inner panel~~,~~ monitoring the ~~PMS(oc)~~open circuit string

Microswitches

2 Micro switches (nominal and redundant) are mounted~~ ~~ at each SADM hinge~~.~~. The micro-switch uses single wiring~~ ~~.

Grounding

Two redundant ground lines, in separate harnesses are used. All panels will have redundant ground spots,~~,~~ ~~that~~ which are connected through bleed resistors to these ground lines.

Power Monitoring String

~~Redundant~~ 2 power monitoring strings (PMS) are ~~placed~~ available on each wing.~~on the inner panel, together with 2 thermistors.~~ ~~2~~ One PMS on the inner panel'~~s~~ ~~are~~ is used for O/C voltage measurements, and ~~are~~ is combined with the signal harness over the flex-prints. ~~2~~ The other PMS'next to the inner pannel~~s~~ measures the S/C current, and ~~are~~ is considered part of the power harness. All these items are redundant (i.e. available on each wing) and therefore no redundant harness is used for them.

ESD Measures

The Rosetta specification gives 10V as maximum allowable charging potential, while taking into account a plasma current density of 5 nA/cm^2;. Since the cell area is approximately 25 cm^2, the maximum current will be 125 nA. Below 10 V, the maximum resistance to ground is then 80 MΩ. Therefore, the specification will be met when connecting the conductive cover-glasses with conductive patches under the condition that items such as synchro cables, pulleys and partially wiring are excluded from this requirement.

~~Compliance to the ESD requirements has been verified in the standard DVT tests (note: no actual plasma environment).~~

Sun Acquisition Sensor

New developed bracket attachment points are provided in the edge-members, ~~that~~ which are used for the S~~s~~un A~~a~~cquisition S~~s~~ensors belonging to the AOCMS.

2.1.10. Harness Design

The harness performs the electrical connection between all electrical and electronic equipment in the ROSETTA spacecraft. It provides distribution and separation of power supplies, signals, scientific data lines, pyrotechnic firing pulses, and all connections to the umbilical, safe/arm brackets/connectors and test connectors.

The harness consists of the following subassemblies:

- Payload Support Module Harness
- Bus Support Module Harness
- Harness to the Lander I/F

Furthermore the harness / cables are divided into three harness EMC classes: power, signal and data, and the pyro harness. Their routing is physically separated. In addition to the appropriate twisting and shielding techniques this minimises the probability of electrical cross talking of critical lines.

The harness design follows a distributed single point grounding scheme.

Redundant functions have their own connectors and are routed in separate bundles and in a different way as far as practical.

All connectors supplying power have female contacts.

To achieve a complete Faraday cage around the harness each of the harnesses has its own overall shield made of aluminium tape with an overlap of at least 50 % for harnesses within the spacecraft and a double shield for harnesses outside the spacecraft. As fixation points for the harness aluminium bases (Ty-bases) are bonded to the structure with a two component conductive glue. The distance of the Ty-bases is selected such that the harness withstands all specified environmental conditions.

To avoid interruptions of the shield between the connector and the overall shield, redundant connection wires are used between connector case and harness overall shield. In case of pyro-lines and sensible interfaces conductive connector boots are implemented.

To prevent contamination the harness was -baked-out in a thermal vacuum chamber prior to integration.

2.2. Payload Description

The following payload description has been taken from the Experiment Interface Documents provided by ESA.

2.2.1. ALICE

2.2.1.1. Scientific Objectives

The scientific objectives of the Alice investigation are to characterize the composition of the nucleus and coma, and the nucleus/coma coupling of comet 46P/Wirtanen through the observation of spectral features in the EUV/FUV region from 700-2050 Å region. Alice will provide access to the measurement of noble gas abundances, the atomic budget in the coma, major ion abundances in the tail and in the region where solar wind particles interact with the ionosphere of the comet, determine the production rates, variability, and the structure of H_2O and CO, and CO_2 gas surrounding the nucleus and the far-UV properties of the solid grains. Alice will also map the cometary nucleus in the FUV.

Ultraviolet spectroscopy is a powerful tool for studying astrophysical objects, and has been applied with dramatic success to the study of comets. Alice will provide unprecedented improvements in sensitivity and spatial resolution over previous cometary UV observations. For example, Alice will move the sensitivity threshold from the ~1 Rayleigh level achievable with the Hubble Space Telescope to the milli Rayleigh level in deep integrations. In addition, Alice will (by virtue of its location at the comet) move the spatial exploration of nucleus UV surface properties from the present-day state-of-the-art (i.e., no data available on any comet) to complete nuclear maps at Nyquist-sampled resolutions of a few hundred meters. Stars occulted by the absorbing coma will also be observed and used to map the water molecule spatial distribution, giving us hints at how the production regions are located on the nuclear surface.

Through its remote-sensing nature, Alice will be able to:

- Obtain compositional and morphological information on the comet prior to the rendezvous, thereby providing planning observations for in situ instruments prior to entering orbit about the comet.
- Map the spatial distribution of key species in the coma, and small coma dust grains, as a function of time as the comet responds to the changing solar radiation field during its approach to the Sun.
- Obtain compositional and production rate measurements of nuclear jets and other inner coma features even when the Orbiter is not in the vicinity of these structures.

- Obtain comet ionosphere measurements around perihelion in order to connect nucleus activity to changes in tail morphology and structure, and coupling to the solar wind.

The primary scientific themes of the Alice investigation will be:

- Determining the rare gas content of the nucleus to provide information on the temperature of formation and the thermal history of the comet since its formation. Ar and Ne will be prime targets of the Alice investigations.

- Determining the production rates and spatial distributions of their key parent molecule species, H_2O, CO and CO_2, thereby allowing the nucleus/coma coupling to be directly observed and measured on many timescales in order to study the chemical heterogeneity of the nucleus and its coupling to the coma.

- Obtaining an unambiguous budget of the cosmogonically most important atoms C, H, O, N, and S through the detection of their emissions far from the nucleus. This is required to understand their production processes and to derive the elemental composition of the volatile fraction of the nucleus. Coupled to the measure of the major molecule abundances of the nucleus, this will give us the total contribution of the secondary parent species to the compositional makeup of the nucleus.

- Studying the onset of nuclear activity and nucleus output variations related to changing solar aspect and nuclear rotation with unprecedented sensitivity.

Additional scientific themes will also be addressed by Alice, including:

- Spectral mapping of the complete nucleus at far-UV wavelengths to characterize the distribution of UV absorbers on the surface. , in particular water icy patches and organics.

- Studying the photometric properties and ice/rock ratio of small grains in the coma as an aid to understanding the size distribution of cometary grains and how they vary in time. Also, studying the grain coma to establish the relative contributions of the nucleus and coma grains to the observed gases.

- Mapping the time variability of O^+, N^+, S^+ and C^+ emissions in the coma and ion tail in order to connect nuclear activity to changes in tail morphology and structure, and tail interaction/coupling to the solar wind.

Table 2-3 -summarizes the performances characteristics of Alice

Table 2-4 summarizes the estimated ground and flight calibration precision and stability targets for Alice.

Alice Characteristics & Performance Overview	
Bandpass	700-2050 Å
Spectral Resolution ($\Delta\lambda$ FWHM)	10 Å (700 Å); 13 Å (2050 Å) (extended source)
Spatial Resolution	0.1 x 0.5 degrees ^{2}
Nominal Sensitivity	0.5 (1900 Å)-7.8 (1150 Å) counts s^{-1} R^{-1}
Field of View	0.1 x 6.0 degrees^2
Pointing	Boresight with OSIRIS, VIRTIS
Observation Types	Nucleus Imaging and Spectroscopy; Coma Spectroscopy
	Jet and Grain Spectrophotometry; Stellar Occultations (optional observations)
Telescope/ Spectrograph	Off-axis telescope, 0.15m Rowland circle spectrograph
Detector Type	2-D Microchannel Plate

Table 2-3: Alice Characteristics and Performances

Parameter		Nominal Value	Ground Calibration Precision	Long-Term Stability	Flight Calibration Precision
Dark Count Rate		4-7 cts s^{-1}	±2%	±20%	±2%
Wavelength Scale		N/A	<1 Å	3-4 Å	<1 Å
Flat Field Uniformity		±20%	±1%	±5%	N/A
Lyman- Scatter (integral scatter)		1-2% (goal)	$<10^{-3}$ (goal)‡	N/A	$<3 \times 10^{-3}$ (goal) ‡
Off-axis Scatter (6 deg. off-axis)		$<10^{-6}$ (goal)	$<10^{-7}$ (goal)‡	N/A	$<10^{-7}$ (goal)
Absolute[1] Effective Area:	Point Source	0.01-0.5cm^2	<30%	30%	30% (goal)
	Extended Source	0.01-0.5cm^2	30%	30%	<50% (goal)†
Spectral[1] Resolution:	Point Source	5.6 Å	±1.5 Å (±1/2 pixel)	<3 Å (goal)	±1.5 Å (±1/2 pixel)

Parameter		Nominal Value	Ground Calibration Precision	Long-Term Stability	Flight Calibration Precision
	Extended Source	10-12 Å	±1.5 Å (±1/2 pixel)	<3 Å (goal)	±1.5 Å (±1/2 pixel)
Spatial Resolution:	Point Source	0.6 deg	0.15° (±1/2 pixel)	0.03 deg	±0.15° (±1/2 pixel)
	Extended Source	0.6 deg	±0.15° (±1/2 pixel)	0.03 deg	±0.15° (±1/2 pixel)
† May do better at Ly α (1216 Å) ‡ Estimate includes Ly α notch in detector photocathode 1) Wavelength dependent					

Table 2-4: Alice Calibration precision and Stability Targets

2.2.1.2. Design Overview of Alice

The *Alice* UV spectrometer is a very simple instrument. An opto-mechanical layout of the instrument is shown in Figure 2-30. Light enters the telescope section through a 40 x 40 mm^2 entrance aperture and is collected and focused by an f/3 off-axis paraboloidal (OAP) primary mirror onto the approximately 0.1° x 6° spectrograph entrance slit (see below for a description of the entrance slit geometry). After passing through entrance slit, the light falls onto a toroidal holographic grating, where it is dispersed onto a microchannel plate (MCP) detector that uses a double-delay line (DDL) readout scheme. The 2-D (1024 x 32)-pixel format, MCP detector uses dual, side-by-side, solar-blind photocathodes of potassium bromide (KBr) and cesium iodide (CsI). The predicted spectral resolving power ($\lambda/\Delta\lambda$) of *Alice* is in the range of 105-330 for an extended source that fills the instantaneous field-of-view (IFOV) defined by the size of the entrance slit. *Alice* is controlled by an SA 3865 microprocessor, and utilizes lightweight, compact, surface mount electronics to support the science detector, as well as the instrument support and interface electronics. Figure 2-31 shows a 3D external view of *Alice*. The resulting design is highly systems-engineered to minimize mass and complexity, and enjoys strong parts-level heritage from previous UV spectrometers.

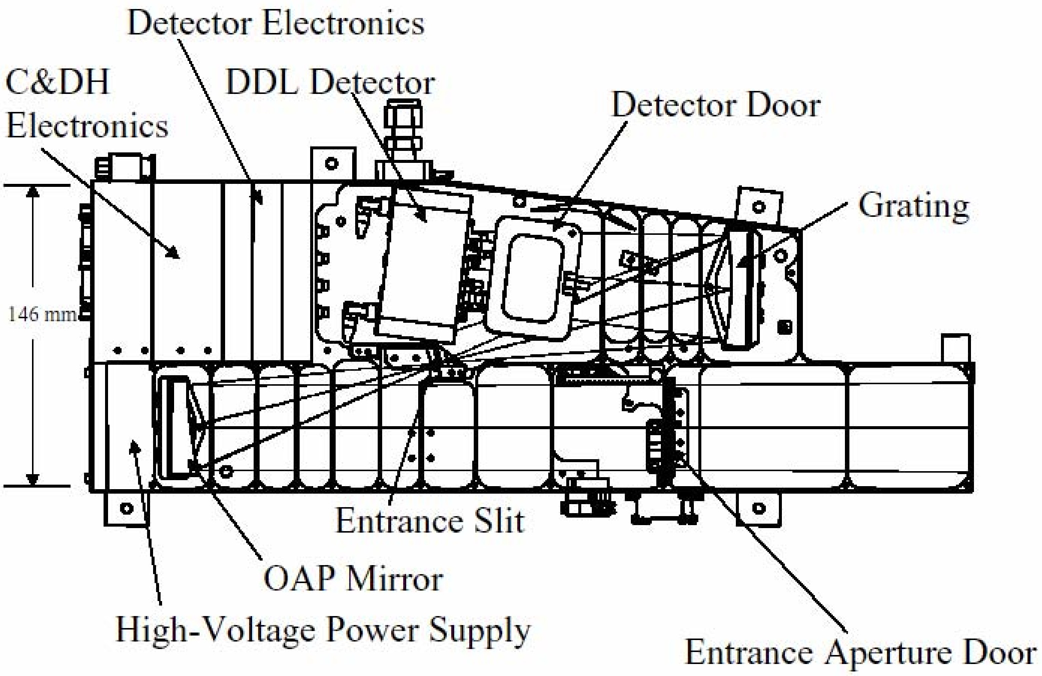


Figure 2-30: The Opto-mechanical Layout of Alice

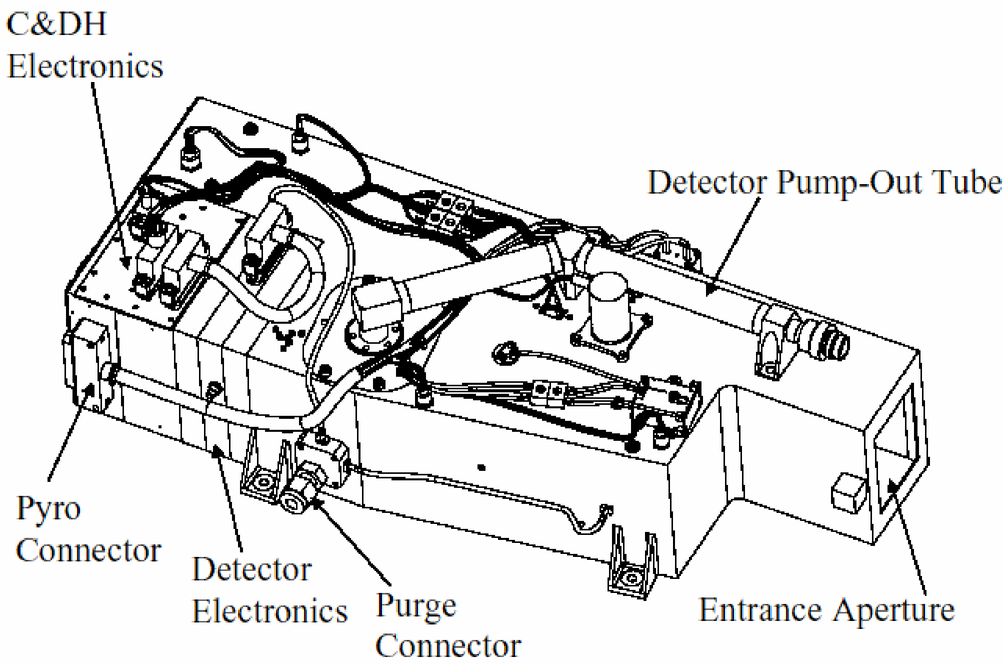


Figure 2-31: External view of ALICE

The major elements of Alice are

- a 41 x 65 mm^2 off-axis paraboloidal primary telescope mirror,
- a 50 x 50 mm^2 toroidal holographic diffraction grating,
- a front aperture contamination door that will close on close-comet encounters
- a 2-D imaging photon-counting microchannel plate (MCP) detector assembly with vacuum cover/window assembly,
- a detector high voltage power supply, and a
- microprocessor controller board with power controller and command-and-data handling electronics.

These six elements are packaged into an extremely lightweight aluminum housing.

2.2.2. MIRO

2.2.2.1. Scientific Objectives

The investigation, Microwave Instrument for the Rosetta Orbiter (MIRO), addresses the nature of the cometary nucleus, outgassing from the nucleus and development of the coma as strongly interrelated aspects of cometary physics and searches for outgassing activity on asteroids. MIRO is configured both as a continuum and a very high spectral resolution line receiver. Center-band operating frequencies are near 188 GHz (1.6 mm) and 562 GHz (0.5 mm). Spatial resolution of the instrument is approximately 5 m at a distance of 2 km from the nucleus; spectral resolution is sufficient to observe individual, thermally broadened, line shapes at all temperatures down to 10 K or less. Four key volatile species - H_2O, CO, CH_3OH, and NH_3—and the isotopes—$H_2{}^{17}O$ and $H_2{}^{18}O$—are pre-programmed for observation. The primary retrieved products are abundance, velocity, and temperature of each species, along with their spatial and temporal variability. This information will be used to infer coma structure and processes, including the nature of the nucleus/coma interface.

MIRO will sense the subsurface temperature of the nucleus to depths of several centimeters or more using the continuum channels at millimeter and submillimeter wavelengths. Model studies will relate these measurements to electrical and thermal properties of the nucleus and address issues connected to the sublimation of ices, ice and dust mantle thickness, and the formation of gas and dust jets. The global nature of these measurements will allow in situ lander data to be extrapolated globally, while the long duration of the mission will allow us to follow the time variability of surface temperatures and gas production. Models of the thermal emission from comets are very crude at this time since they are unconstrained by data, and MIRO will offer the first opportunity to gather subsurface temperature data that can be used to test thermal models. MIRO is highly complementary to the IR mapping instrument on the orbiter, having similar spatial resolution but greater depth penetration.

2.2.2.2. Design Overview of MIRO

The MIRO instrument will provide both very sensitive continuum capability for temperature determination and extremely high-resolution spectroscopy for observation of molecular species. The instrument consists of two heterodyne radiometers, one at millimeter wavelengths (1.3 mm) and one at submillimeter wavelengths (0.5 mm). The millimeter and the sub-millmeter radiometers have continuum bandwidths of 0.5 GHz and 1.0 GHz respectively in addition, the submillimeter receiver has a spectroscopic bandwidth of 180 MHz and a spectral resolution of 44 kHz. In the spectroscopic mode, 4096 spectral channels each having a bandwidth of 44 kHz, will be observed simultaneously.

2.2.2.2.1. Performance Characteristics

The performance parameters that govern the MIRO instrument design include system sensitivity, spatial resolution, radiometric accuracy (both absolute and relative), beam pattern and pointing accuracy, together with the mass, power, volume envelope, and environmental conditions available within the spacecraft.

The MIRO instrument performance characteristics are summarised in Table 2-5.

2.2.2.2.2. System Overall Configuration

Four units will be provided. A block diagram is shown in Figure 2-32, the sensor configuration in Figure 2-33

- The Sensor Unit consists of the telescope, baseplate, and optical bench. The Sensor Unit is mounted to the spacecraft skin at the baseplate. The telescope, mounted on the baseplate, is outside the spacecraft, while the optical bench, also mounted to the baseplate, is inside the spacecraft. The optical bench carries the millimeter- and submillimeter-wave receiver front ends (RFEs), the calibration mechanism, and the quasi-optics for coupling the telescope to the RFEs.

- The Sensor Backend Electronics Unit is flush mounted internal to the spacecraft on a louvered radiator. It contains the intermediate frequency processor, the phase lock loop, and frequency sources.

- The Electronics Unit is flush mounted internal to the spacecraft on a louvered radiator. It contains the Chirp Transform Spectrometer (CTS), the instrument computer, and the power conditioning circuits.

The Ultra-Stable Oscillator (USO) Unit is flush mounted internal to the spacecraft and provides the high accuracy frequency reference for the instrument.

Equipment	Property	Millimeter-Wave	Submillimeter-Wave
Telescope	Primary Diameter Primary F/D Sidelobes Spatial Resolution Footprint size (at 2 km)	30 cm 1 –30 dB 22 arcmin ~15 m	30 cm 1 –30 dB 8 arcmin ~5 m
Spectral Performance	Frequency Band IF Bandwidth Spectral Resolution Allocated Spectral Range Accuracy	186.7–189.7 GHz 1–1.5 GHz	546.4–579.2 GHz 5.5-16.5 44 kHz nominally 20 MHz 10 kHz
Spectrometer	Center Frequency Number of channels	1350/180 MHz 4096	
Radiometric Performance	DSB Receiver Noise Temperature SSB Spectroscopic Sensitivity (300 KHz, 2 min) relative absolute Continuum Sensitivity (1 sec): relative absolute	2000 K 1 Krms 3 Krms	5000 K 2 Krms 3 Krms 1 Krms 3 Krms
Data Rates	Instantaneous Rate Continuum Mode Spectroscopic Mode On-board Storage	 <1 kbps 2 kbps 0.2 Gb (one day's data volume, Mode 3, 100% duty cycle)	

Table 2-5: MIRO Instrument Performance Characteristics

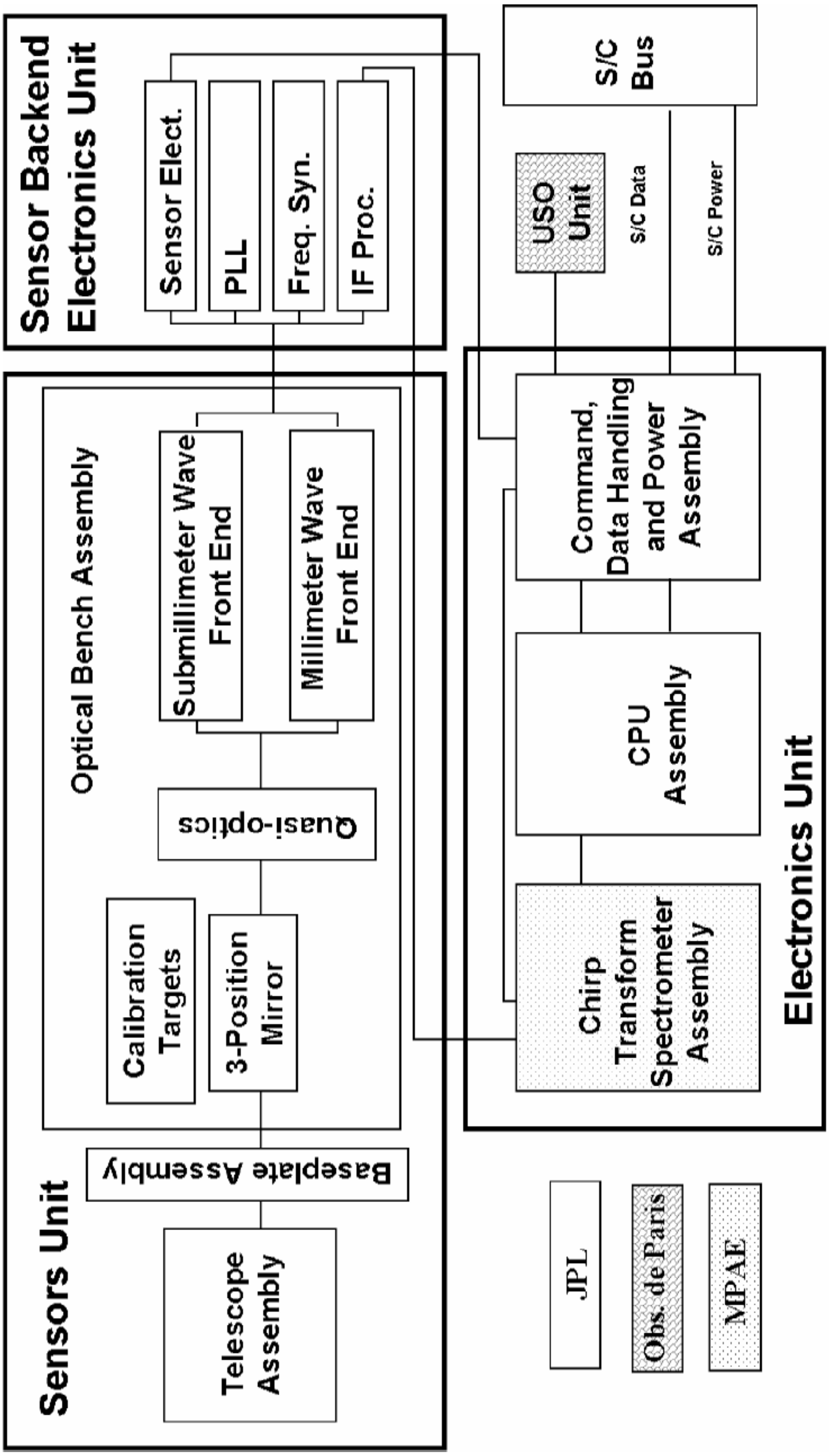


Figure 2-32: MIRO instrument block diagram

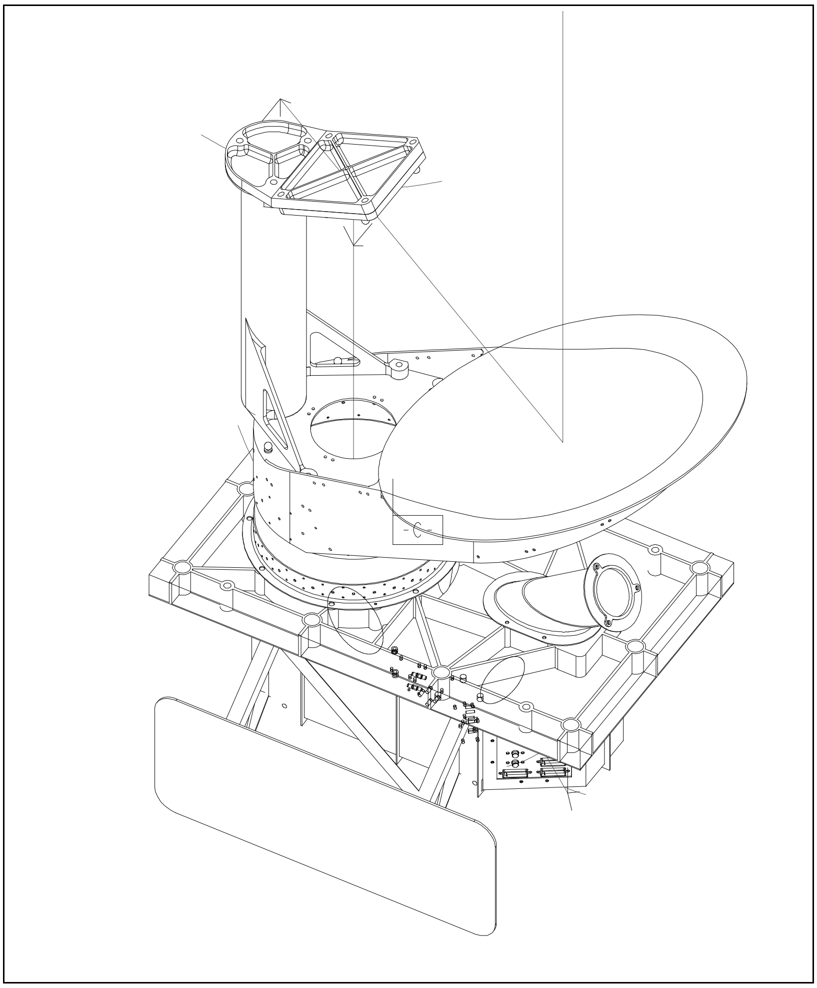


Figure 2-33: Sensor Unit Configuration

2.2.3. VIRTIS

2.2.3.1. Science Objectives

The primary scientific objectives of the VIRTIS during the Rosetta mission are:

- to study the cometary nucleus and its environment,
- determine the nature of the solids of the nucleus surface,
- identify the gaseous species,

- characterize the physical conditions of the coma,
- measure the temperature of the nucleus.

Secondary objectives include helping with the selection of landing sites and providing support to other instruments.

Tertiary objectives include the detection and characterization during flybys of the asteroids Siwa and Otawara.

2.2.3.2. Design Overview of VIRTIS

VIRTIS is an imaging spectrometer combining three data channels in one compact instrument. Two of them are devoted to spectral mapping (Mapper optical subsystem: -M). The third channel is devoted to spectroscopy (High resolution optical subsystem:-H).

As shown in the functional block diagram of Figure 2-34, the -M and -H optical subsystems are housed inside the Cold Box of the Optics Module. The Optics Module is externally mounted to the -X panel of the spacecraft with the -M and -H co-aligned and boresighted in the positive Z direction. Both optical systems have their slits parallel to the Y axis; the -M has the ability to point and scan by rotating the primary mirror around the Y axis. The Optics Module is electrically connected by the Inter-Unit Harness.to the -M and -H Proximity Electronics Modules and to the Main Electronics Module, which are internally mounted to the spacecraft on its -Y panel.

The -M utilizes a silicon charge coupled device (CCD) to image from .25 um to 1 µm and a mercury cadmimum telluride infrared focal plane array (IRFPA) to image from 1µm to 5 µm. The -H employes the same HgCdTe IRFPA to perform spectroscopy from 2 µm to 5 µm. The electronics to drive the CCD and the two IRFPAs are housed inside the Proximity Electronics Modules, while the remaining electronics boards are housed inside the Main Electronics Module. Both IRFPAs require active cooling to minimize the detector dark current (thermally generated Johnson noise). To minimize the thermal background radiation seen by these two IRFPAs, the Cold Box must be passively cooled to less than 130 K by radiating one of its surfaces toward cold space. While the coolers are housed inside the Optics Module Pallet, which directly interfaces with the warm spacecraft, the cold detectors and optical systems are housed in a cold structure that must be rigidly mounted to the much warmer Pallet while remaining thermally insulated from it. The VIRTIS engineering team is therefore faced with the daunting task of thermal-mechanically attaching this “Cold Box” in two counterposing ways to the Pallet: The cold fingers connecting the two active coolers inside the Pallet to their corresponding IRFPAs inside the Cold Box must maximize the thermal pathway from the coolers to the IRFPAs while remaining mechanically pliant; in contradistinction, the standoff insulators connecting the Cold Box to the baseplate of the Pallet must minimize the thermal pathway between the warm spacecraft and the cold optical subsystems while remaining mechanically rigid. In this way the structure and the delicate subsystems that it supports are not only guaranteed to survive launch vibrations, but the structure can also help in minimizing the usual thermal gradients that adversely affect the alignment of low temperature optical systems.

It is clear that the technical challenge is formidable, but it is by no means insurmountable. One approach that should ensure success is to simplify the thermal-mechanical design (ie. obviate the need for a radiator, cold finger, and cold plate) and rely on a series of backup innovative techniques to reduce temperature impacts at various levels: new MLI materials and mounting techniques, new detector technologies, clever baffling of thermal background, and proper use of optical filtering. Therefore the philosohpy of the VIRTIS team, which is to simplify the thermal-mechanical design to the greatest extent possible, can still be maintained while guaranteeing the extensive scientific return that is only possible through an instrument of this class. The team also intend to work closely with the spacecraft engineers to ensure that the interface to the spacecraft is likewise kept simple and straightforward.

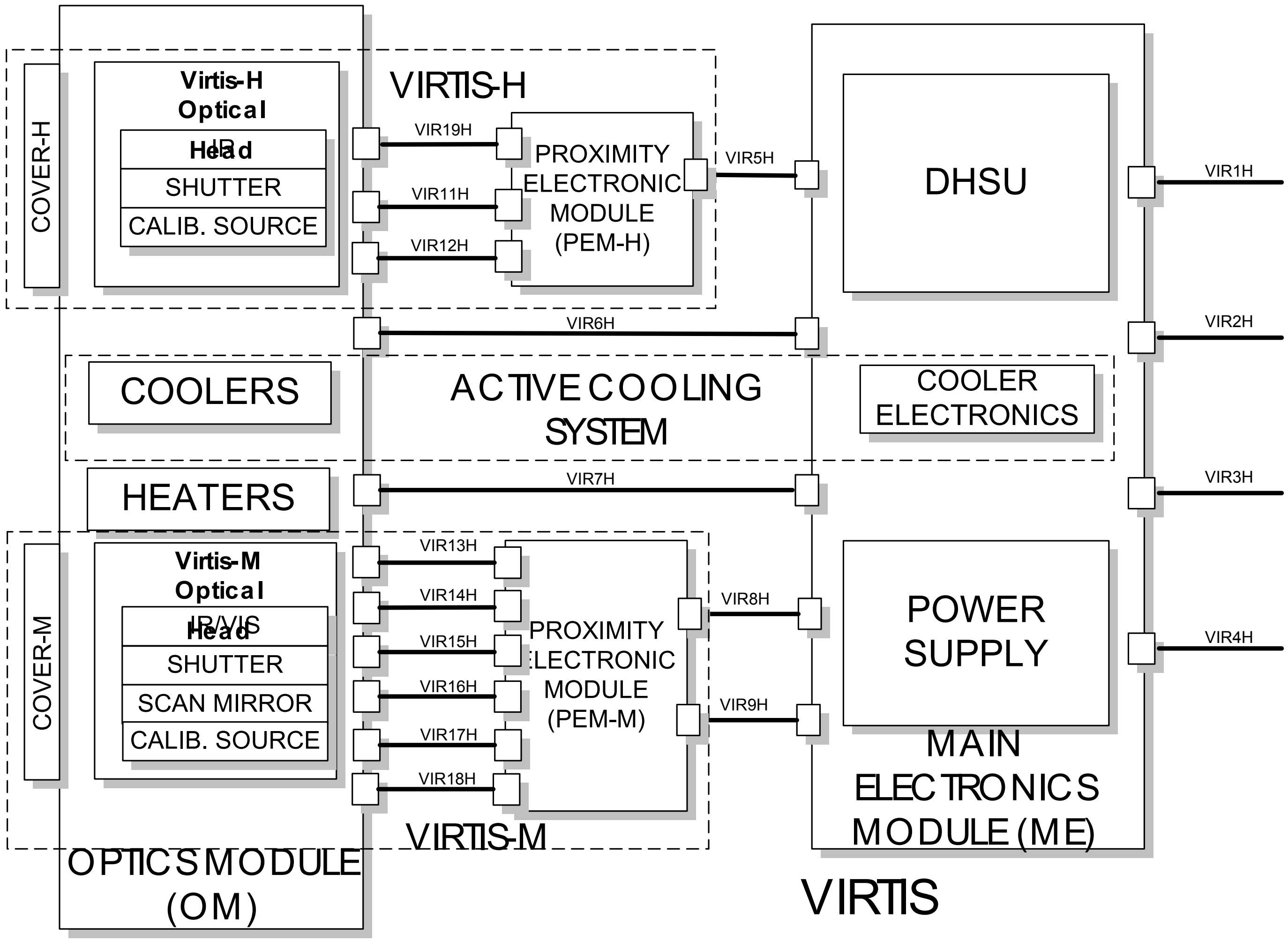


Figure 2-34: Functional Blockdiagram

2.2.4. OSIRIS

2.2.4.1. Scientific Objectives

OSIRIS (Optical, Spectroscopic, and Infrared Remote Imaging System) was proposed as an imaging system with extended spectroscopic capabilities. The physical and chemical state of the surface of a cometary nucleus is essentially unknown. Versatile instrumentation is therefore required combining the widest possible wavelength range with high spatial resolution.

While the spectrometer part as well as the infrared were deleted, we keep the name until a better extension of the acronym is found.

The expected small size of the target comet Wirtanen with an estimated radius of less than half a kilometre places even more emphasis on high spatial resolution in order to characterise the volume, shape and surface properties with the same relative accuracy as for the originally assumed object with a radius of two kilometres. With the present design of the NAC and WAC the smaller size of Wirtanen will have to be compensated by closer orbits.

Determination of the bulk volume of comet Wirtanen will require complete mapping with a resolution of better than 25 cm per pixel. The orbiter will have to be closer to the nucleus than 5 km for extended time intervals. On average the mean distance of the orbiter from the nucleus should be a factor four smaller than assumed during the proposal phase to achieve comparable quantitative measurements.

The determination of the overall mass loss requires to quantify changes of the volume during the perihelion passage to about an order of magnitude better. Good overall coverage and quantitative observations of active areas with a resolution of about 3 cm per pixel require the orbiter to be nearer to the nucleus than three cometary radii or 1.5 km over extended time intervals. These close up views are also required before the end of the mission (nominally at perihelion) to determine the changes due to the cometary activity.

The loss of the high resolution imaging in the IR makes a mineralogical and chemical analysis of apparent changes due to activity much more difficult. Information will have to be retrieved from albedo and phase variations and will require much more complex (and complete) observational sequences, higher data rates and volumes, and extensive modelling. The results will only be satisfying in fortuitous circumstances.

It is highly desirable to make movies, i. e., a rapid sequence of images to analyse outbursts. The time intervals are presently limited by the recharge time of the shutters. Images with reduced resolution (2x2 pixels) can be achieved in less than one second.

Several major goals such as the mapping of the detailed topography and determination of the nucleus volume to better than 1 % may not be feasible because of the severely limited data rate and achievable total data volume provided by the spacecraft. The resolution of mapping possible landing sites on the nucleus will also be limited by the data rate that can be transmitted.

Some important parameters of the dust can be best determined by observations of the forward scattered light, i. e., during an eclipse in the shadow of the nucleus. OSIRIS strongly support the request for operations in this situation.

2.2.4.2. Design Overview of OSIRIS

The Remote Imaging System consists of five main units: A Wide Angle Camera (WAC), and a Narrow Angle Camera (NAC), both with structure, optics and detectors, a NAC CRB Box, containing the NAC CCD Readout Boards, the CRB dedicated power converters and the shutter electronics, a WAC CRB Box containing the WAC CCD Readout Boards, the CRB dedicated power converters and the shutter electronics, an Electronics Box (E-Box), housing the Data Processing Unit (DPU) and other electronics modules as detailed in the next chapter.

Figure 2-35 shows a block diagram of the camera system.

The current baseline which this specification follows is to mount the two cameras separately to the s/c wall, on the outside of the s/c. The radiators for the FPA and for the WAC will be mounted to the camera units. This minimises the mass of the s/c interface structure and allows easy cooling of the detectors. NAC and WAC CRB Boxes need to be located as close as possible to the respective camera to minimise harness length. The rest of the electronics, in the E-Box, may be located farther away. A sketch of the layout is shown in Figure 2-36.

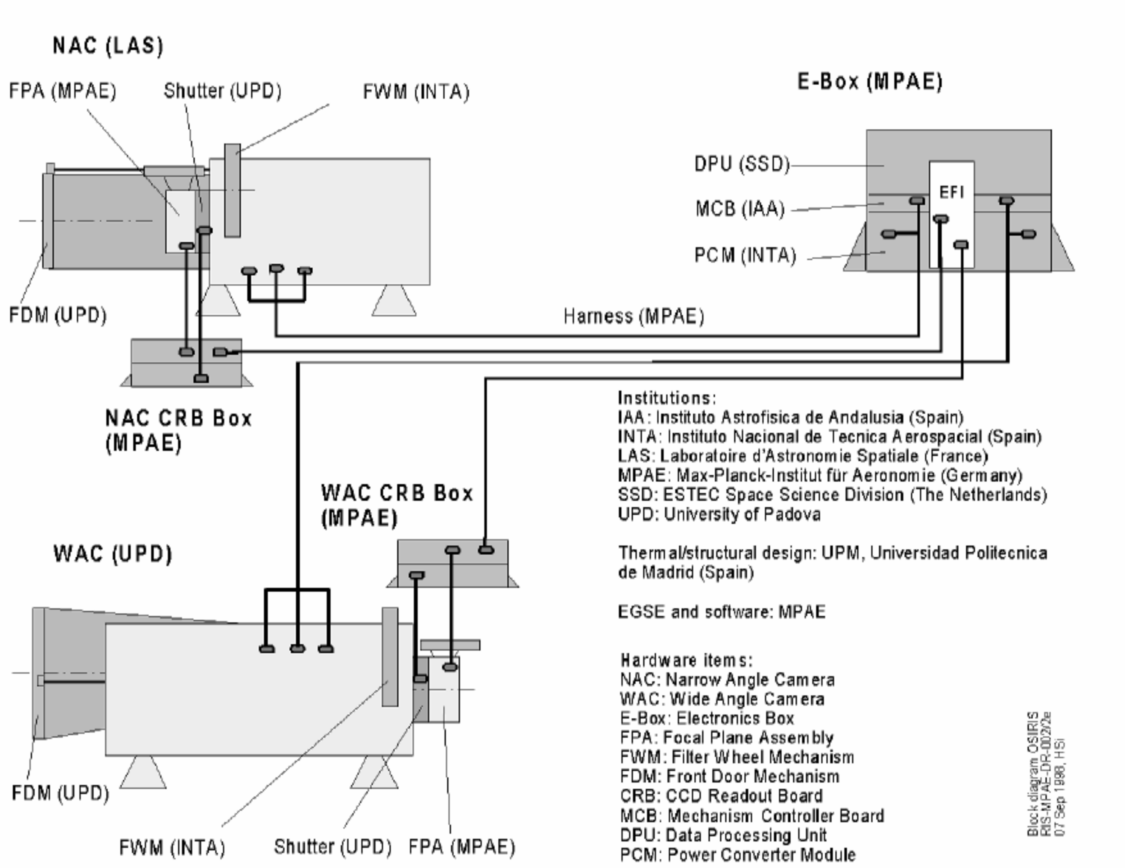


Figure 2-35: Block diagram of OSIRIS

The five units are: NAC, WAC, NAC CRB Box, WAC CRB Box, and E-Box containing DPU and other electronics modules.

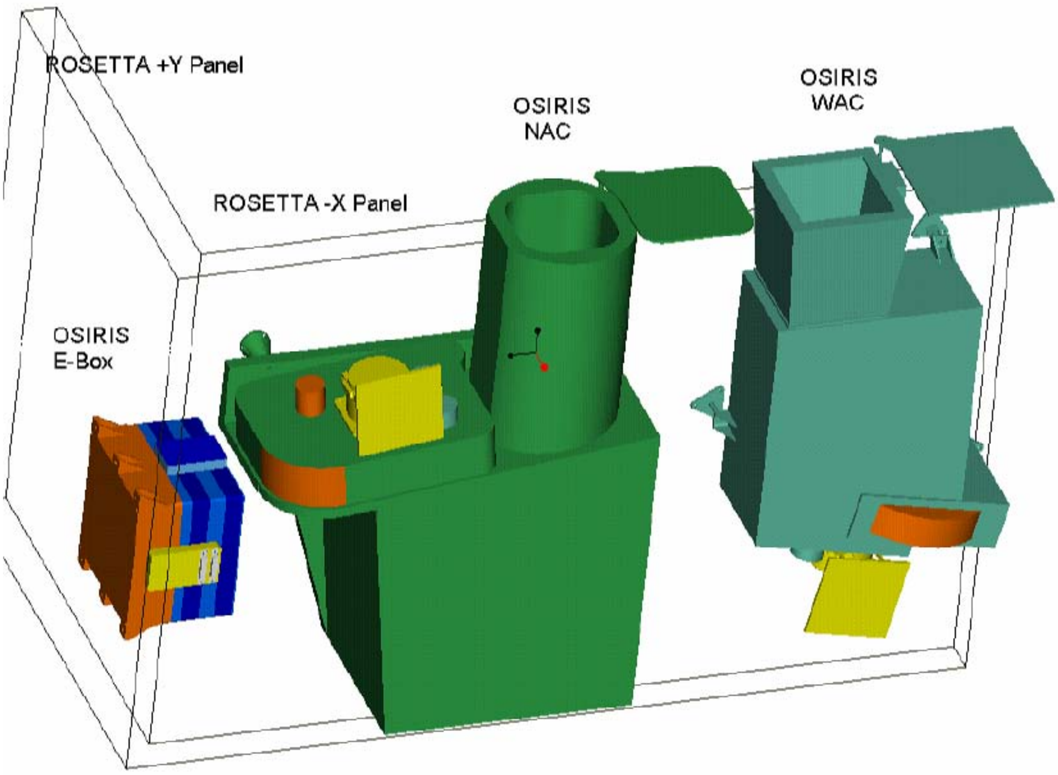


Figure 2-36: Sketch of OSIRIS

The -x panel is drawn transparent to show the cameras mounted on its outside. NAC and WAC CRB Boxes are mounted on the inside of the panel. The E-Box is mounted on the +y panel inside the s/c.

(Old configuration, new accommodation is baseline with NAC and WAC swapped)

The OSIRIS electronics consists of a separate Electronics Box (E-Box), two electronics boxes close to the cameras containing the CCD Readout Boards (NAC/WAC CRB Box), and peripheral electronics boards located in the NAC and WAC.

The Electronics Box contains three functional modules:

- Data Processing Unit (DPU), consisting of the digital signal processor board (DSP) with extension board (EXT), the mass memory board (MMB), and the DPU interface board (DIB), consisting of spacecraft interface and experiment specific electronics;
- Mechanism controller board (MCB) containing micro controllers (for filter wheels, front doors), PROMs, H/K acquisition channels (A/D conv.);
- Power converter module (PCM) with DC/DC switching regulators, over current protection switches, filters, solid state and latch relays.

The NAC CRB Box and WAC CRB Box contain

- The CCD Readout Boards (CRB) for NAC and WAC, respectively. The boards contain the analogue interfaces to the focal plane electronics, A/D converters, CCD control, clock driver, the interface to the DPU;
- Shutter electronics, containing energy buffer capacitors with switch;
- CRB dedicated power converter with local ground stud.

Peripheral Electronics are:

- NAC and WAC focal plane assembly electronics with CCD, preamplifiers and protection resistors.

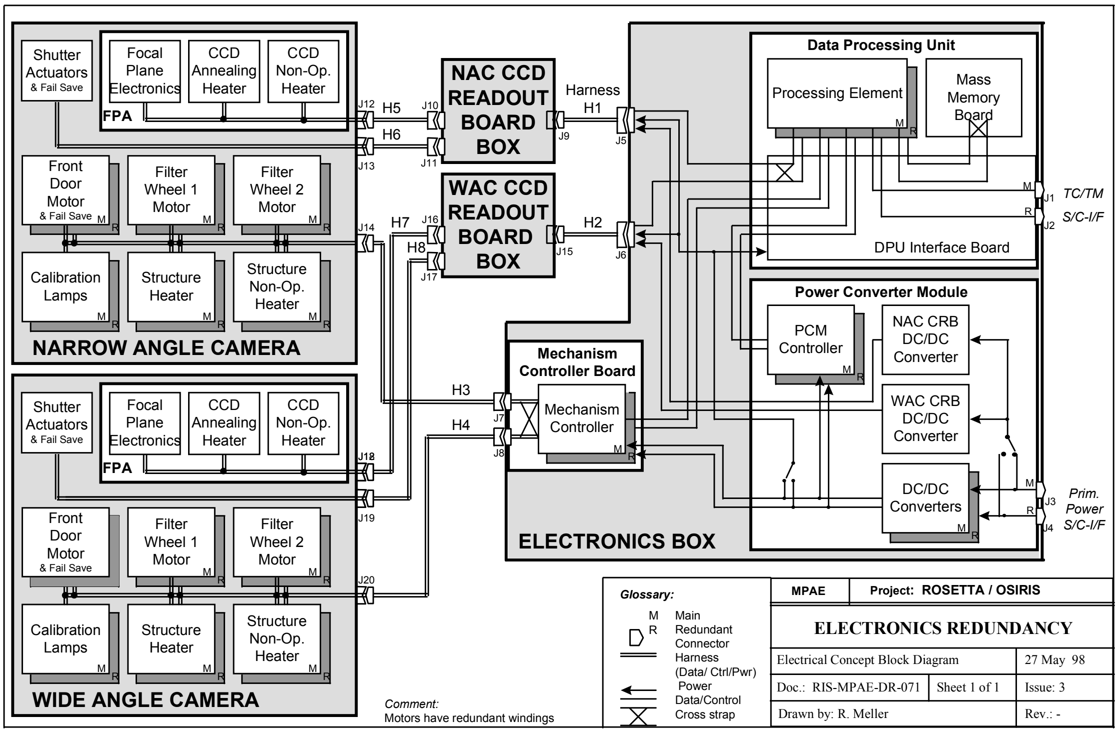


Figure 2-37: Block diagram of the electrical concept of OSIRIS

2.2.5. COSIMA

2.2.5.1. Scientific Objectives

The COSIMA investigation addresses all scientific objectives summarized in the ROSETTA A/O. Its centre unit is a time-of-flight (TOF) secondary ion mass spectrometer (SIMS) instrument with a mass resolution well above 2000 unparalleled in previous space research before. The COSIMA team will contribute to enhance the knowledge of comets their role in and their record of the solar system in detail by providing in situ measurements performed on individual dust particles emitted by the target comet (46P/Wirtanen) and collected by COSIMA dust collector subsystem. From the flight data we shall determine:

- the elemental composition of solid cometary particles to characterize comets in the framework of the solar system chemistry;
- the isotopic composition of key elements in solid cometary particles such as H, C, Mg, Ca, Ti in order to establish boundary conditions for models of the origin and evolution of comets and thereby of the solar system;
- the chemical states of the elements;

- variations of the chemical and isotopic composition between individual particulate;
- changes in composition that occur as functions of time (“short-term variations”) and orbital position;
- the variability of the composition of different comets by comparing the results to those obtained previously from comet Halley;
- the presence of an organic component that is not associated with a rocky phase
- the molecular composition of the organic phase of the solid cometary particles
- the molecular composition of the inorganic phase of the solid cometary particles
- the chemical state of the organic matter characterized by its saturation degree oxidation state and bond types which in turn will allow:
- to compare the composition of the solid particles to the elemental and isotopic composition of the neutral and ionized atmosphere of the comet;
- to gain insight into the molecular composition of the inorganic phase of the particulate with emphasis on the degree of equilibration of the mineral assemblage;
- to assess the exobiological relevance of the cometary organic matter as possible organic precursor material with free enthalpy as the driving force for self organization.
- to evaluate the relation of the association of inorganic phases and mineral components in cometary matter to the formation of prebiotic organic molecules on the early Earth.

Many members of the COSIMA team have already participated in the PUMA and PIA investigations for VEGA and GIOTTO, respectively the missions to comet p/Halley. They have contributed to the main findings which were published in 1986-1991 comprising the following major results:

- distribution of light elements (Clark et al., 1987)
- confirmation of the CHON component (Kissel et al., 1986 and 1986a)
- large range of elemental ratios (Langevin, 1987)
- ion formation upon dust particle impacts (Kissel and Krueger, 1987)
- mass and density of individual dust particles (Maas et al., 1989)
- overall chondritic composition (Jessberger et al., 1988)

- light element overabundance versus CI Chondrites (Jessberger et al., 1986, 1987)
- unequilibrated nature of silicate component (Jessberger and Kissel, 1991; Fomenkova et al., 1992, 1994)
- light carbon in Halleys dust (Solc et al., 1987; Jessberger and Kissel, 1991)
- characterization of the organic component (Kissel and Krueger, 1987a)
- mass loss from CHON particles (Krueger et al., 1991)
- possible existence of very small particles (attodust) (Utterback and Kissel, 1990; Sagdeev et al., 1989)

These results are the basis for a more elaborate approach implemented in COSIMA to obtain data with much more detail and a higher precision than was possible in the fast flybys. By now cometary dust is the only extraterrestrial material of known source to be an intimate mixture of thermally largely unaltered low temperature organic material with high temperature solid mineral grains mixed down to sizes of at least 100 nm. Combining the results of Anders & Zinner (1993), Jeßberger and Kissel (1991) and more recently Eberhardt (1995) one may conclude that cometary dust in its micro volumes may well contain the unmixed and isotopically variable components from the presolar sources that provided most of the matter (above H) for our solar system. Whereas this matter has been thoroughly mixed and drastically altered when the sun and the planets formed, the dust from p/Halley with its high degree of dis-equilibrium may well be considered to represent the original presolar material in the most pristine state encountered and analysed so far. The predominance of and micron sized dust in cometary material has been confirmed in a recent analysis by Sekanina (1995) of the impact of comet P/Shoemaker-Levy~9 (1993e) on Jupiter. Dust of the same small size range also dominates the cold areas around young stars as described by Hanner (1995).

2.2.5.2. Design Overview of COSIMA

The COSIMA instrument is a Time-of-Flight (TOF) Secondary Ion Mass Spectrometer (SIMS) equipped with a dust collector, a primary ion gun, an optical microscope (COSISCOPE) for target characterization. Once a target has been exposed to cometary dust (description of the dust collector see below) the respective lot is moved in front of the microscope (description see below) and imaged under shallow angle LED-illumination. On board image evaluation detects the presence and location of dust particles above a few µm in diameter and calculates their position relative to the target reference point. Once the presence of such features is established, the target is moved in front of the mass spectrometer. Pulses of 3 ns duration of ^{115}In-ions at 10 keV and about 10 µm in diameter from the primary ion gun hit the selected feature. Secondary ions from the cometary matter are extracted by the secondary ion extraction lens (SIL) into the TOF section. After passing deflection plates for beam steering the ions travel through a field free section. Next they pass a two stage reflector, return through the drift section to the ion detector.Its main element is a single stage microsphereplate, where the ions are detected at last. The arrival time for each ion is measured to about 2 ns. The precision of the timing of the primary ions, the correct adjustment of the dimensions and the voltages of the mass spectrometer and the precise measurement of the flight time are needed to obtain the high mass resolution of the COSIMA instrument (note: the value of the mass resolution is half the value of the time resolution. If 4 ns fwhm are assumed, mass resolution of 2000 is achieved for ions of 16000ns flight time. This occurs for ion masses of above 28 Da).

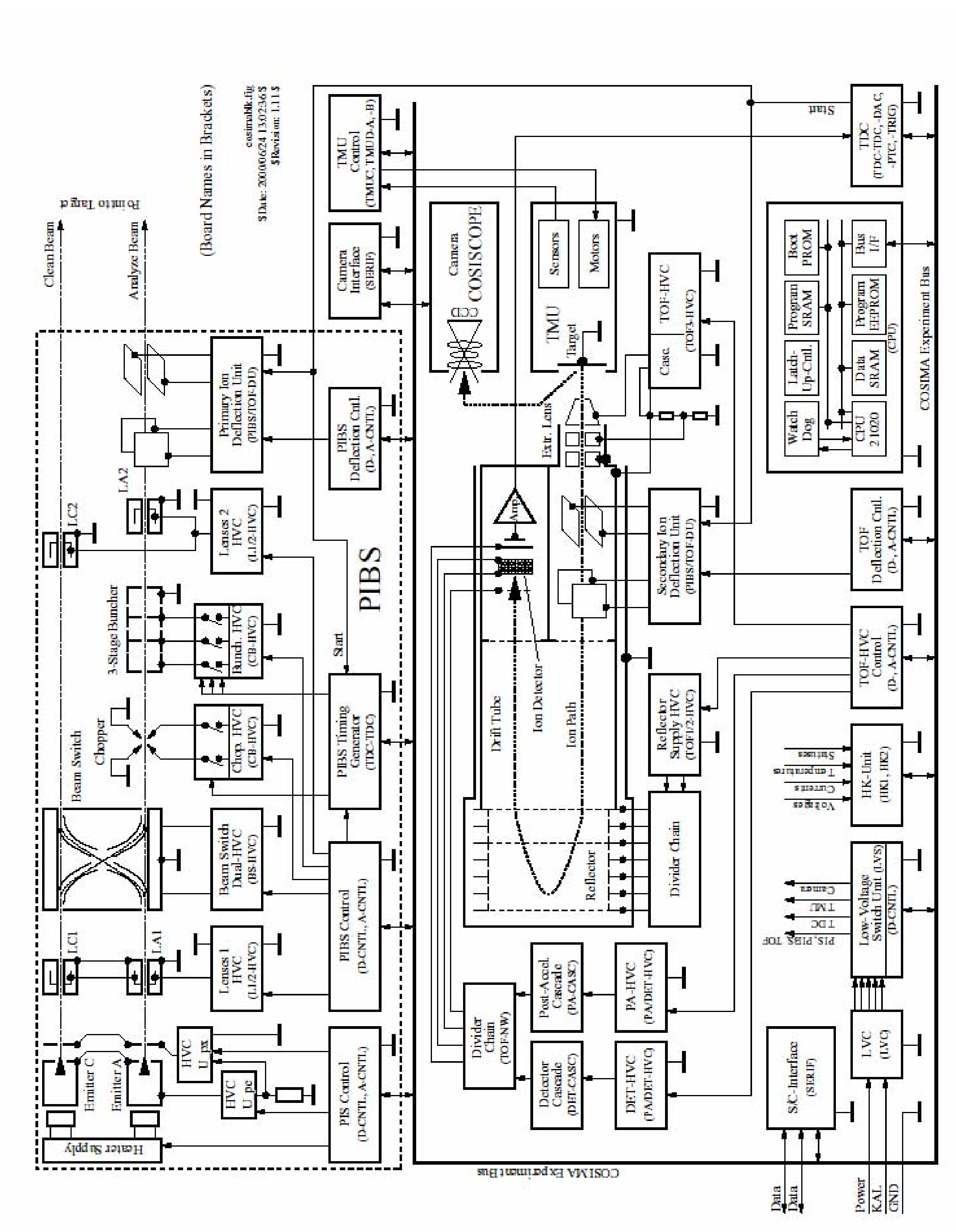


Figure 2-38: Cosima Schematic Block Diagram

2.2.6. MIDAS

2.2.6.1. Scientific Objectives

The proposed MIDAS experiment is dedicated to the microtextural and statistical analysis of cometary dust particles. The instrument is based on the technique of atomic force microscopy. This technique, under the conditions prevailing at the Rosetta Orbiter permits textural and other analysis of dust particles to be performed down to a spatial resolution of 4 nm.

During the rendezvous with the comet MIDAS will provide the following information:

- images of single particles with a spatial resolution of 4 nm,
- statistical evaluation of the particles according to size, volume, and shape,
- size distribution of particles ranging from about 4 nm to a few µm,
- shape, volume and topographic structure of individual particles,
- temporal variation of particle fluxes,
- spatial variation of particle fluxes, and
- measurements on local elastic properties if further studies show that they do not affect the tip lifetime

During the cruise phase to the comet MIDAS will provide:

- characterization of the dust environment in the vicinity of the asteroids for which a fly-by is planned
- imaging of impact craters caused by fast interplanetary dust particles, and
- statistical analysis of craters on the exposed surface in terms of particle size and volume.

MIDAS will deliver global images, i.e. complete images of the entire scan field, and images of individual dust particles. The latter are contained in the former, since selected particles are identified from the global image. These particles are then re-scanned with a much higher resolution.

2.2.6.2. Design Overview of MIDAS

MIDAS is designed to analyse microdust particles collected in the interplanetary - and cometary environment, irrespective of their electrical conductivity and shape by means of atomic force microscopy. The sizes of the particles range from about 4 nm to a few µm. The dust collector includes a mechanism which controls the particle flux onto a wheel most likely made of polished silicon. After analysis, another of the 64 facets of the wheel is exposed to the ambient dust flux. The MIDAS microscope consists of five functional parts: a one shot cover and a funnel to protect the aperture on the ground and during launch, the shutter to define the exposure time to the dust flux, the robotics system for manipulation of the dust particles, the scanner head, and the supporting electronics.

The heart of the atomic force microscope (AFM) is a very small tip which maps the surface of the particle. An AFM is capable, in principle, of imaging details down to atomic resolution. In the simplest case, the tip remains in permanent contact with the surface and follows its height variations with a control mechanism which keeps a constant force on the tip (contact mode). In a technically more complex mode, the tip scans the surface while its supporting cantilever vibrates at one of its natural resonance frequencies. There are two dynamic modes: (a) the tip does not come closer to the surface than a few tenths of a nanometer (non-contact mode) or (b) the tip hits the surface during its sinusoidal oscillation (tapping mode). In all three modes it is essential either to keep the force constant or to measure it accurately in order to derive an image of the surface.

The tip must move over the surface in a reproducible manner, which can be relatively easily achieved by piezo electric scanners in three independent directions. The combination of the tip, supporting cantilever, and piezo-electric actuators is called scanner head. Due to life time requirements, several tips will be employed.

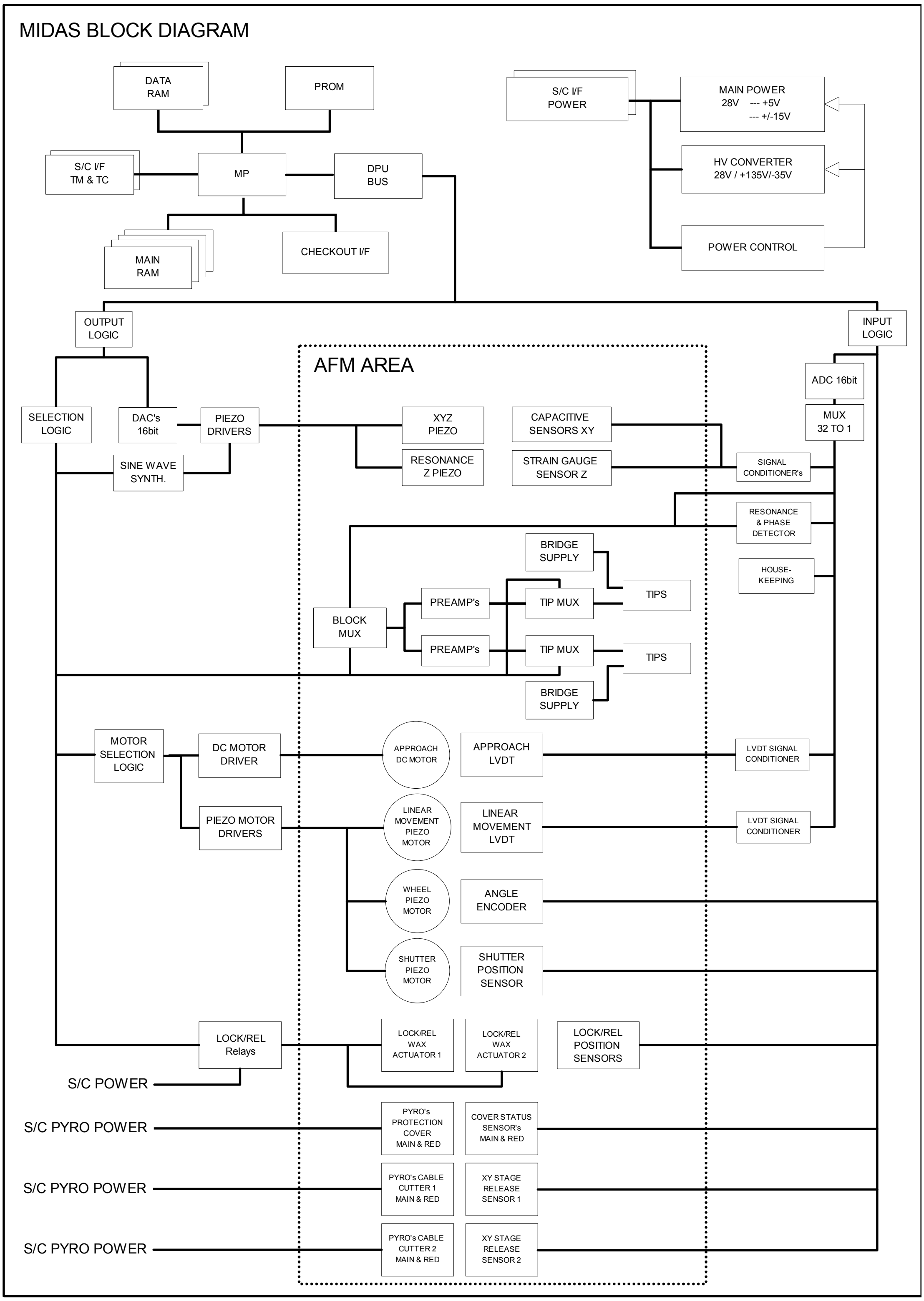


Figure 2-39: Block Diagram

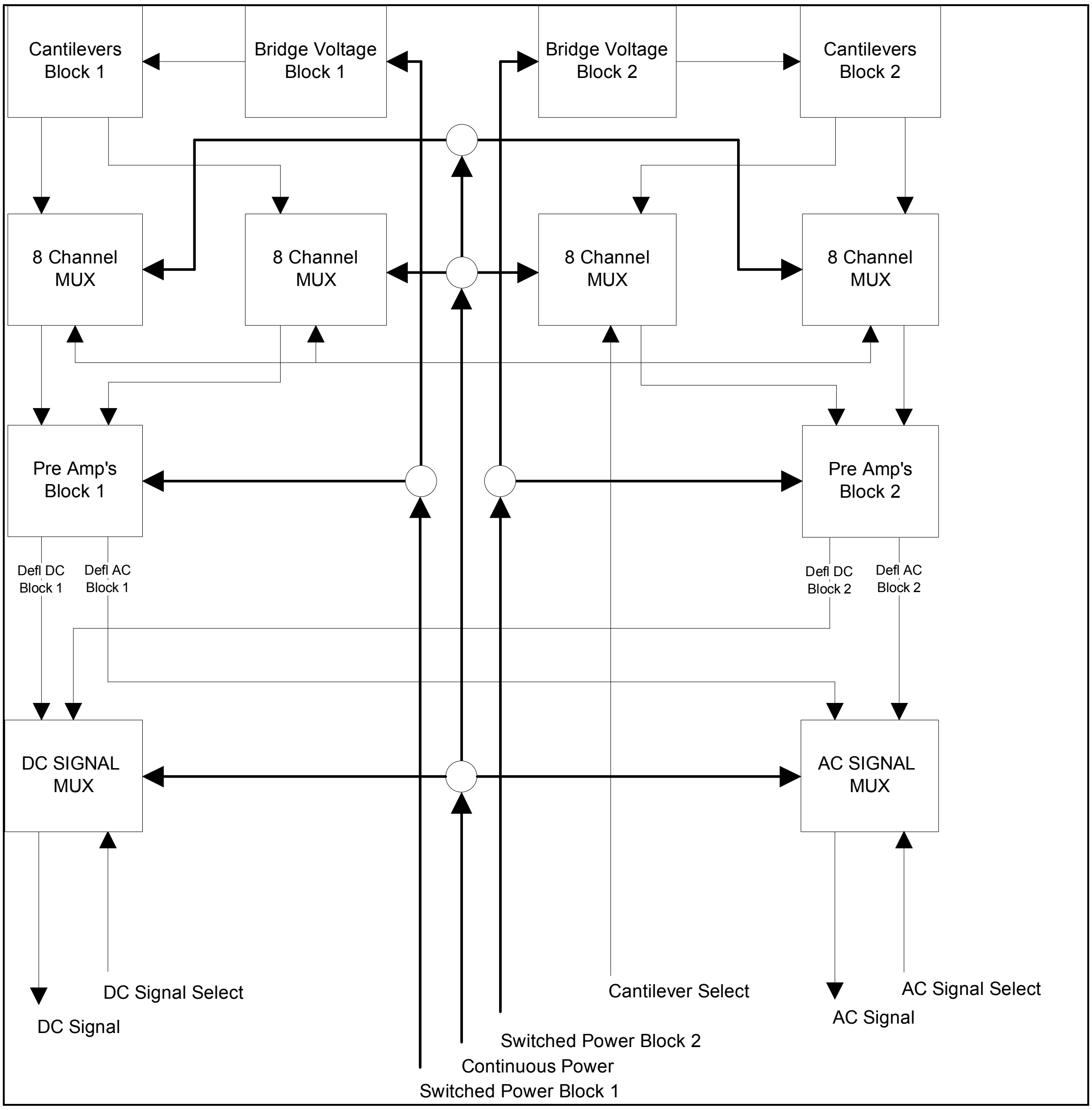


Figure 2-40: Sensor and Associated Electronics Schematics

2.2.7. ROSINA

2.2.7.1. Scientific Objectives

The prime objective of the Rosetta mission is the study of a cometary nucleus and its close environment. One of the in situ investigations required to fulfill this objective is a Gas and Ion Mass Spectrometer. The Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA) instrument package proposed here will achieve the prime measurement objective of the Gas and Ion Mass Spectrometer for the Rosetta mission. This prime measurement objective is:

- To determine the elemental, isotopic and molecular composition of the atmospheres and ionospheres of comets as well as temperature and bulk velocities of neutral and ionized components and homogenous and inhomogeneous reactions of neutrals and ions in the dusty cometary atmosphere and ionosphere.

In determining the composition of the atmospheres and ionospheres of comets, the following prime scientific objectives, also defined by the Rosetta Science Definition Team will be achieved:

- To determine the global molecular, elemental, and isotopic composition and the physical and morphological character of the cometary nucleus
- To determine the processes by which the dusty cometary atmosphere and ionosphere are formed and to characterize their dynamics as a function of time, heliocentric and cometocentric position.
- To investigate the origin of comets, the relationship between cometary and interstellar material and the implications for the origin of the solar system.
- To investigate possible asteroid outgassing and establish what type of relationship exists between comets and asteroids.

In order to fulfill these goals an instrument containing three sensors has been proposed. These three sensors, the Double Focusing Mass Spectrometer (DFMS), the Reflectron Time of Flight (RTOF), and the COmet Pressure Sensor (COPS) together with their common Data Processing Unit (DPU) have the following characteristics (ref. Table 2-6):

Component	Mass Range [amu]	Mass Resolution m/Δm(at 1%)	Sensitivity Gas [A/Torr](1)	Ion(2)	Dynamic Range(3)	Pressure Range [Torr](4)	FOV	Highest time resolution for full spectrum
DFMS (5)	12-100	3000	10^{-5}	10^4	10^{10}	10^{-5} - 10^{-15}	20° x 20° 2°x 2° (6)	120 s
RTOF	1- >300	>500	10^{-3}	10^3	$10^6/10^8$	10^{-6} - 10^{-17}	10° x 40°	4 s / 5 min.
COPS			$3x10^{-2}$		10^6			10 sec.

Table 2-6: ROSINA Performance

1 $1x10^{-3}$ A/Torr corresponds to 0.2 counts/s if density is 1 cm^{-3}.Emission current of the ion source at 10 µA, can be increased (up to a factor of 5) or decreased

2 Counts per second for cometary ion density of 1 cm^{-3}

3 Ratio of highest to lowest peak in one measurement cycle

4 Total measurement range

5 High resolution mode

6 Narrow field of view entrance

2.2.7.2. Design Overview of ROSINA

The ROSINA mass spectrometer consists of three sensors, each optimised for part of the scientific objectives while at the same time complementing the other sensors. In view of the very long mission duration they also provide the necessary redundancy.

Sensor I (DFMS) is a double focusing magnetic mass spectrometer with a mass range 1- 100 amu and a mass resolution of 3000 at 1% peak height. This sensor is optimized for very high mass resolution and large dynamic range.

Sensor II (RTOF) is a reflectron type time of flight mass spectrometer with a mass range 1->300 amu and a high sensitivity. The mass resolution is better than 1000 at 1% peak height. This sensor is optimized for high sensitivity over a very broad mass range.

Sensor III (COPS) consists of two pressure gauges providing total pressure and ram pressure of the gas

2.2.7.2.1. Double Focusing Mass Spectrometer

The double focusing mass spectrometer is a state of the art high resolution (resolution $m/\Delta m > 3000$ at 1% peak height) with a high dynamic range and a good sensitivity. It is based on well proven design concepts which were optimized for mass resolution and dynamic range using modern methods for calculating ion optical properties.

The DFMS has two basic operation modes: a gas mode for analysing cometary gases and an ion mode for measuring cometary ions. Switching between the gas and ion modes requires changing only a few potentials in the ion source and suppression of the electron emission that is used to ionize the gas. All other operations are identical for the two modes.

Figure 2-41 gives an overview of the DFMS. The three main parts are the ion source, the analyser and the detectors. The instrument is housed in a vacuum-tight enclosure and will be thoroughly degassed by baking and launched under vacuum. The ion source region will be opened during the cruise phase to the comet by removing the protective cap.

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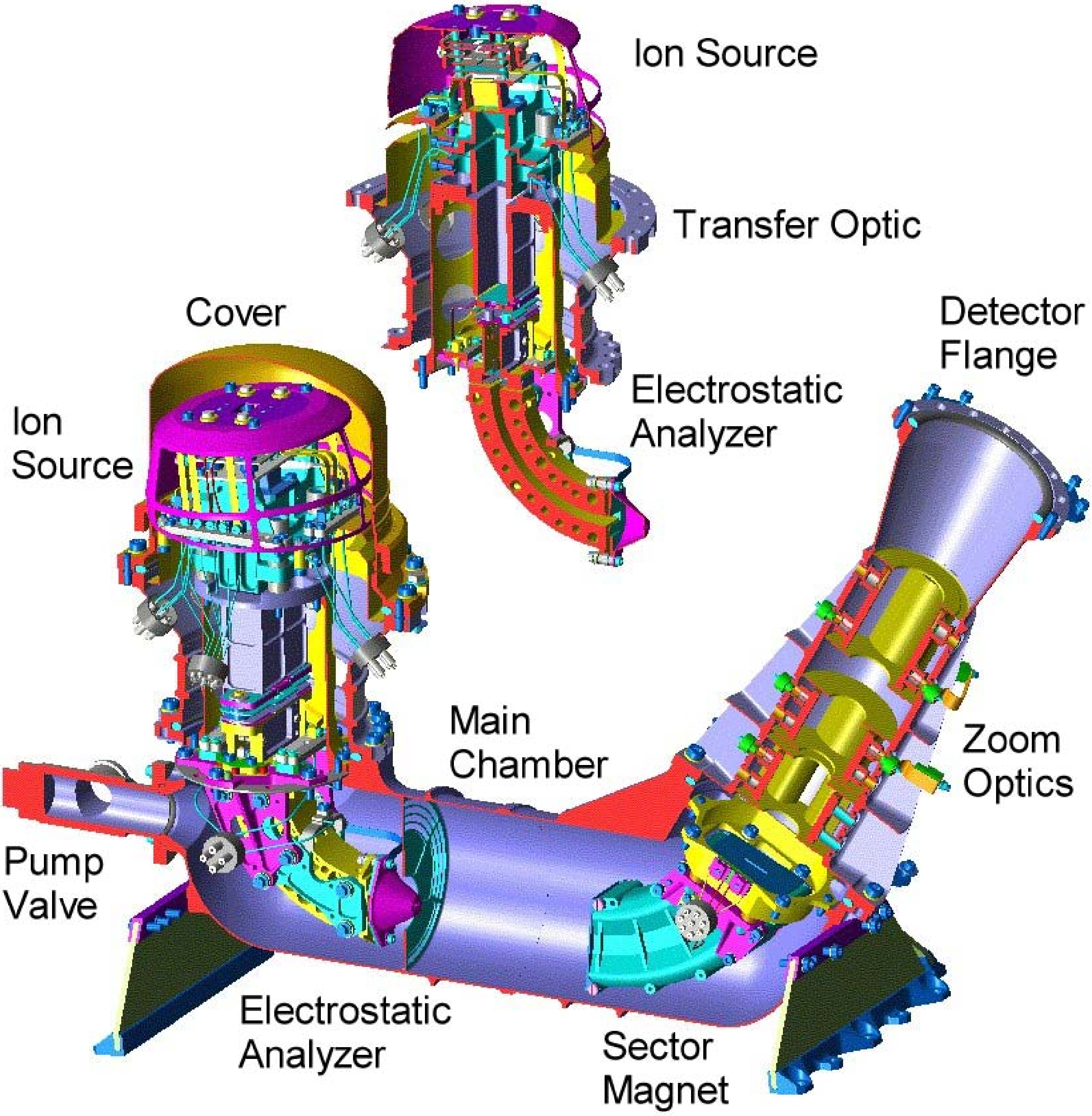
Ion Source
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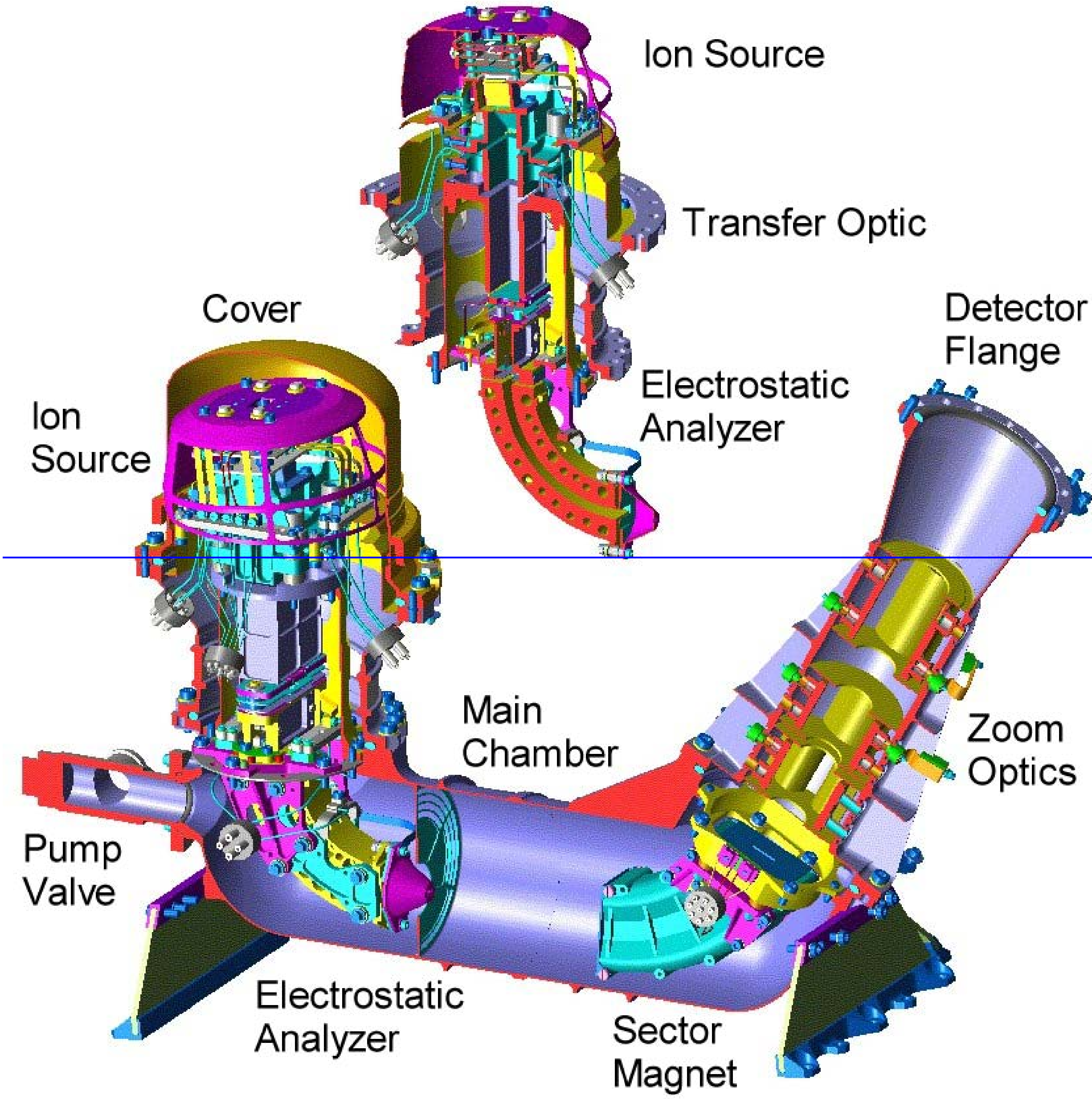


Figure 2-41: Three-dimensional view of the main elements of DFMS

2.2.7.2.2. Reflectron Time of Flight Spectrometer

The reflector time of flight (RTOF) spectrometer was designed to complement the DFMS by extending the mass range and increasing the sensitivity of the full instrument package. TOF instruments have the inherent advantage that the entire mass spectra are recorded at once, without the need of scanning the masses through slits. The ROSINA RTOF will include two similar and independent source-detector systems, one for cometary ions and one for cometary neutrals using the same reflector (Figure 2-42). This configuration guarantees high reliability by almost complete redundancy.

A Time of Flight spectrometer operates by simultaneous extraction of all ions from the

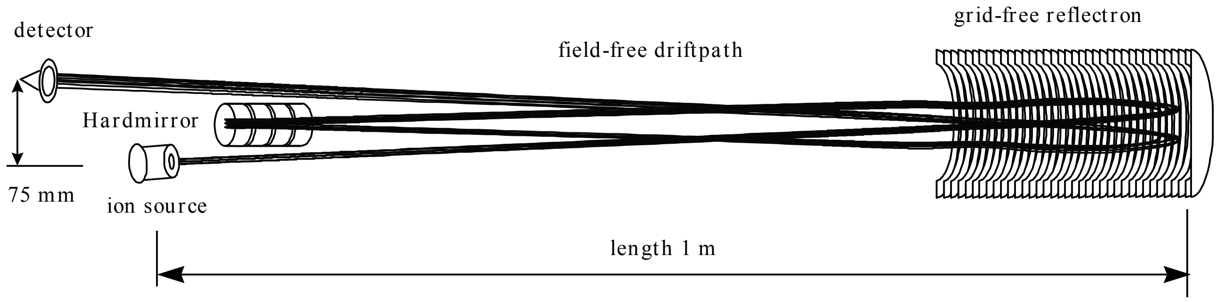


Figure 2-42: Schematic view of the main elements of the RTOF Sensor

ionization region into a drift space such that ions of a given *m/q* are time-focused at the first time focus plane (TF) at the beginning of the drift section. Hereby the temporal spread of such an ion packet is bunched from about 800 ns at the exit of the ionizationregion to about 3 ns (mass = 28 amu). Those very short *m/q* ion bunches are then imaged onto the detector by the isochronous drift section. Because different *m/q* bunches drift with different velocities, the drift length determines the separation of the bunches. The reflector incorporates the isochronity in the drift section.

Mass resolution is determined by the drift time and the temporal spread of the ion packets. Unlike other types of spectrometers, TOF spectrometers have no limit to the mass range. In practice the mass range is limited by the electronics, e.g. by the size of the signal accumulation memories.

2.2.7.2.3. Comet Pressure Sensor (COPS)

The COPS instrument consists of two sensors dedicated to the measurement of the neutral gas parameters around the comet, mainly the total density and the radial flow.

The first sensor, is a Bayard-Alpert type pressure gauge. Free electrons emitted from a filament (Tungsten Rhenium) at the potential of +30 Volt are accelerated toward a cylindrical anode (grid or helix wire) which is kept on the potential of +200 Volt. Inside the cylindrical anode grid is mounted a very thin molybdenum wire (0.15 mm diameter), called collector whose voltage is maintained at 0 volt . Electrons then are orbiting around the collector, ionizing neutrals along their path, and eventually being trapped on the anode. The ions created are collected by the collector, the resulting current is proportional to the total density of the gas (or total pressure). On can write:

$$n_{tot} \propto S \bullet I_{electrons} \bullet I_{ions}$$

where S is called the sensitivity of the gauge.

Usually the emission current is maintained constant, but an other operational mode will be available for which the ion current will constant, thus saving the electron emitter. The gauge will be isolated from the external plasma by an other cylindrical grid at S/C potential. For redundancy, two filaments will be used.

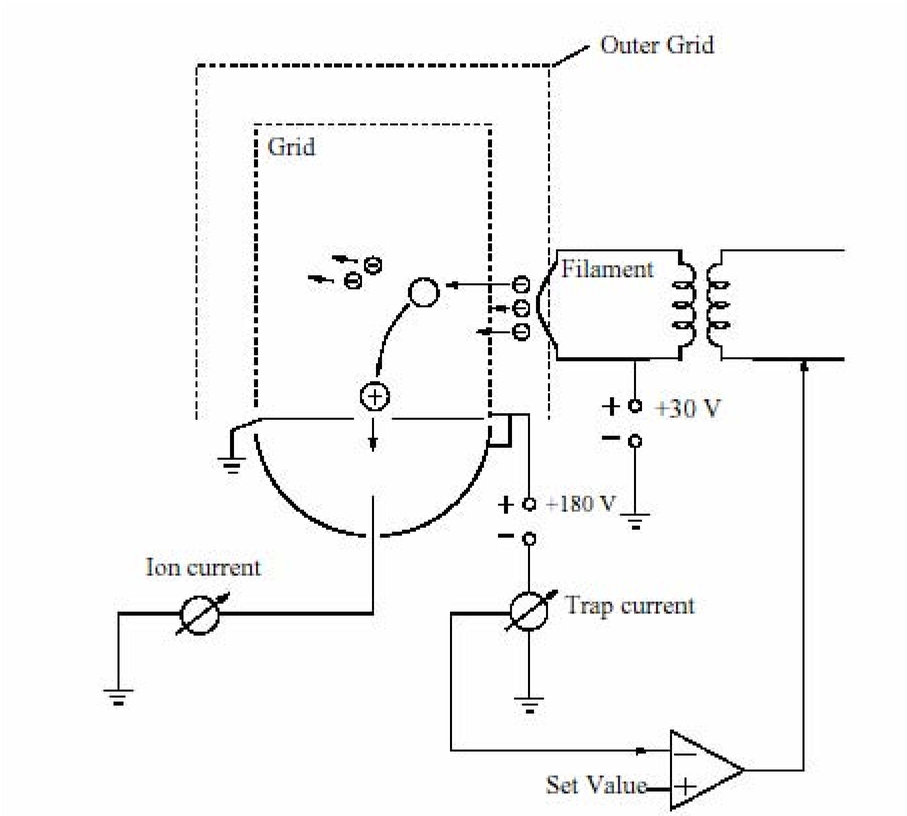


Figure 2-43: Schematic of the nude gauge

The second sensor is called the equilibrium chamber. A spherical chamber, containing a pressure gauge and whose opening is facing the comet, will indirectly measure the molecular flow that comes from the comet through the ram pressure measurement.

Indeed, assuming a Maxwellian distribution for the gas and equilibrium between the flows ϕ into and out of the chamber, the density measured by the gauge is:

$$n_{in} = \frac{\Phi}{\sqrt{\frac{kT_{wall}}{2\pi m}}}$$

A more detailed expression of ϕ is:

$$\Phi = \frac{n_{tot}v}{4}\left\{e^{-\mu^2 \cos^2 \Psi} + \sqrt{\pi}\mu\cos\Psi\left[1 + erf(\mu\cos\Psi)\right]\right\}$$

where μ is the thermal Mach number, Ψ is the angle between the flow velocity vector and the z axis of the S/C, and ν the mean speed of the molecules.

The knowledge of n_{tot} through the nude gauge will lead to the determination of the parameter μcosΨ with the equilibrium chamber. This parameter contains information about the temperature, speed and eventual non radiality of the gas flow, what is definitely of first interest for supporting the detailed analysis of the DFMS and RTOF instrument.

The pressure gauge used in the equilibrium chamber is type of an extractor type gauge. In this configuration, eventual X rays created by the impacts of electrons with the anode grid (or the equilibrium chamber) can not reach the collector, placed behind a shield. The created ions are attracted toward the collector thanks to a lens-like system. The electrons are flying though the anode and then end on a trap.

This geometry (only suitable for gas at rest) also has a higher precision and reproductibility than the conventional BAG. The usual filament for the electron source is replaced by a microtip solid state electron emitter (Baptist et al., 1995). The main advantage is reduced power consumption. For redundancy, two microtip arrays will be used.

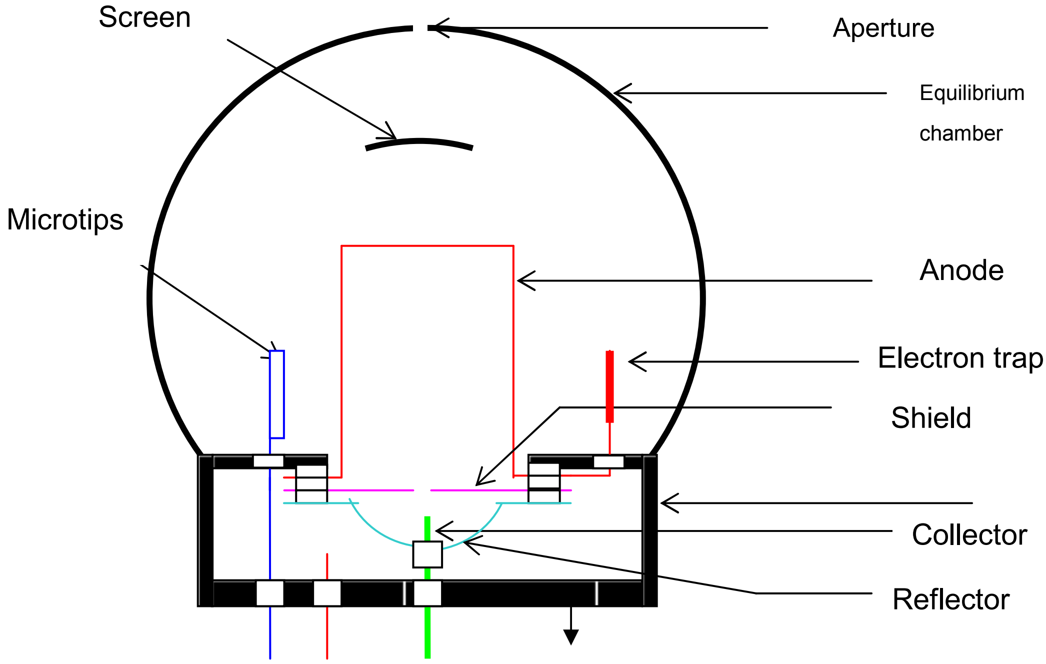


Figure 2-44: Schematic of the Equilibrium Chamber

The second purpose of the instrument is to monitor the actual gas pressure on the S/C in order to have a general alert system for all the instruments which have to be turned off in case of a dangerous increase of the pressure (>10^{-4} Torr).

2.2.8. CONSERT

2.2.8.1. Scientific objectives

The purpose of the experiment is to determine the main dielectric properties from the propagation delay and, through modelling, to set constraints on the cometary composition (materials, porosity…) to detect large-size structures (several tens of meters) and stratification, to detect and characterize small-scale irregularities within the nucleus. A detailed analysis of the radio-waves which have passed through all or parts of the nucleus will put real constraints on the materials and on inhomogeneities and will help to identify blocks, gaps or voids. From this information we attempt to answer some fundamental questions of cometary physics : How is the nucleus built up? Is it homogeneous, layered or composed of accreted blocks (cometesimals, boulders). What is the nature of the refractory component ? Is it chondritic as generally expected or does it contain inclusions of unexpected electromagnetic properties? With the answer to these questions, it should also be possible to provide answers to the basic question of the formation of the comet. Did it form directly from unprocessed interstellar grain-mantle particles or from grains condensed in the presolar nebula ? Did the accretion take place in a multi step process leading first to the formation of cometesimals which then collided to form a kilometres size body ?

2.2.8.2. Experiment overview

The experiment concerns the rough tomography of the comet nucleus performed by the CONSERT instrument (COmet Nucleus Sounding Experiment by Radiowave Transmission). It works as a time domain transponder between one module which will land on the comet surface (Lander) and an other which will fly around the comet (Orbiter). The Figure 2-45: give a schematic diagram of the experiment which is detailed in Barbin et al. Basically, a 90 MHz sinusoidal waveform is phase modulated by a pseudorandom code or PSK (Phase Shift Keying) Coding. Such frequency, in the radio range, is expected to minimize the losses during the propagation inside the comet material and the generated pulse code maximize the signal to noise ratio. In this experimental conditions great attempt is made on the good measurement of the mean dielectric properties and on the detection of large size embedded structures or small irregularities within the comet nucleus.

Consert Electronics Architecture

In Figure 2-45 a complete structure of CONSERT experiment on the orbiter is given. At the left is the antenna which is connected to the Transmit and Receive (TR) switch. The upper part of the figure shows the receiver. From left to right, one can recognize the Radio Frequency section, with Front End Amplifier (FEA), Band Pass filters, automatic gain control (AGC), then a mixer with a 120 MHz Local Oscillator. It is followed by a wide band intermediate frequency section (WIF) at 30 MHz feeding the in-phase and quadrature detectors. A low pass filter is provided for both I and Q base band amplifiers (WBB) and a high pass section is present to eliminate DC components. Each receiver section (RF, WIF, and WBB) has a maximum gain of about 30 dB and each AGC gain take a value between 0 and -31 dB. Therefore, the total gain of the analogic part take a value between 28 and 90 dB. The in-phase and quadrature signals are converted by two 8-bits analog to digital converters. The accumulation realize in the coherent integrator systems (CANACCU) and the tuning Phase Locked Loop (PLL) will not be considered here. The bottom part of the diagram corresponds to the Transmitter with a shift register pseudo-noise (PN) generator, frequency multipliers, a phase modulator and a power amplifier.

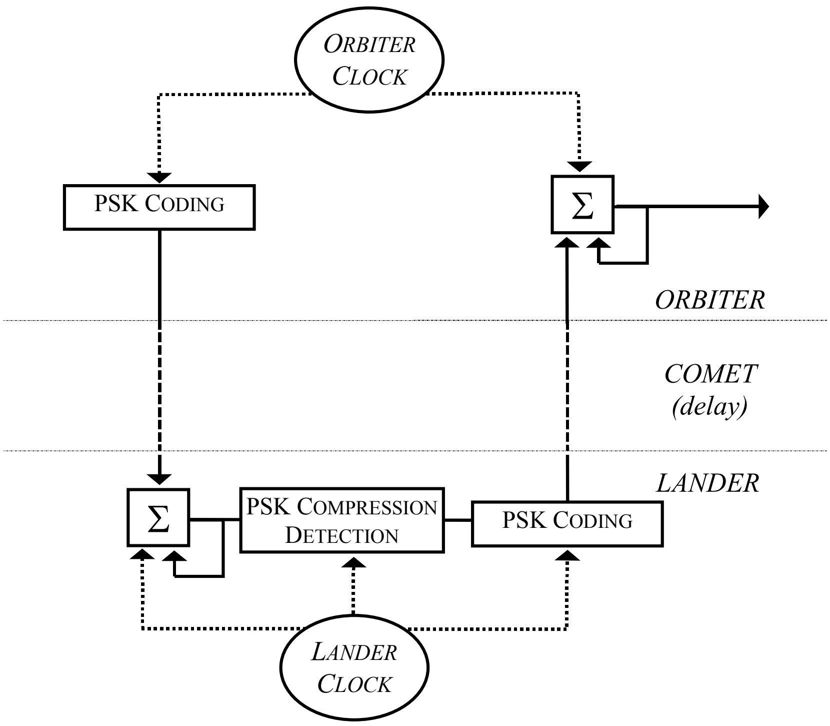


Figure 2-45: Block diagram of the CONSERT experiment

The coded signal is emitted from the Orbiter. The Lander make a coherent addition (Σ) and a detection of the correlation principal peak. A clean coded signal is finally emitted with the found delay. The Orbiter accumulate the signal and send it to the earth (via the satellite interface).

2.2.9. GIADA

2.2.9.1. Scientific Objectives

The prime scientific objectives defined by the Science Team for the ROSETTA mission are described in the ESA SCI(93)7 volume and are summarised in the ROSETTA AO document (section 1.2.1). Among them, it is clearly indicated the need of studying the physico-chemical characteristics and the dynamic evolution of cometary dust grains. This implied the indication of a dust flux and velocity analyser in the ROSETTA model payload.

It is clear that a dust monitoring system has to be considered as a key instrument for the success of the mission, for at least three main reasons:

- it will provide unique scientific data on dust fluxes and dynamic properties; they are a fundamental source of information on dust emission processes, on dust-gas relations in the inner coma environment and on overall dynamic evolution of cometary dust in the coma.
- the data provided by the instrument are absolutely needed to track in time the deposition rates of solid materials on the spacecraft. This has a major importance for critical surfaces such as optical elements, radiators, solar panels and any other element whose performances can be affected by the progressive dust accumulation.
- the results coming from the dust monitoring instrument will be of mutual interest for other key experiments of the ROSETTA mission, such as the imaging spectrometer, the camera and the mass spectrometer.

The aim of a system such as the **G**rain **I**mpact **A**nalyser and **D**ust **A**ccumulator (hereinafter GIADA) is to fulfil the previous tasks.

2.2.9.2. Design Overview of GIADA

The GIADA experiment includes three modules: GIADA 1, GIADA 2 and GIADA 3.

The GIADA 1 module is aimed at measuring the momentum and the scalar velocity of single grains. It is oriented towards the nucleus so to detect “direct” grains mainly and is equipped with an entrance protection cover.

The GIADA 2 module is the electronic box and contains the DPU, which is interfaced with sub-systems and S/C. It controls the acquisition of data and operation of the sub-systems.

The GIADA 3 module, devoted to the flux measure, is formed by five sensors pointing in different directions. The sensors are quartz micro-balances, able to monitor the cumulative dust deposition in time. One of the sensors has to point towards the nucleus, while the other four have to cover the widest possible solid angle. In the ideal case, the sensors should be oriented as shown in Figure 2-46. Of course, the final pointing configuration will have to be optimised in order to avoid directions which are obscured by parts of the S/C, such as solar panels, antenna, etc., or other instruments of the payload.

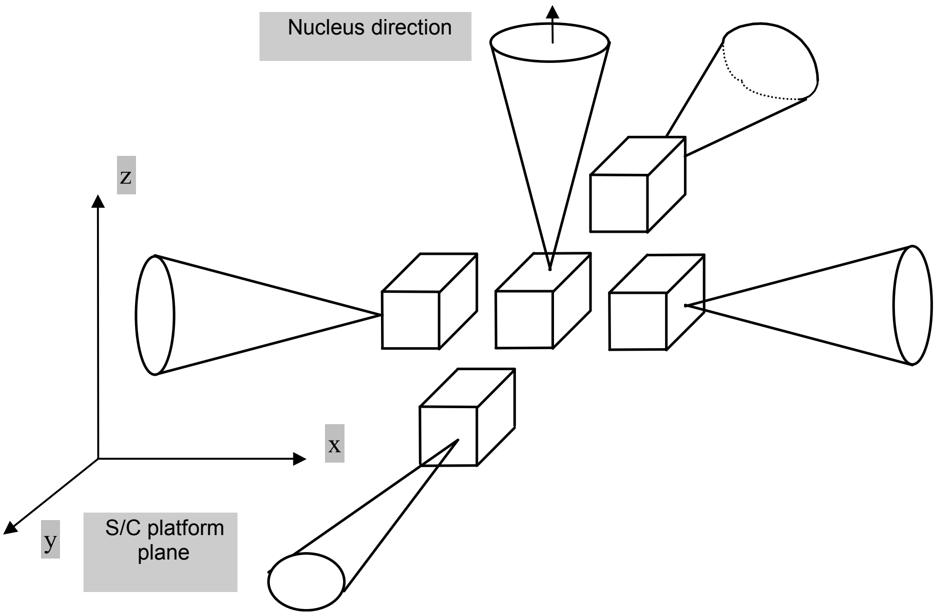


Figure 2-46: Ideal case of pointing directions for the flux sensors

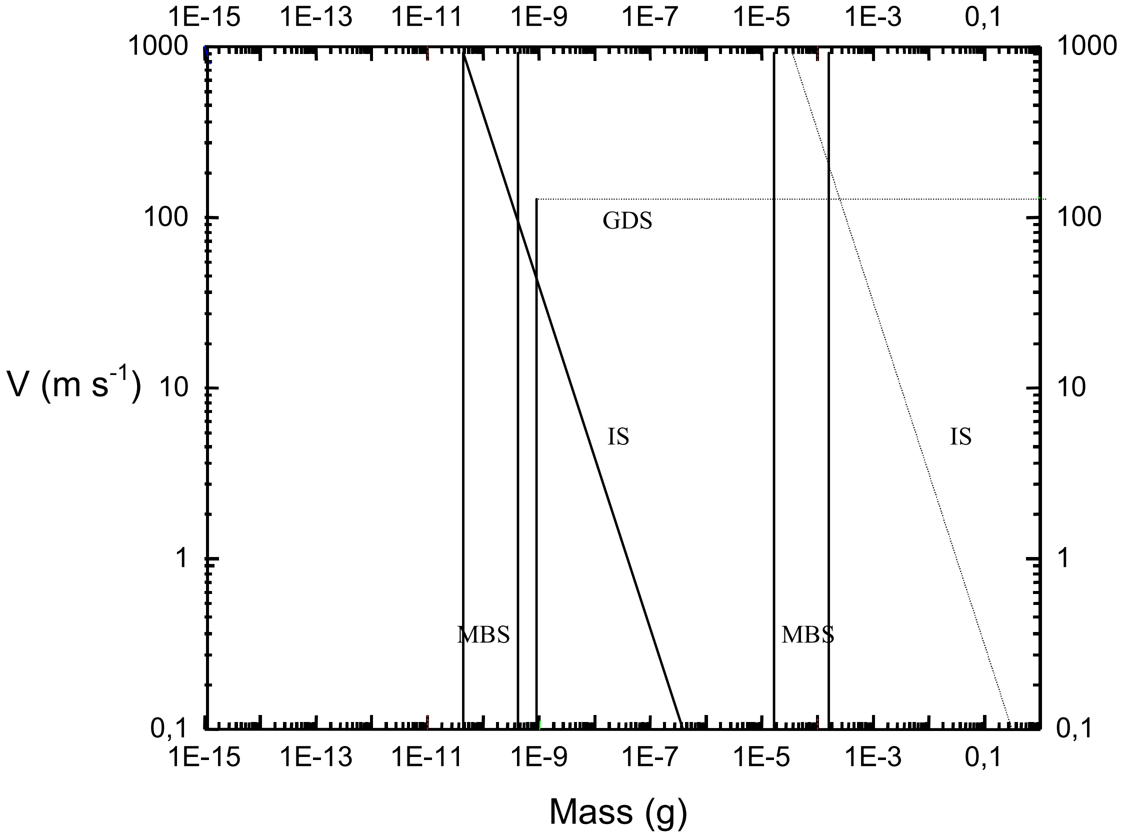


Figure 2-47: Mass and velocity ranges

In Figure 2-47 we report the size and velocity ranges covered by the different sub-systems. In the Figure the MBS lower limit is given as a range, as it depends on the final choice of the crystal frequency. GDS and IS are able to detect the grain passage or impact even above the upper limit (saturated signal). The Instrument Summary is given in Table 2-7.

During the cruise phase, the entrance of GIADA 1 is closed by a cover which protects GIADA 3 module, also. The baseline is a multi-shot cover with redundant operating mechanism.

The material of the structure will be selected taking into account the following criteria: mechanical behaviour (vibration, temperature, etc.), mass, electrical properties (dust trapping) and optical properties (stray-light and radiative couplings).

Modules	**Sub-systems**	
GIADA 1	Grain Detection System Grain Impact Sensor	(GDS) (IS)
GIADA 2	Main Electronics	(EL)
GIADA 3	5 Micro-Balance Sensors	(MBS's)
Measured quantities		
Dust flux and fluence	by MBS's + IS	
Momentum of single grains	by IS	
Scalar velocity of single grains	by GDS + IS	
Field of view (FWHM)		
GIADA 1 (IS + GDS)	35 ÷ 48 deg	
GIADA 3 (each MBS)	40 deg	

Table 2-7: Flux measurements by Micro-Balance Sensors (MBS)

Cometary dust mass flux can be directly measured by monitoring the mass deposition per unit surface as a function of time. This can be done by means of piezoelectric transducers, which give an output signal whose frequency is proportional to the mass deposited on the sensor.

According to the working principle, the measured physical quantity is the shift of the resonance frequency of a quartz oscillator. The shift is due to the variation of its mass, as a result of material accretion. By using specially cut crystals, whose frequency has an extremely small temperature dependence, a high sensitivity can be achieved. An improvement of the detection system can be obtained by mixing the signal from the sensing crystal with that of a second quartz crystal, used as reference. The beat frequency of the mixed signals is independent from temperature and power supply fluctuations.

Thus, the sensor (see Figure 2-48) consists of a matched pair of quartz crystals, resonating at frequencies of the order of 10 - 25 MHz. The sensing crystal is displaced in frequency approximately 1 KHz below the reference crystal. The output of a mixer circuit gives a signal which is perfectly linearly related to the mass deposition in a frequency range up to about 1% of the resonating frequency.

So far, micro-balances have been extensively used for gas contamination monitoring: gas condenses on the sensor surface, which is maintained at the proper temperature. In the case of measurement of solid particle flux, grain sticking coefficient is a driving parameter to be controlled to guarantee an efficient collection. In general, it can be tuned by choosing appropriate surface characteristics and temperature. The crystals are optically polished and metal plated, while the sensing surface can be worked to get the required sticking and residence time properties. This can be done by choosing the roughness of the surface or by applying a special coating, with an extremely low vapour pressure, which aids in the accommodation of particles.

Crystal temperature can influence the capability to collect solid particles. It could be controlled, with respect to the heat sink temperature, by means of a Peltier device, capable of heating or cooling the sensor on a temperature range of about 150 °C.

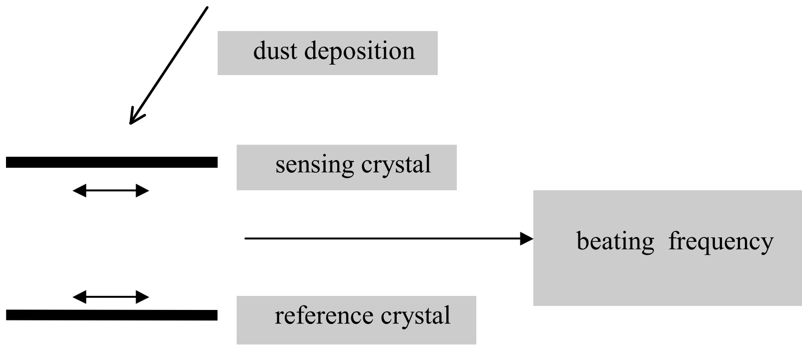


Figure 2-48: Schematic view of a quartz crystal micro-balance

The most important parameters which characterise the performances of micro-balances are the mass sensitivity and range, and the time resolution. For the application to ROSETTA, the sensitivity has to be high enough to detect a mass deposition of the order of about 10^{-11} g. The detection limit of the micro-balances is determined by their stability and accuracy of output frequency measurement, which is in turn related to the sampling time. Moreover, an increase in the fundamental resonance frequency leads to a higher sensitivity. The required mass operative range is determined by the expected fluxes: a range covering 5 to 6 decades can be easily achieved.

Depending on physical properties of the coating, if the sensor is saturated (about 10^{-4} g), it could be possible to “clean” its surface by a thermal cycle able to release most of the deposited dust lag. According to the expected fluxes (see section 1.1.4 of related EID-B), we foresee that saturation could occur only for the sensor pointing to the nucleus. During the recycling, a thermo-gravimetric analysis could be performed. By choosing an appropriate temperature trend vs. time, release of different kinds of material deposited on the sensor can be detected.

Concerning the time resolution of measurements, during the normal operation, i.e. for flux measurement, a good S/N ratio can be obtained with an integration time of the order of some seconds. A relatively high sampling frequency is useful only during the thermo-gravimetric analysis, to follow the release of materials from the sensor surface.

2.2.9.2.1. Velocity-momentum measurements; GDS + IS

This sub-system points towards the nucleus so to collect "direct" grains, mainly. The aperture size is 100 cm^2. In order to have a sufficiently high statistics of detection, a wide acceptance angle (about 40 deg) is required.

The general concept that can be applied in the scenario of the ROSETTA mission is to measure, for each entering grain, the *time-of-flight* between two reference stages (parallel planes) and the *momentum* released during the impact on the surface of the bottom stage (Figure 2-49).

This approach allows the direct determination, for each analysed grain, of various quantities:

- the *momentum*, *p*, is directly measured;
- the *mass, m,* is obtained from *p* and *v*. The measurement of *m* can be converted in *size, s,* when the density of grains is measured by other experiments on board ROSETTA.

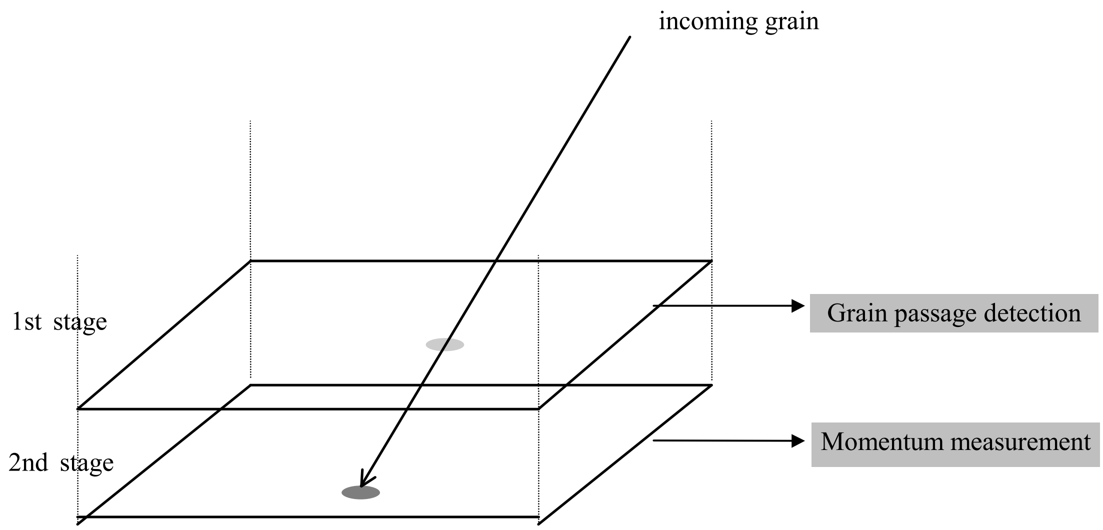


Figure 2-49: Schematic view of the velocity / momentum detection sub-system

The bottom stage is a diaphragm equipped with five piezoelectric sensors able to detect the grain impact. Piezoelectric transducers have been used as impact impulse sensors since Explorer I mission and have given excellent results on the Mir space station. Several papers concerning their use in space experiments have demonstrated their high reliability. The distinctive characteristic of any linear elastic system, like a piezoelectric (PZT) crystal, is that the maximum displacement of the system is directly proportional to the impulse imparted, and the displacement of the crystal produces a proportional potential. Through calibration, a known impulse may be equated with a specific charge produced on the electrodes of the PZT crystal. The detected signal is proportional to the momentum of the incident grain through the factor (1+*e*), with *e* = coefficient of restitution.

2.2.9.2.2. Grain passage detection by the Grain Detection System (GDS)

The monitoring of the passage of small particles through the upper stage of GIADA 1 (see Figure 2-49) can be based on:

- optical detection;
- detection of plasma produced by perforation of an Al film.

Both these techniques are, in principle, compatible with the ROSETTA scenario and can be considered as alternative solutions. They have been carefully considered and comparatively analysed during the Phase A of the GIADA project. Performances, complexity and critical aspects of the two concepts have been taken into account.

The system based on plasma detection by Al foil perforation appears to show several limitations, in the case of application to the ROSETTA scenario. In fact, it is expected that a large fraction of grains entering GIADA will have very low velocities. The use of very thin Al foils to allow penetration also from slow grains has two main drawbacks: a) the produced signal could be too weak to obtain a reasonable signal to noise ratio; b) the required foil thickness could face strong technological and duration problems. Thus, the system based on plasma detection seems to have two limitations: a) scientific, as it could produce a significant selection of detectable grains, which could affect the statistical reliability of the results obtained by GIADA; b) technical, for the production and operation of the device.

In the optical detection option, the use of high illumination sources, such as laser diodes, is needed to guarantee a scattered/reflected signal sufficiently high to be detected. Four sources (laser diodes), emitting light to form a curtain on the measurement plane, and eight detectors (photodiodes), placed at 90 deg with respect to the sources (Figure 2-50), allow the measurement of the scattered/reflected light signal produced by the passage of each grain entering the system. The detected signal is proportional to the geometric cross-section area and the reflectivity/scattering efficiency of the particle.

We notice that, for sufficiently large grains, the measured signal can be related to the ***reflection/scattering*** properties of the particles and can give hints about the aggregation status (e.g. fluffy vs. compact; round vs. irregular) of particles.

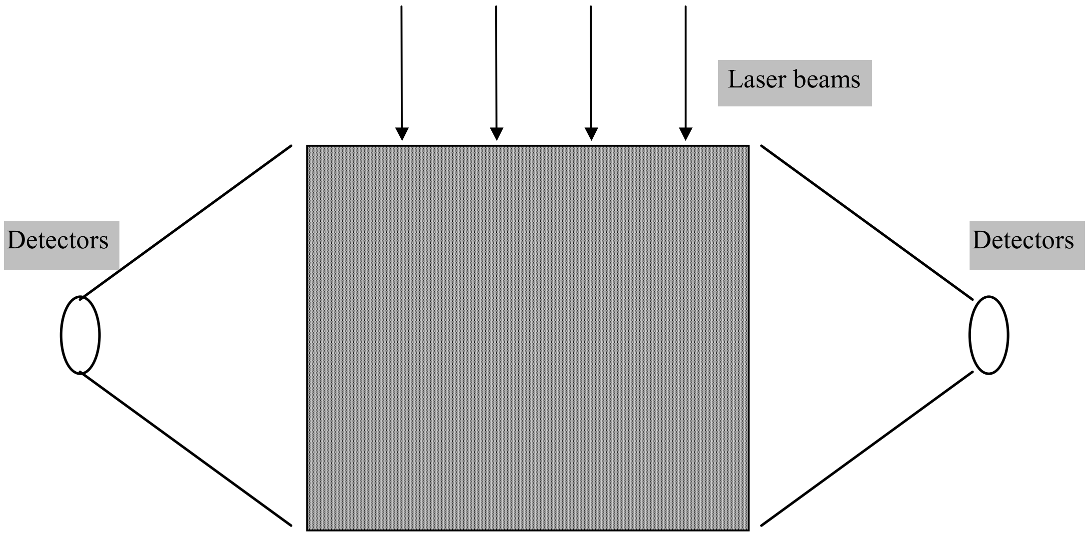


Figure 2-50: Top-view of the optical detection system

The study performed on the system based on optical detection has demonstrated its feasibility and compatibility with the ROSETTA rendezvous configuration, because of the expected grain velocity. It ensures a high reliability of detection. This system will introduce a uniform cut-off for grains smaller than about 10 µm, so that no alteration on the statistics for grains larger than 10 µm should occur. On the other hand, the technical feasibility of this device is confirmed by the performed analysis. In particular, laser diodes similar to those foreseen in the present GIADA design have been already space qualified for long term non-op conditions and op duration compatible with the GIADA requirement.

In the light of the elements reported above it is decided that after the study phase, i.e. after the ECDR, only the optical detection concept is maintained in the GIADA design as a baseline, while the plasma detection concept is abandoned. For this reason, in the rest of the EID-B document and in all the documentation concerning GIADA, the acronym GDS (Grain Detection System) indicates the optical detection system and no reference is given any more to the other system.

2.2.9.2.3. Additional information from solar panels

Solar panels will be polluted by “reflected” grains coming from the sun direction. As mentioned, GIADA will be of great help to predict degradation of solar panel performances.

On the other hand, if it will be possible to calibrate the solar panel performance degradation as a function of dust deposition, housekeeping data can have a scientific value concerning dust flux monitoring. In fact, the solar panels will constantly be oriented towards the sun direction. In other words, the solar panels will collect dust coming from the sun direction, i.e. “reflected” grains, only.

2.2.10. RPC

2.2.10.1. Scientific Objectives

The Rosetta Orbiter Plasma Consortium (RPC) will consist of five sensors:

- Langmuir Probe (LAP)
- Ion and Electron Sensor (IES)
- Ion Composition Analyser (ICA)
- Fluxgate Magnetometer (MAG)
- Mutual Impedance Probe (MIP),

as well as a joint

- instrument control, spacecraft interface, and power management unit (PIU).

The scientific objectives are far reaching and related to the overall scientific aims of the ROSETTA mission. It is intended to investigate the following scientific areas of interest:

- the physical properties of the cometary nucleus and it's surface

Special emphasis will be paid to determine the electrical properties of the crust, its remnant magnetization, surface charging and surface modification due to solar wind interaction, and early detection of cometary activity

- the inner coma structure, dynamics, and aeronomy

Charged particle observation as planned will allow a detailed examination of the aeronomic processes in the coupled dust-neutral gas-plasma environment of the inner coma, its thermodynamics, and structure such as the inner shocks

- the development of cometary activity , and the micro- and macroscopic structure of the solar-wind interaction region as well as the formation and development of the cometary tail

In order to realize these investigations extensive in-situ monitoring of the plasma electrons and ions, their composition, distribution, temperature, density, flow velocity, and the magnetic field is necessary. These anticipated measurements will improve the understanding of the coupling processes of cometary dust, gas, and plasma as well as its interaction with the solar wind. The plasma and fields measurements thus provide complementary information to that of other Rosetta instruments for a deeper understanding of the overall physics and chemistry of an active comet.

The planned asteroid flybys of the ROSETTA spacecraft will provide an excellent opportunity to study in detail the physics of the solar wind - asteroid interaction. The proposed payload is also most suitable to investigate this interaction. Furthermore, the planned observations will allow us to study the magnetic and electric conductivity properties of the asteroid.

2.2.10.2. Design Overview of RPC

A plasma consortium is proposed with five different sensors and a common plasma interface unit (PIU) as a single interface between the package and the spacecraft. Such a highly integrated package saves spacecraft resources such as mass and power. Great care has been taken to provide robust sensors of proven technology that will operate and survive in a cometary environment. The sensors proposed bear heritage from many different space missions such as GEOS 2, ARCAD 3, Voyager, Giotto, CLUSTER, Viking, Freja, MARS-96, and Cassini.

Sensor etc.	Mnemonic	Responsible Group
LAngmuir Probe	LAP	IRF-U, Uppsala
Ion and Electron Sensor	IES	SwRI, San Antonio
Ion Composition Analyser	ICA	IRF-K, Kiruna
Fluxgate MAGnetometer	MAG	TU Braunschweig
Mutual Impedance Probe	MIP	LPCE, Orleans
Plasma Interface Unit	PIU	ICSTM, London
Electrical Ground Support Equipment	EGSE	KFKI-RMKI, Budapest

The accommodation of the sensors and interfaces is indicated in Figure 2-51 and Figure 2-52 and is as follows:

- LAP two sensors, each mounted at the tip of an about 1.5 m boom, separated > 1 m in the direction towards the nucleus
- IES body mounted at the nucleus facing edge of the instrument platform
- ICA body mounted at the nucleus facing edge of the instrument platform
- MAG two sensors mounted at a distance of about 0.95 m from the s/c and close to the tip of the about 1.5 m long -x-boom, i.e. the boom pointing away from nucleus

- MIP boom mounted: the four electrodes that make up the sensor are mounted at a minimal distance of 1 m from the spacecraft structure, sensor pointing towards the comet direction (within 45º).
- PIU The PIU is contained within the RPC common electronic box, which also houses the MAG, MIP and LAP electronics.

Note: No metalic structure should lie between the MIP sensor and the opposite LAP sensor.

A block diagram of the package is given in Figure 2-53.

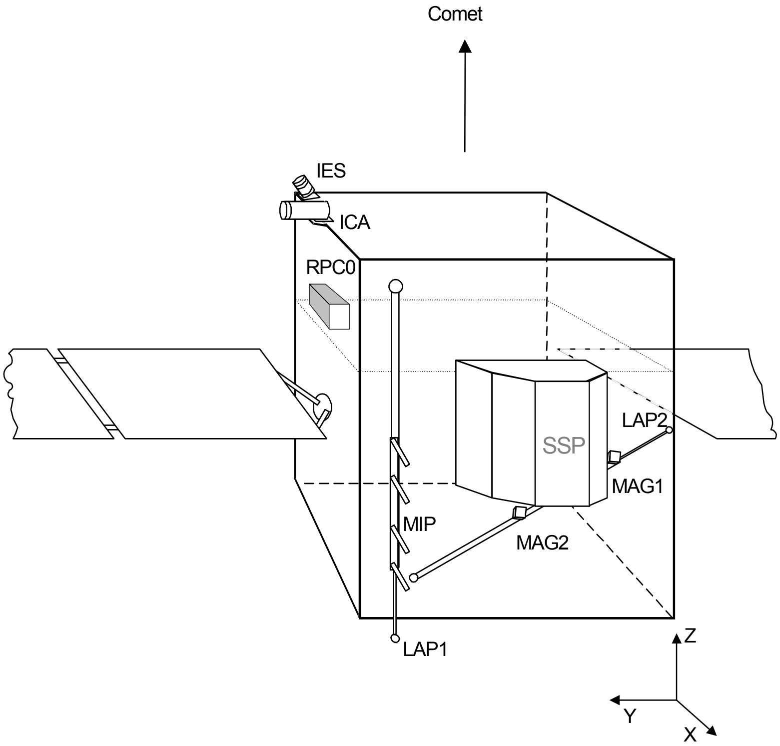


Figure 2-51: Rosetta Plasma Consortium (RPC) Sensor Layout (stowed)

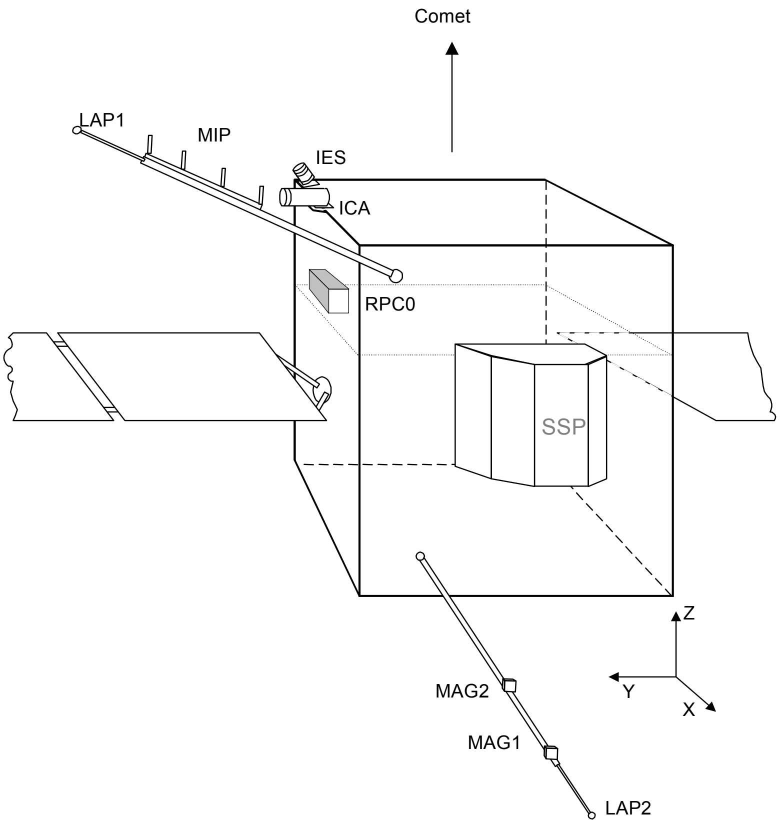


Figure 2-52: Rosetta Plasma Consortium (RPC) Sensor Layout (deployed)

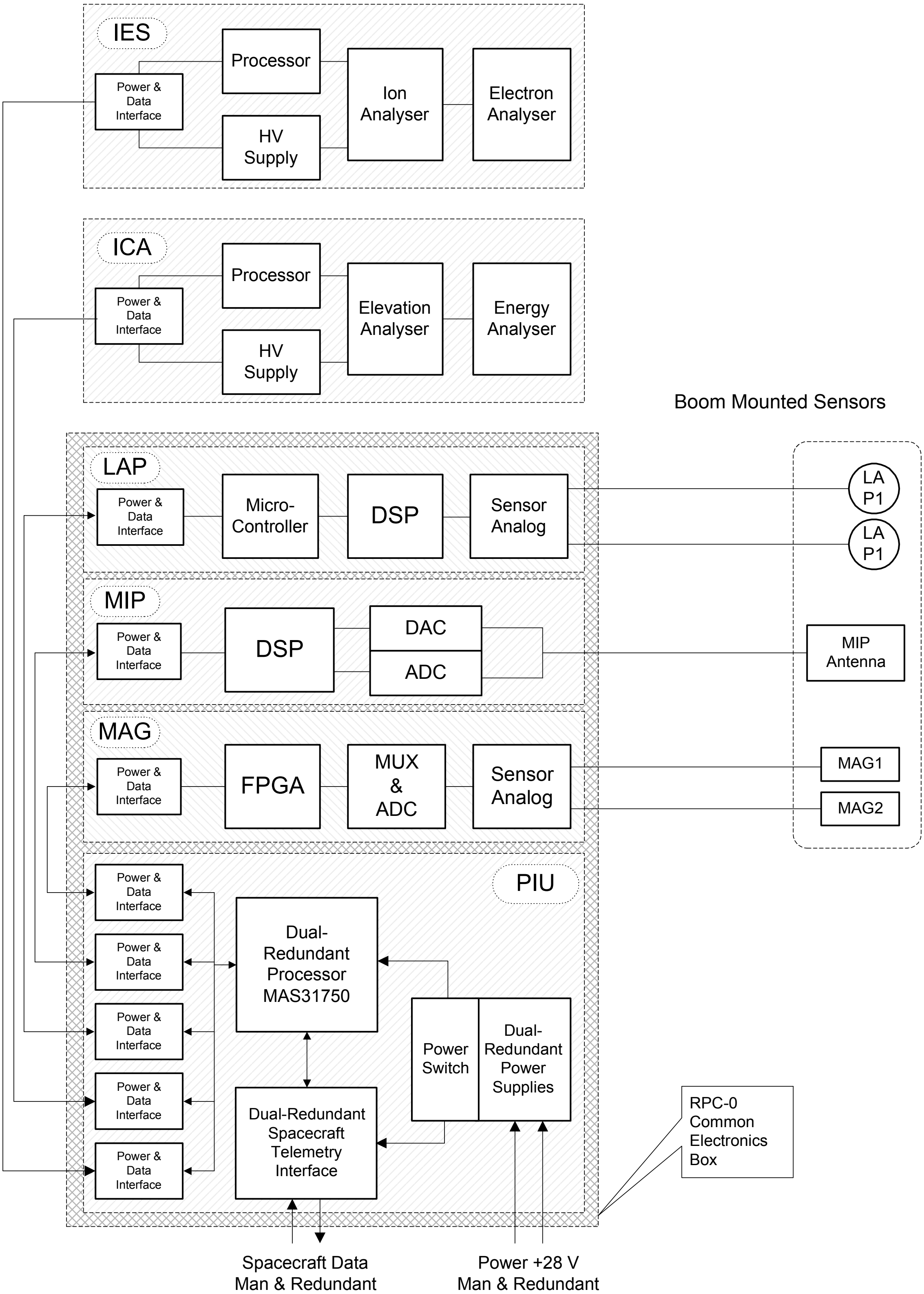


Figure 2-53: RPC Overall Block Diagram

2.2.11. SREM

The Standard Radiation Envirionment Monitor (SREM) is an instrument designed for monitoring of the radiation environment of the satellite.

SREM detects and counts electrons, protons and cosmic rays with a coarse spectral resolution. The electron detector ‘telescope’ consists of a single silicon detector while the proton detector is based on two silicon detectors in a tandem configuration. Events are sorted, according to their energy, into ‘bins’: 2 bins for electrons and 12 bins for protons and cosmic rays. The electron bins count the number of events with energies greater than 0.5 MeV and 1.0 MeV respectively; the proton bins cover the range from 20 MeV to 400 MeV.

SREM can count up to the rate of 10^5 events per second in an angular range of 20° half-cone.

2.2.12. RSI

2.2.12.1. Scientific Objectives

The primary scientific objectives of RSI, addressing the scientific objectives as defined in the Rosetta AO, are divided into following categories: Gravity Field and Dynamics, Cometary Nucleus, and Cometary Coma. The secondary scientific objectives of RSI are studies which are not covered by the ESA prime scientific objectives but will significantly enhance the science return of the mission.

Primary Scientific Objectives

Doppler data provide time-resolved measurements of the spacecraft motion and the plasma state and thus may be used for physical investigation of the nucleus and the inner coma of comet P/Wirtanen. In particular, the following scientific objectives may be addressed by an analysis of dual-frequency one-way or two-way radiometric tracking data, together with information provided by other Rosetta experiments, e.g. Remote Imaging System (OSIRIS):

Gravity Field and Dynamics

- Cometary mass and bulk density
- Cometary gravity field coefficients
- Cometary moments of inertia and spin state
- Cometary orbit, lightshift, thermal properties of the nucleus
- Asteroid mass and bulk density

Cometary Nucleus

- Size and shape (from S/C occultation observations)
- Internal structure (from nucleus sounding)
- Dielectric constant and roughness of the surface (from bistatic radar experiment)
- Rotation, precession and nutation rates (from bistatic radar)

Cometary Coma

- Distribution of mm - dm size particles (from coma sounding)
- Plasma content of the inner coma (from coma sounding)
- Gas and dust mass flux (from non-gravitational perturbations of the *Rosetta* S/C)

Regarding investigations of the cometary gravity field and its internal structure, shape models derived from Rosetta imagery may be used for the construction of theoretical gravity models and compared with the observed gravity field coefficients. Image data will, furthermore, provide information on the orientation and rotation of the nucleus, required for the determination of the cometary gravity field and the moments of inertia.

<u>Secondary Scientific Objectives</u>

During its cruise to comet P/Wirtanen, the Rosetta spacecraft will pass through five solar conjunctions and three oppositions and additionally another two conjunctions and one opposition during the primary mission. It is proposed to perform radio sounding observations of the solar corona and a search for gravitational radiation during solar conjunctions and oppositions, respectively:

Solar Corona Science

- Electron content of the inner corona, solar wind acceleration, search for coronal mass ejections, turbulence

Search for Gravitational Radiation

- Search for plane-transverse-polarised long-period (50 s to 1200 s) gravitational waves crossing the solar system

Scientific objective	Supported by spacecraft capabilities?	Supported by operations?
Nucleus mass	yes	yes
Bulk density	yes	yes
Gravity coefficients: J2 Higher harmonics	yes	yes(1)
Non-gravitational perturbations	yes	yes
Gas & dust jets	yes	yes
Dust grain distribution	yes	yes(2)
Electron content	yes	yes(2)
Nucleus size & shape	yes	yes(2)
Bistatic radar	yes	yes(2)
Microwave propagation through nucleus	yes	yes(3)
Asteroid mass	mimi.,Rod.: no Siwa: yes	yes
Solar corona sounding	yes C4 - C6: no	C1: during hibernation C2, C3, C7: yes

notes:

1 Degraded capabilities at heliocentric distances less than 3.25 AU, full capabilities beyond 3.25 AU

2 Depends on support of occultations, excluding eclipses

3 Not supported (depends on depointing of the HGA)

Table 2-8: RSI Scientific Objectives vs. USO Option

2.2.12.2. Design Overview of RSI

The Project baseline is that RSI uses the S/C radio subsystem without modifications.

In order to enhance the scientific measurements (in particular for the one-way downlink mode) an Ultra Stable Oscillator (USO) will be used with the S/C radio subsystem (procured by Project).

The prime purpose of the USO is to serve as a phase coherent frequency reference source for the simultaneous S-band and X-band downlink transmission when the transponder is operated in the one way mode. The connection of the USO into the transponder circuitry is via a coax cable. The basic requirements concerning the USO are a short term frequency stability of 10^{-12} per 10...1000 seconds time interval (Allan variance) with a design goal of 10^{-13} and a very low phase noise. The frequency stability and low phase noise can be achieved by quartz oscillators.

The time to reach the specified frequency stability is quoted by the quartz-USO manufacturers to be in the order of one month.

2.2.13. Lander

2.2.13.1. Scientific Objectives

- It is the general aim of the scientific experiments carried and operated by the Rosetta Lander to obtain a first in-situ composition analysis of primitive material from the early solar system, to study the composition and structure of a cometary nucleus, reflecting growth processes in the early solar system, to provide ground truth data for the Rosetta Orbiter experiments and to investigate dynamic processes leading to changes in cometary activity.
- The primary objective of the Rosetta Lander mission is the in-situ investigation of the elemental, isotopic, molecular and mineralogic composition and the morphology of early solar system material as it is preserved in the cometary nucleus. Interpretation of the chemical composition of surface material benefits strongly from the knowledge of fractionation and aging processes which occur in the upper surface layers since it allows to draw conclusions on the original cometary material. Physical and thermal properties of near-surface material affect these fractionation processes. Therefore, the investigation of the composition together with the physical and thermal properties of surface and subsurface material and the study of the thermal behaviour over many insolation cycles and over a significant variation of insolation intensity (i.e. heliocentric distance) are desired.
- Long-term in-situ observations on the surface of a cometary nucleus can reveal phenomena which are not observable remotely by the Rosetta Orbiter: local erosion of the surface by sublimating ices, modifications of texture and chemical composition of near surface materials, changes in dust precipitation and heat flux through the surface, which is the determining parameter for all processes modifying cometary material. Long-term observations will allow to

study these processes and transient activity phenomena as a function of distance to the sun.

- Measurement of the absorption and phase shift of electromagnetic waves penetrating the comet nucleus will help to determine its internal structure. Seismometry and magnetometry will also be used to investigate the interior of the comet.
- The in situ measurements performed by the Rosetta Lander instruments will also provide local ground truth to calibrate Orbiter instruments. Close-up panoramic observations of cometary material in the vicinity of the Lander can calibrate albedo and topographical features observed by the Orbiter camera. In-situ chemical and mineralogical analysis of surface material by the Lander payload provides a means to correlate chemical and mineralogical compositions with brightness at various infrared wavelengths observed by the Orbiter.

The scientific objectives of the Rosetta Lander can be listed according to their priority as follows :

1. Determination of the composition of cometary surface and subsurface matter: bulk elemental abundances, isotopic ratios, minerals, ices, carbonaceous compounds, organics, volatiles - also in dependence on time and insolation.
2. Investigation of the structure and physical properties of the cometary surface: topography, texture, roughness, regolith scales, mechanical, electrical, optical, and thermal properties, temperatures. Characterization of the near surface plasma environment.
3. Investigation of the global internal structure.
4. Investigation of the comet/plasma interaction

Provision of ground truth data for Orbiter instruments.

Long-Duration Mission

Cometary activity is one of the most spectacular short-term variable phenomena of bodies in the solar system, within a time scale between weeks to years. Seasonal and diurnal variation of surface temperatures are the driver for sublimation and erosion of the surface. Cometary surfaces are expected to be layered according to the volatility of the material components: the most volatile components have retreated to the cold interior of the nucleus, while refractory materials may be concentrated near the surface. Physical and thermal properties affect this fractionation process. Consequently, interpretation of the surface chemical composition requires good knowledge of heat and mass transport in the near surface regions of the comet. This knowledge can only be obtained by investigation over at least several diurnal insolation cycles. The (presently only vaguely known) cometary rotation period, which appears to be rather short (six hours to days), sets a lower limit for the observation time scales. Another time scale is given by the evolution of cometary activity, which is a major fraction of the orbital period.

- From a technical and scientific point of view the various instruments of the payload require quite different operation times. Those experiments observing the development of the surface characteristics as a function of increasing insolation will desire long-term operation.

- In addition, the penetration and sampling as well as the nucleus sounder (requiring as many Rosetta Orbiter periods as possible) relies on longevity of the Lander. A passive seismometer needs natural stimulation processes like thermal stress, meteoritic impacts (tbc) or outbursts. Thermal stress is assumed to be connected with the diurnal cycle. The chances to detect seismic events caused by meteorites increase linearly with time.

- A long-term mission allows adaptation of the instruments to the cometary environment with respect to comet physical parameters and allows interactive operation of the payload. For example, potentially interesting targets can be identified (camera imaging), measurements can be correlated and repeated systematically, and measurement parameters and modes can be adapted, varied and optimized, thus enhancing the quality and credibility of results. Some instruments require long observation periods to improve data statistics for unambiguous interpretation.

2.2.13.2. Hardware Description

- The baseline configuration of the Rosetta Lander is shown in figure 2-56. The Lander structure will consist essentially of a carbonfibre sandwich baseplate, an instrument platform, and a polygonal sandwich construction, all manufactured in high-modulus carbonfiber material. Part of the instruments and subsystems will be underneath a hood which is covered with solar cells. The instrument platform is thermally insulated with regard to the ground plate which will be exposed to the environment. One part of the ground plate is forming a “balcony” providing space for external instruments and subsystems, like the drilling and sampling system the ovens for the EGAs, MUPUS, ROMAP, ÇIVA-M and the APX-spectrometer..

- The Rosetta Lander will be supported by a landing gear, consisting of a foldable tripod and a central mechanism, that dissipates most of the landing impact energy and allows rotation of the main structure with respect to the landing gear and height adjustment. The three legs will be unfolded after separation from the Orbiter during descent. They are connected to the main structure via a central extendable tube. At impact, the energy will be dissipated within this tube by accelerating a motor. Rotability allows investigation of several spots underneath the Lander by the experiments, adds flexibility to the drilling system and allows stereoscopic panoramic imaging (360° stereo imaging) with a single stereo camera sensor. It also eases both, thermal and power control.

- Immediately after impact an anchoring harpoon will be fired to secure firm fixation of the Lander to the ground.

- The Lander´s descent will be initiated by the eject from the main S/C; a pushoff mechanism with variable Δv is foreseen. Attitude control during descent will be maintained by use of a flywheel. A cold-gas system (ADS - active descent system) with one vertical thruster is implemented. In case of a complete malfunction of the eject device the Lander could be released by an emergency device. The ADS will provide vertical thrust for reducing the descent time and cope with the gas drag due to the comets activity. At impact, most of the energy is dissipated in the landing gear; to avoid rebound due to the residual energy, the ADS vertical thruster is fired again. The thrusteris mounted on top of the hood, above the center of gravity .

- The Rosetta-Lander is equipped with a Sample Drill & Distribution (SD2) subsystem which is in charge to collect cometary surface samples at given depth and distribute them to the following instruments: ÇIVA-M (microscope (MS) & Infrared Spectrometer (IS)), the ovens, serving COSAC and PTOLEMY. Comet sample from pre-determinated and/or known (measured) depth are collected and transported by SD2 to well defined locations:
    - MS & IS viewing place
    - ovens for high temperature (800°C) heating
    - ovens for medium temperature (130°C) heating.
    - ovens with a window, where samples can be investigated by ÇIVA-M
- The SD2 design concept includes:
    - drill unit
    - sampler unit
    - carousel for sample distribution
    - control electronics
    - volume checker.

- Telemetry and Telecommand data links to the Rosetta Orbiter, which acts as a relay for telecommunications to Earth, are provided by a redundant S-band telecommunications system. Patch antennas are foreseen for data transfer to and from the Orbiter. They will be mounted above the “balcony”. A Lander / Orbiter telecommunications unit will be part of the ESS, mounted to the Orbiter.

- A central data management system (CDMS) will control all Lander functions, deliver commands to the experiments ,packaging of the scientific data as well as their transmission to the Orbiter. The CDMS will also make command and data storage available.

- The thermal subsystem is based on internal superinsulation of the main body, the reduction of heat leaks and absorber areas. Electrical dissipation of about 5 W in average is required to realise longevity. A first scientific sequence (lasting several days), however, is possible also, relying on the primary batteries only. No use of

RHUs is foreseen. The main instrument compartment is kept at temperatures above -40°C.

- Solar cells on the hood with a projected area of approximately 0.4 m^2 generate >11 W electrical power averaged over the (illuminated) day, taking into consideration the degradation of the cells during cruise. About 4 W will be available to the scientific experiments at 3 AU through descent, landing and surface operations. Batteries, both, primary- and secondary-, support Lander operation at night time, cover peak-power requirements, and ensure the first sequence (day and night). A central power management system provides standardised power interfaces to all subsystems and experiments.

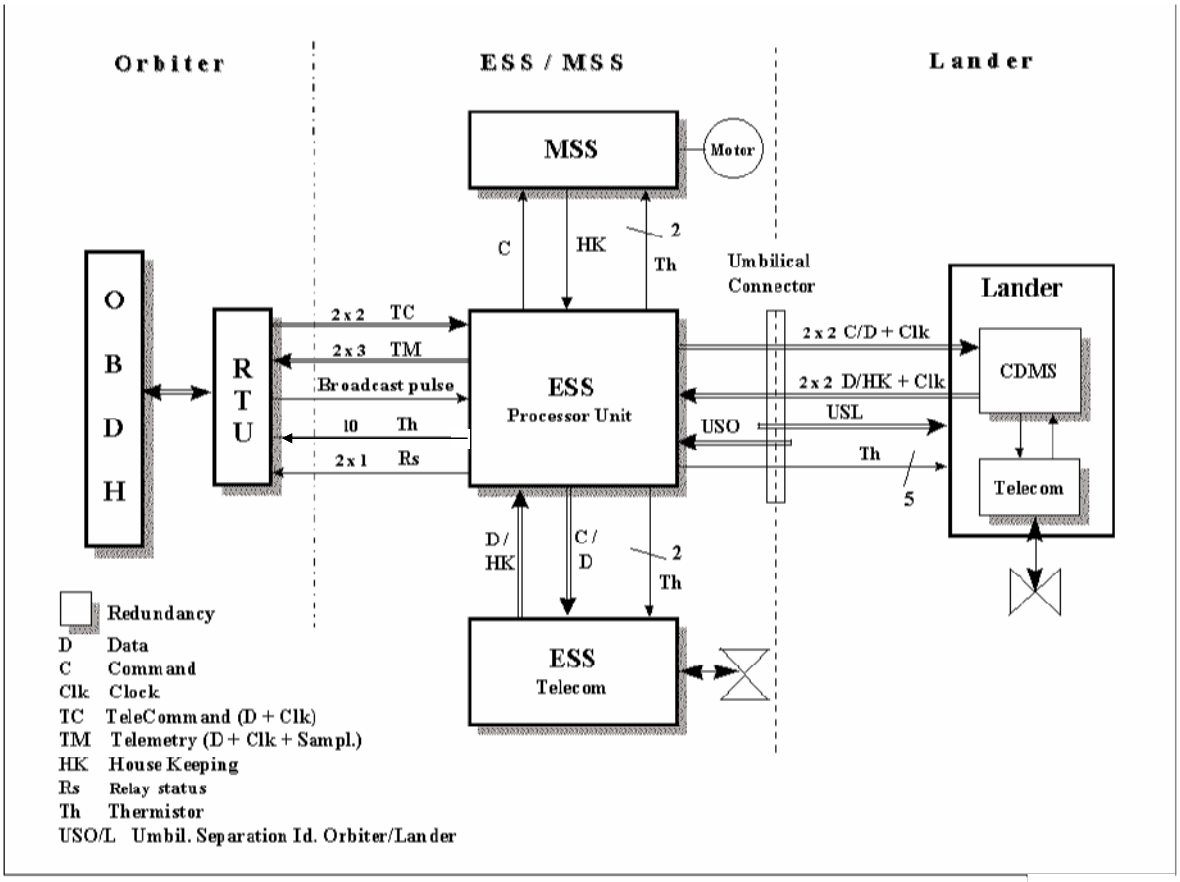


Figure 2-54: Functional blockdiagram of the Rosetta Lander data system

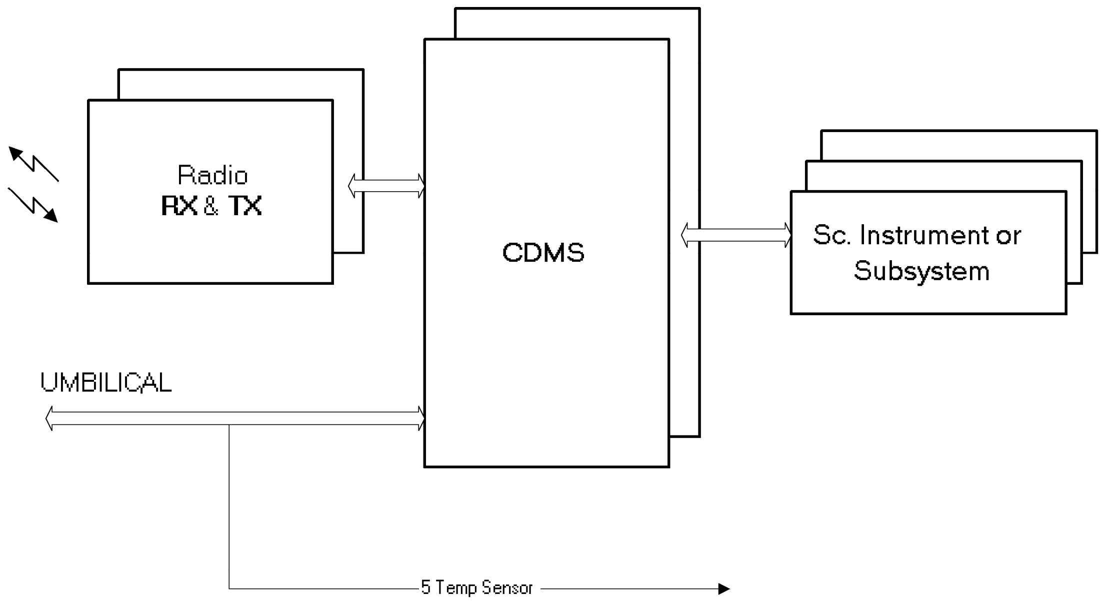


Figure 2-55: Schematics of Rosetta Lander instruments and instrument electronics

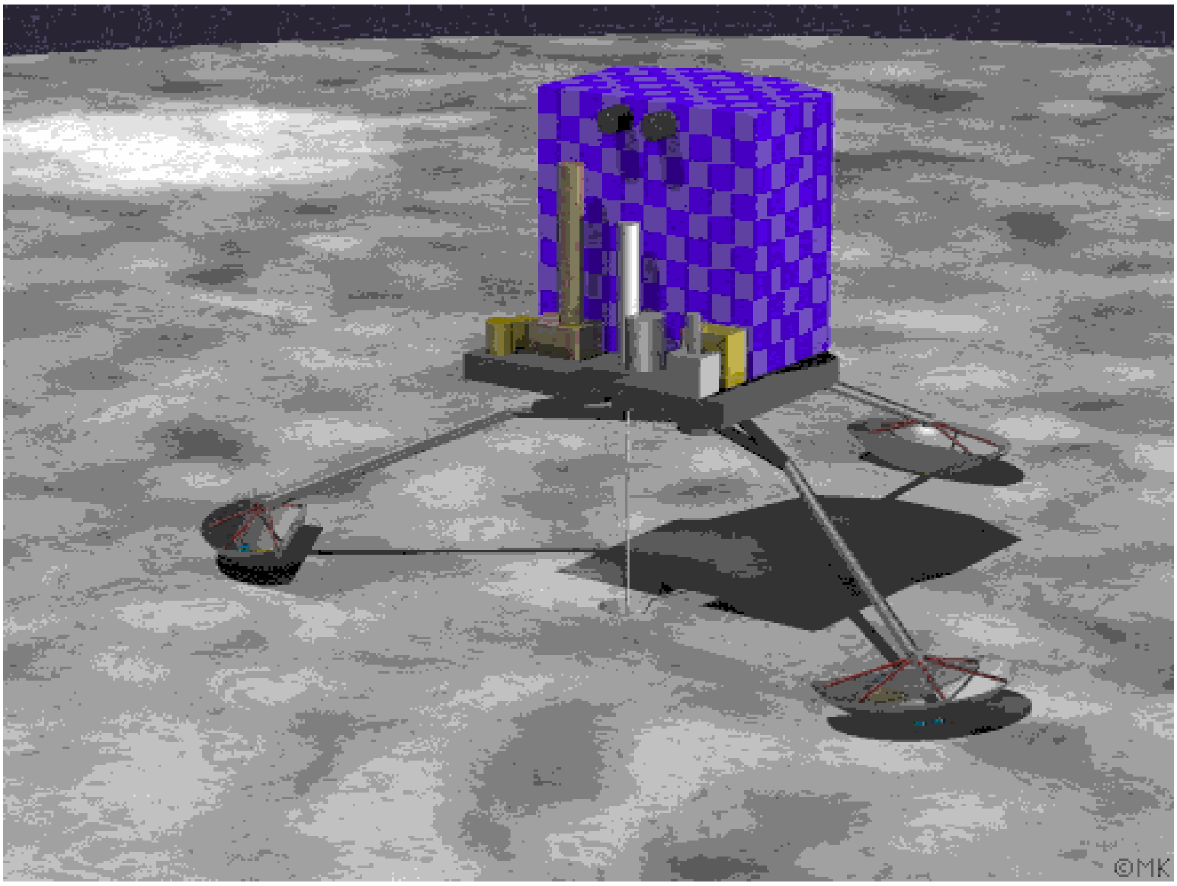


Figure 2-56: Preliminary Rosetta Lander configuration

2.3. System Configuration

This section has been transferred to §3.1

2.4. System Budgets

See §16 of the Users Manual.

3. SYSTEM LEVEL OPERATIONS

3.1. System Level Modes

The **Prelaunch Mode** will be used during final preparation and checkout activities on the launch pad. It is automatically entered when the spacecraft is switched on; in this way it will be used also during all ground testing.

The spacecraft is in the **Launch Mode** from removal of umbilical until it has autonomously performed all operations after separation to achieve a safe Sun pointing attitude and communications via LGA is established. These operations are controlled by a dedicated program, which is continued also in failure cases.

The **Activation Mode** follows the Launch Mode, when control is taken over from ground. It is used until completion of spacecraft check-out and payload commissioning (3 months). In principle this is not a specific system mode, but is used here to denote the variety of configurations used during check-out operations. ~~The spacecraft check-out will also include a test of the Spinning Hibernation Mode.~~

The **Active Cruise Mode** is used during the interplanetary cruise phases in all time intervals around major mission events, such as planetary and asteroid fly-bys, major orbit manoeuvres and the comet rendezvous manoeuvre. It is characterised by daily tracking, monitoring and commanding. It is also the mode to which the ground will switch back in case of on-board anomaly requiring analysis or reconfiguration, or after the spacecraft has autonomously entered the Safe Mode. In the Active Cruise Mode the navigation camera will be used during the periods for comet detection and approach navigation.

The **Hibernation Mode** is an operational mode without ground support. It is used during the long interplanetary cruise phases between major mission events. There are two different modes:

Deep Space Hibernation Mode (DSHM): In the last phase at solar distances between 4.7 and 5.~~25~~ 33 AU the spacecraft is inertially stabilised by a spin around the axis with maximum inertia. Sun pointing is optimised for aphelion and the power consumption is minimised. The spacecraft is almost entirely passive: only two CDMUs with 2 PMs, the receivers/decoders, power supply, and thermostat controlled heaters are operational.

Near Sun Hibernation Mode (NSHM): In the hibernation phases with Sun distances below 4.5AU the S/C will be in an active 3-axis control mode (one sided limit cycle control) with a certain deadband, typically ±10°, by means of thrusters and star tracker. The attitude control, using on-board stored ephemeris data, can be either with the X-axis Sun-pointing or Earth-pointing. The Earth-pointing strategy has been adopted as baseline ~~(preferred by ESOC),~~ since it allows to get in contact with the spacecraft via MGA, without leaving

NSHM. On the other hand this strategy needs regular ground contacts for re-positioning of the solar arrays. Two Avionics processors will be active. This mode, however with the X-axis Sun-pointing, would also be used as an emergency back-up strategy in the deep space phase, in case the spinning mode is not possible (after a SADM failure). This, however, is considered as a non-credible failure mode and therefore not relevant as solar array sizing case; the increased power consumption has to be covered by the available margins.

After a system alarm in the Near Sun Hibernation Mode the spacecraft enters Safe Mode and activates S-Band downlink via HGA.

The **Asteroid Fly-by Mode** is used before, during and after asteroid fly-bys, when the asteroid is visible by the navigation camera. The scientific payload will be operated during the pre-fly-by navigation and targeting and during the fly-by itself. During fly-by the payload line of sight will remain asteroid pointing by closed loop tracking with the navigation camera. HGA tracking will be stopped during the near fly-by. Science data is recorded during this phase and transmitted to ground after Earth re-acquisition.

The **Near Comet Mode** is dominated by scientific activities of comet characterisation and observation. The instrument line of sight will remain pointing to the nucleus, the HGA to the Earth, and the solar arrays to the Sun. This mode also covers the delivery phase of the surface science package and extends through perihelion passage of the comet.

The **Safe Mode** is primarily designed to ensure a safe Sun pointing attitude, a safe power situation (solar arrays Sun pointing), and accessibility from ground via HGA, MGA, or LGA. When the Safe Mode is established, the spacecraft is 3-axes stabilised with use of reaction wheels (if enabled by ground), star tracker and gyros (only 1 in deep space), and the HGA and MGA are pointed to the Earth. The payload is switched off with nonops heaters on (default mode) or configured to any mode as required.

For the transition to Safe Mode the AOCMS Sun Keeping Mode (SKM) is activated, in which thrusters, gyros, and the Sun sensors on the solar panels are used to bring and maintain the solar arrays perpendicular to the Sun.

The Safe Mode- attitude is established by orienting the Y-axis near perpendicular to the ecliptic plane, and rotation of the spacecraft body around the Y-axis until the X-axis points to Earth, while the solar array is kept Sun pointing. The orientation of the Y-axis (+Y or -Y upwards) is determined by a flag set by the ground. In this attitude the HGA and MGA are both available for communications as well as both LGAs for emergency commanding. By default, one S-band receiver is connected to the HGA the other to the front LGA. S-band downlink via HGA is initiated. A dedicated program for TC Recovery will ensure command access, if no command has been received during a pre-programmed period of time, i.e. if an antenna or RX failure is suspected.

It should be noted, that this attitude will not be acceptable during some short phases directly following launch and around the ~~two~~ three Earth fly-bys. This is on one side due to the potential conflict between this guidance strategy and the Sun pointing requirements (when so close to Earth), and on the other side due to the large SSCE angle, for which a limit of about 70° should be assumed for SSP and orbiter payload safety (sun in +X/+Y quadrant); in these phases direct Sun pointing of the X-axis will be established, based on a ground-set "Earth-distance" flag, with command accessibility via HGA and the LGAs.

In the Safe Mode the spacecraft is capable of surviving on its own for a virtually ‘unlimited’ time provided that the Sun distance is compatible with the power demand. Depending on the cause for entering Safe Mode, the DMS and AOCMS processors are reconfigured or not.

The Safe Mode may be entered:

- on command from ground
  No processor re-configuration is performed in this case
- initiated from the Mission Timeline (MTL)
  This kind of Safe Mode entry at predefined times in the mission serves as a back-up for loss of command capability. These time tagged Safe Mode entries will normally be cancelled prior to their execution time, if everything runs well. Also in this case no processor re-configuration will be performed.
- initiated after an on-board anomaly, which is not immediately recoverable.
  The spacecraft will always first attempt to recover from a failure and continue with the planned operations. Only if this is not possible the Safe Mode will be entered. The Safe Mode entry criteria are the following:
- System alarm during routine operations (battery discharge for longer than 5 min ~~or DMS controlled attitude out-of-limit~~). Both operational processors are switched over, because the AOCMS did not recognise the critical situation; then Safe Mode is entered.
- AOCMS detects non-allowed attitude or other not immediately recoverable critical failure. Safe Mode is entered without processor reconfiguration.
- Further failure in AOCMS, when already in back-up mode (SKM) and no more redundancy is available. Both operational PMs are switched over and Safe Mode is entered again.
- WD triggering, S/W failure, PM undervoltage, non recoverable DMS/AOCMS link failure. Both operational PMs are switched over and Safe Mode is entered.

The **Survival Mode** will be entered, in case the Safe Mode as described above cannot be achieved autonomously due to a major on-board anomaly or if this transition is disabled. In this case the AOCMS stays in Sun Keeping Mode (SKM), which is the first AOCMS back-up in transition to Safe Mode. In between the spacecraft may also be configured to Sun Acquisition Mode (SAM) in case the Sun was lost on the Sun sensors used by SKM, but afterwards it returns to SKM. The principles of these modes are:

- SKM keeps the solar arrays fixed and points them to the Sun by use of the Sun sensors on the solar arrays, thrusters, and gyros (nominally 2)

- in SAM the solar arrays will be aligned to point along the S/C +X-axis, and the +X-axis is pointed to the Sun by use of the Sun sensors on the S/C body, thrusters, and gyros (nominally 2).

Both these AOCMS modes do not use known failed units (ground controlled configuration table). Acquisition of 3-axis attitude by means of STR and subsequent transition to Safe Mode is attempted, if not disabled from ground, until a time-out is elapsed.

Being not able to enter Safe Mode means basically, that either the onboard ephemerides are lost (the spacecraft does not know where to find the Earth), or the AOCMS cannot perform an autonomous attitude determination with its star trackers (e.g. due to cometary dust).

If this is the case, the spacecraft will enter Survival Mode, which in terms of AOCMS means the MGA Strobing Mode, as a submode of SKM. In this mode the solar arrays will be driven to an offset angle from the +X-axis, which corresponds to the current Sun-S/C-Earth angle (SSCE), taken from a table stored on-board. During this rotation of the solar arrays the Sun will be maintained within a few degrees of the solar array perpendicular. Finally, the MGA boresight will be pointing at an offset from the Sun direction, where the Earth can be found. The AOCMS then performs a small rate (0.05°/sec) around the Sun line. The OBCP "Survival Mode" will initiate S-band carrier downlink via the MGA, which can be picked up on ground once per revolution (may need DSN 70m station). Recovery from this mode is in principle performed by a command to start an OBCP, which will stop the rotation at the right point and switch to X-band downlink for TM data transmission to ground.

The transition from SKM to its submode MGA Strobing can be disabled from ground. In this case the AOCMS stays in the normal SKM. This would be used e.g. in deep space if the Near Sun Hibernation Mode is used instead of the spinning mode, i.e. the transitions to AOCMS Safe/Hold Mode and MGA Strobing Mode are disabled to force the AOCMS to stay in SKM in case of problems in NSHM.

System Mode	Basic Configuration	Active Surveillance	Special Operations
Pre-launch Mode	only DMS on, AOCMS PM on, external power supply	~~General health check by On-board Monitor,~~ DMS/AOCMS FDIR, processor watchdog	final checkout, loading of data for separation sequence
Launch Mode	Initially: DMS on, SSMM in standby with 1 MM, AOCMS PM on, separation sequence program running, power supply from batteries Finally: DMS on, AOCMS in Sun Acquisition Mode, TT&C S-band downlink on, power supply from solar arrays, X-axis and solar arrays Sun pointing	~~General health check by On-board Monitor,~~ DMS/AOCMS FDIR, processor watchdog, separation status checked by separation sequence, time-out for AOCMS operations, programs to ensure uplink and downlink (TX and RFDU switching)	after separation: AOCMS activation, RCS priming, downlink initiation, Sun acquisition, SA deployment, Sun re-acquisition
Activa-tion Mode	DMS on, AOCMS in Normal Mode, TT&C S- or X-band downlink via HGA (initially in S-band via LGA), 3-axis stabilised, SA Sun pointing ~~attitude~~	~~General health check by On-board Monitor,~~ DMS/AOCMS FDIR, processor watchdog, program for TC Recovery (back-up for RX failure), system alarms (attitude and power anomaly)	HGA deployment and Earth acquisition, overall checkout and calibration, booms deployment, ~~test of spin hibernation, tracking~~ orbit determination
Active Cruise Mode	DMS on, AOCMS in Normal Mode or Orbit Control Mode, TT&C S- or X-band downlink via HGA, 3-axis stabilised, SA Sun pointing ~~attitude~~	~~General health check by On-board Monitor,~~ DMS/AOCMS FDIR, processor watchdog, program for TC recovery, system alarms	~~Tracking~~Orbit determination, delta-v manoeuvres, navigation, calibrations, eclipse during Mars Fly-by, payload as required
Deep Space Hiber-nation Mode	CDMU on, AOCMS in SBM mode, inertial spin stabilisation mode, wake-up timers on, thermostat control of heaters	~~none~~DMS FDIR, processor watchdog, periodic switch on of heaters	~~None~~autonomous wake-up (entry into Safe Mode) when SCET > Wake-up time
Near Sun Hiber-Nation Mode	DMS on, AOCMS in NSHM, 3-axis active control mode with 2 PMs, star tracker, thrusters, X-axis ~~Sun or~~ Earth pointing	system alarms and attitude anomaly alarm, DMS/AOCMS FDIR; after alarm go to Safe Mode	~~regular~~ reduced experiment maintenance operations (i.e. switch on and off), solar array pointing updates

System Mode	Basic Configuration	Active Surveillance	Special Operations
Asteroid Fly-by Mode	DMS on, TT&C X-band downlink via HGA, SA Sun pointing, payload on, AOCMS in AFM mode: closed loop asteroid tracking with navigation camera, during Near Fly-by: HGA tracking stopped	~~General health check by On-board Monitor,~~ DMS/AOCMS FDIR, processor watchdogs, program for TC Recovery, hot redundancy of essential equipment (gyros, navigation camera, STR)	slew manoeuvres, Sun and Earth re-acquisition
Near Comet Mode	DMS on, TT&C X-band downlink via HGA, navigation camera and payload on, AOCMS in Normal Mode: 3-axis stabilised, SA Sun pointing, instruments comet pointing;	~~General health check by On-board Monitor,~~ DMS/AOCMS FDIR, processor watchdogs, program for TC Recovery, system alarms	any instrument pointing direction, scanning, SSP delivery, orbit manoeuvres
Safe Mode	DMS on, AOCMS in Safe/Hold Mode; SA Sun pointing, X-axis Sun or Earth pointing, 3-axis stabilised using gyros, star tracker, RWs (if enabled by ground); TT&C S-Band downlink via HGA; RXs on HGA/LGA; payload off	~~General health check by On-board Monitor,~~ DMS/AOCMS FDIR, processor watchdogs, program for TC Recovery, system alarms	For transition to Sun pointing: 2 gyros, thrusters, and Sun sensors are used (AOCMS in SKM or SAM, then to Safe/Hold Mode)
Survival Mode	DMS on, AOCMS in SKM submode ‘MGA Strobing’ (or in SKM if this submode is disabled), SA Sun pointing with offset from +X-axis = SSCE angle, fixed small residual rate around Sun vector; control by thrusters, Sun sensors, gyros; S-Band carrier downlink via MGA, RXs on MGA/LGA, payload off	~~General health check by On-board Monitor,~~ DMS/AOCMS FDIR, processor watchdogs, program for TC Recovery	At transition to Survival Mode the SA is driven to strobing position

Table 3-1: System Mode Summary

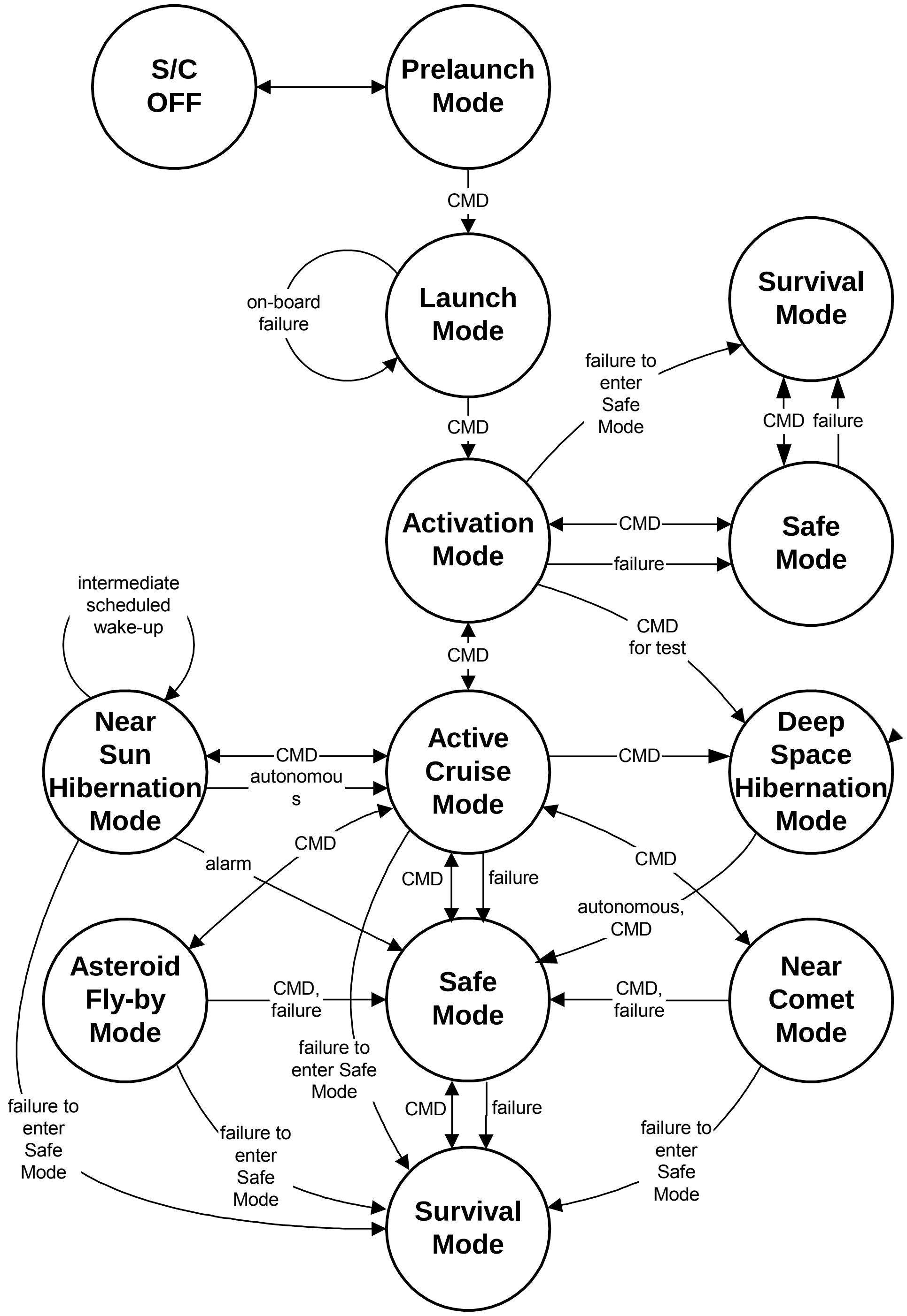


Figure 3-1: System Mode Transition Diagram

3.1.1. Spacecraft Configuration

In the following Table 3-1a the nominal configuration of the basic system modes and some special modes is shown. The 'Activation Mode' is not listed, it is basically the same as the 'Active Cruise Mode'.

Item	Launch	after Separation	Active Cruise Mode	NSHM	Delta-v near sun	Asteroid Near Fly-by	DSHM - Max Sun Distance	Delta-v deep space	Near Comet Phase	Safe Mode (standard)	Safe Mode (>4.21AU after DSHM)	Survival Mode (S-Band dl)	Rec from Survival M. (X-Band)	Remarks
S/C Mode	LM	LM	ACM	NSHM	ACM	AFM	DSHM	ACM	NCM	Safe Mode	Safe Mode	Survival Mode	Survival Mode	
AOCMS Mode	SBM	SAM	NM	NSHM	OCM	AFM	SBM	OCM	NM	SHM	SHM	SKM-ESP	SKM-EAH	
Payload Units	Off	Off	Off/On	Off/(On)	Off	On	Off	Off	On	Off	Off	Off	Off	(On) for maintenance
Thermal Control	Heater configuration cannot be meaningfully presented in this table; it is referred to FCP-SY0370													
Telecommunications														
USO	-	-	x	-	x	x	-	-	x	-	-	-	-	off above 4.4 AU
Receiver 1 S- or X-Band	S	S	S	S	S	S	S	S	S	S	S	S	S	
Transmitter 1 S- or X-Band	-	S/-	-	-	-	-	-	-	-	-	-	-	X	
Receiver 2 S- or X-Band	S	S	X	X	X	X	S	X	X	S	S	S	S	
Transmitter 2 S- or X-Band	-	-/S	X	-/X	X	X	-	S	X	S	S	S	-	Safe Mode D/L above 4.46 AU before DSHM / 4.04 AU after DSHM for 5h per 12h
Antenna connections and RFDU/WIU switch status														see Table 3-3 below
TM Bit Rate (bps)	-	2730.6	high	≥ 42.6	high	high	-	≥ 21	high	carrier	carrier	carrier	64	
TC Bit Rate (bps)	2000	2000	high	≥ 15.6	high	high	7.8	1000	high	7.8	7.8	7.8	7.8	
Coherency On	-	-	*	*	*	*	*	*	*	x	x	x	x	* as needed for link performance or Ranging

Item	Launch	after Separation	Active Cruise Mode	NSHM	Delta-v near sun	Asteroid Near Fly-by	DSHM - Max Sun Distance	Delta-v deep space	Near Comet Phase	Safe Mode (standard)	Safe Mode (>4.21AU after DSHM)	Survival Mode (S-Band dl)	Rec from Survival M. (X-Band)	Remarks
TWT	-	-	x	x	x	x	-	-	x	-	-	-	x	
EPC	-	-	x	x	x	x	-	-	x	-	-	-	x	
Data management														
CDMU 1	x	x	x	x	x	x	x	x	x	x	x	x	x	
CDMU 2	x	x	x	x	x	x	x	x	x	x	x	x	x	
S/S RTU	x	x	x	x	x	x	x	x	x	x	x	x	x	
PL RTU	-	-	x	x	x	x	-	-	x	-	-	-	-	
SSMM	x	x	x	x	x	x	-	x	x	x/Stby	x/Stby	x/Stby	x/Stby	above 4.15/3.74 AU before/after DSHM only 1 MM/MC/PS
OBDH Bus Bandwidth	full	full	normal	normal	normal	normal	full	normal	normal	full	full	full	full	
Battery Discharge Alarm	-	-	x	x	x	x	-	x	x	x	x	x	x	
Other Surveillances: see Avionics UM, §4.4.5.19														
AOCMS														
AOCMS Interface Unit	-	x	x	x	x	x	-	x	x	x	x	x	x	
Reaction Wheel Shaft Heaters	-	-	x	-	x	x	-	-	x	x	-	-	-	
Thrusters	-	x	-	x	x	-	-	x	-	-	x	x	x	
No. of Reaction Wheels	-	-	3	-	3 hold	4	-	-	3	3	-	-	-	
No. of Gyros	-	2	1/0	-	2	2	-	2	1/0	2	2	2	2	
Sun sensors in control loop	-	x	-	-	-	-	-	-	-	-	-	x	x	
Pressure Transducers	-	x	x	x	x	x	-	x	x	x	x	x	x	
Antenna Drive Electronics	-	-	x	-	hold	x	-	hold	x	x/-	x/-	-	-	In Safe Mode above 4.28/3.86AU before/ after DSHM only intermittent

Item	Launch	after Separation	Active Cruise Mode	NSHM	Delta-v near sun	Asteroid Near Fly-by	DSHM - Max Sun Distance	Delta-v deep space	Near Comet Phase	Safe Mode (standard)	Safe Mode (>4.21AU after DSHM)	Survival Mode (S-Band dl)	Rec from Survival M. (X-Band)	Remarks
Solar Array Drive Electronics	-	-	x	-	-	x	-	-	x	x/-	x/-	x	x	mechanisms operation for 2 min/day
Navigation Camera/StarTracker														
Electronics	-	-	x	x	x	x	-	x	x	x	x	-	-	
Camera	-	-	-	-	-	x	-	-	x	-	-	-	-	
Star Tracker	-	-	x	x	x	x	-	x	x	x	x	-	-	
Heater	-	-	x	x	x	x	-	x	x	x	x	-	-	
Power subsystem														
PCU	x	x	x	x	x	x	x	x	x	x	x	x	x	
P/L PDU	x	x	x	x	x	x	x	x	x	x	x	x	x	
S/S PDU	x	x	x	x	x	x	x	x	x	x	x	x	x	
BCR (Part of PCU)	x	x	x	x	x	x	x	x	x	x	x	x	x	
BDR (Part of PCU)	x	x	x	x	x	x	x	x	x	x	x	x	x	
Thermal Knifes/Pyros	-	x	x	-	-	-	-	-	x	-	-	-	-	
Software Applications														
Power Availability	-	-	-	-	-	-	-	-	-	-	-	-	-	
Separation sequence program:	x	x	-	-	-	-	-	-	-	-	-	-	-	
RCS Priming	-	x	-	-	-	-	-	-	-	-	-	-	-	
SA Deployment	x	x	-	-	-	-	-	-	-	-	-	-	-	
TC Link Monitor	x	x	x	x	x	x	-	x	x	x	x	x	x	
TC Link Recovery	-	-	-	-	-	-	-	-	-	-	-	-	-	
TCS SW	-	-	x	x	x	x	-	x	x	-	-	-	-	see also fcp-sy0370
PF TMT SW	-	-	x	x	x	x	-	x	x	-	-	-	-	see also fcp-sy0370

Item	Launch	after Separation	Active Cruise Mode	NSHM	Delta-v near sun	Asteroid Near Fly-by	DSHM - Max Sun Distance	Delta-v deep space	Near Comet Phase	Safe Mode (standard)	Safe Mode (>4.21AU after DSHM)	Survival Mode (S-Band dl)	Rec from Survival M. (X-Band)	Remarks
PL TMT SW	-	-	x	x	x	x	-	-	x	-	-	-	-	see also fcp-sy0370
DSHAP	-	-	-	-	-	-	x	-	-	-	-	-	-	~~tested in CVP~~
System OBCPs														
TM Link Maintenance	~~x~~-	x	-	-	-	-	-	-	-	-	-	-	-	
HRD Link Control OBCPs	-	-	as needed	-	-	x	-	-	x	-	-	-	-	
DSHM Entry	-	-	-	-	-	-	x	-	-	-	-	-	-	used for DSHM Entry
DSHM Exit	-	-	-	-	-	-	(x)	-	-	-	-	-	-	only in PROM SW
Load Data Pool Parameters	-	-	x	x	x	x	-	x	x	-	-	-	-	
Station Pass Management OBCPs	-	-	x	x	x	x	-	x	x	-	-	-	-	
TM Mode OBCPs	-	-	x	x	x	x	-	x	x	-	-	-	-	
Tank/SSP Heater switch-on/off	-	-	(x)	-	-	-	-	x	-	-	-	-	-	above 4.2/4.0 AU during S/X Band downlink
Payload OBCPs	-	-	as needed	as needed	-	as needed	-	-	as needed	-	-	-	-	
Safe Mode	-	-	-	-	-	-	x (at exit)	-	-	x	x	-	-	
Survival Mode	-	-	-	-	-	-	-	-	-	-	-	x	-	
Recovery from Survival Mode	-	-	-	-	-	-	-	-	-	-	-	-	x	
Safe Mode: Permanent SKM	-	-	-	-	-	-	x	-	-	-	-	-	-	after multiple failures
PL Safing OBCP	-	-	-	-	-	-	-	-	-	x	x	-	-	
Common Mode Heater Re-cycling	-	x	-	-	-	-	-	-	-	x	x	x	x	
Tank Heaters Re-cycling	-	-	-	-	-	-	-	-	-	x	x	x	x	in Safe Mode above 4.46/4.04AU before/after DSHM cycled with D/L
STR SW Heaters Re-cycling	-	x	-	-	-	-	-	-	-	x	x	-	-	

Item	Launch	after Separation	Active Cruise Mode	NSHM	Delta-v near sun	Asteroid Near Fly-by	DSHM - Max Sun Distance	Delta-v deep space	Near Comet Phase	Safe Mode (standard)	Safe Mode (>4.21AU after DSHM)	Survival Mode (S-Band dl)	Rec from Survival M. (X-Band)	Remarks
STR HW Heaters Re-cycling	-	-	-	-	-	-	-	-	-	-	-	x	x	
PL PDU LCLs 8,13,18 Re-cycling	-	-	-	-	-	-	-	-	-	x	x	x	x	turned off from ground when RWs are running
RW Heaters Re-cycling	-	-	-	-	-	-	x	-	-	-	-	-	-	only during DSHM Exit, started from ground

Table 3-1a: Nominal System Configurations

Conf.No	Phase	HGA Pointing	MGA Pointing	RX1 S	TX1 S	RX2 S	TX2 S	RX1 X	TX1 X	RX2 X	TX2 X	SW1	SW2	SW3	SW4	SW5	SW6	SW7
1	LEOP + Earth fly-bys	-	Sun	**LGA-F**	**LGA-F (4)**	**LGA-R**	**LGA-R (4)**	MGA	MGA	HGA	HGA	2	2	2	1	2	2	1
1a	LEOP, HGA deployed	Earth	Sun	**HGA**	**HGA**	**LGA-R**	**LGA-R**	MGA	MGA	HGA	HGA	2	1	2	1	2	2	1
2	Commission-ing	Earth	Earth	**LGA-F**	LGA-F	HGA	HGA	MGA	MGA	**HGA**	**HGA**	1	2	1	1	2	2	1
2	Active Cruise < 4 AU	Earth	Earth	**LGA-F**	LGA-F	HGA	HGA	MGA	MGA	**HGA**	**HGA**	1	2	1	1	2	2	1
3	Active Cruise > 4 AU	Earth	Earth	**LGA-F**	LGA-F	HGA	**HGA**	MGA	MGA	**HGA**	HGA	1	2	1	1	2	2	1
2	Delta-V Man. < 4 AU	Earth	-	**LGA-F**	LGA-F	HGA	HGA	MGA	MGA	**HGA**	**HGA**	1	2	1	1	2	2	1
3	Delta-V Man. > 4 AU	Earth	-	**LGA-F**	LGA-F	HGA	**HGA**	MGA	MGA	**HGA**	HGA	1	2	1	1	2	2	1
2	Target Pointing	Earth	-	**LGA-F**	LGA-F	HGA	HGA	MGA	MGA	**HGA**	**HGA**	1	2	1	1	2	2	1
4	Near Sun Hibernation	Note 1)	Earth or Sun	**LGA-F**	LGA-F	LGA-R	LGA-R	HGA	HGA	**MGA**	MGA/ **MGA**	2	2	-	1	2	1	2

5	Deep Space Hibernation	Note 2)	Note 2)	**LGA-F**	LGA-F	**MGA**	**MGA**/ MGA	MGA	MGA	HGA	HGA	1	2	2	1	2	2	1
6	Safe Mode	Earth	Earth or Sun	**LGA-F**	LGA-F	**HGA**	**HGA**	MGA	MGA	HGA	HGA	1	2	1	1	2	2	1
7	Surv. Mode MGA strobing	Note 3)	Note 3)	**LGA-F**	LGA-F	**MGA**	**MGA**	MGA	MGA	HGA	HGA	1	2	2	1	2	2	1
7a	Surv. Mode LGA strobing	Note 5)	Note 5)	**LGA-F**	LGA-F	**LGA-R**	**LGA-R**	MGA	MGA	HGA	HGA	2	2	2	1	2	2	1

bold : These antennas are used for communication

Table 3-1b: Nominal TT&C configurations during Mission

Notes:

1) HGA position optimised for minimum solar disturbance torques
2) HGA is at position EL = about -44°, AZ ~ 0° (final DSHM Entry position), MGA points along S/C X-axis; S/C rotates around spin axis, which is about 12° away from +X-axis (towards +Z); spin axis is in orbit plane, initially 20° from Sun, at aphelion 5°, finally at 30° from Sun on the other side.
3) In SKM the solar array perpendicular is pointed to Sun; the *MGA* is pointing at a defined offset from the actual solar array perpendicular, which corresponds to the current Sun/spacecraft/Earth angle (Earth strobing position with residual rate of S/C around Sun vector); the MGA is pointing along X-axis, i.e. in SKM it is offset from Sun by the same angle as the solar array is offset from zero-position (= X-axis); the HGA is in skewed canonical position.
4) TX1-S or TX2-S is operating, selected by on-board S/W depending on which LGA is visible from ground (decided by checking the RX AGC signals, i.e. if S-Band RX1 is on-line, S-Band TX1 will be switched on, TX2 off)
5) LGA strobing is selected only for LEOP and the Earth fly-bys, where the MGA cannot point to Earth because of SSCE > 70°. The attitude is the same as for MGA strobing. The downlink is on LGArear because this is the better position wrt Earth during these phases.

3.2. AOCMS Mode Matrix

Unit / *Mode*	AOCMS PM	AIU	IMP (*)	SAS on central body	*SAS on solar array*	STR	CAM	RWA (**)	RCS	SADM ([1])	APM ([1])
Stand-by Mode	1	1	1						1		
Acquisition & Back-up Modes											
SAM											
Rate reduction	1	1	2						1	(a)	(b)/(c)
Sun Capture	1	1	2	2					1	(a)	(b)/(c)
Sun Acquisition	1	1	2	2					1	(b)/(c)	(b)/(c)
Sun Pointing	1	1	2	1	(2)				1	(b)/(c)	(b)/(c)
Biased Pointing	1	1	2						1	(a)	(a)
Star Acquisition	1	1	2	1	(2)	(1)			1	(b)/(c)	(b)/(c)
Safe/Hold Mode											
Earth Acquisition Ini & Earth Acq & Hold Phase	1	1	2		(2)	1			1	(d) (d)/(a)	(a) or (c) (d)/(a)
Earth Pointing Ini	1	1	2		(2)	1		3s	1	(d)/(a)	(d)/(a)
Earth/Sun Pointing	1	1	2		(2)	1		3t		(d)/(a)	(d)/(a)
Wheel Off-loading	1	1	2		(2)	1		3t	1	(d)/(a)	(d)/(a)
Sun Keeping Mode											
Rate reduction	1	1	2						1	(c)/(a)	(a)
Sun Acquisition	1	1	2		1/2				1	(c)/(a)	(a)
Star Acquisition	1	1	2		1/2	(1)			1	(c)/(a)	(a)
MGA strobing	1	1	2		1/2				1	(d)	(b)/(a)

[1] "deep space" case from ro-dss-rs-1036 (SADE SW URD) used

Unit *Mode*	AOCMS PM	AIU	IMP (*)	SAS on central body	*SAS on solar array*	STR	CAM	RWA (**)	RCS	SADM ([1])	APM ([1])
Operational Mission Modes											
Normal Mode											
Gyroless Eph. Pointing	1	1			(2)	1		3t		(d) or (c) or (a)	(d) or (c) or (a)
Gyrostellar Eph. Pointing	1	1	2/1/off		(2)	1		3t		(d) or (c) or (a)	(d) or (c) or (a)
Fine Pointing Stability	1	1	2/1/off		(2)	1		3t		(c) or (a)	(c) or (a)
Fine Pointing accuaracy	1	1	2/1/off		(2)	1		3t		(d)	(d)
Ground commanded Slew	1	1	2/1/off		(2)	1		3t		(d)	(d)
Wheel damping	1	1	2/1/off		(2)	1		3t		(c) or (a)	(c) or (a)
Wheel Off-loading	1	1	2/1		(2)	1		3t	1	(d) or (c) or (a)	(d) or (c) or (a)
Thr. Trans. Mode	1	1	2/1		(2)	1		off/3s	1	(a)	(a)
Orbit Control M.	1	1	2		(2)	1		off/3s	1	(a)	(a)
Asteroid Fly-by M.	1	1	2			1+(1)	1+(1)	4t		(d)[2]	(d)/(c)[2]
Deep-Space Hibernation											
Near Sun Hibern.	1	1			(2)	1			1	(a)/(d)	(a)
Spin-up Mode	1	1	2		(2)				1	(a)	(c)/(d)/(a)
D-S Hibernation	1										

Table 3-2: AOCMS Mode and Application Matrix

Legend:

n =	n units used	PM =	Processor Module
1/off =	occasionally 1 unit	AIU =	AOCMS I/F Unit
(n) =	out of control closed loop	IMP =	Inertial Measurement Unit
	(either for monitoring purpose or for	SAS =	Sun Acquisition Sensor

[2] "near sun" case

	initialisation of STR).	STR =	Star Tracker
ns =	n wheels in speed ctrl mode	CAM =	Navigation Camera
nt =	n wheels in torque ctrl mode	RW =	Reaction Wheel
		SADM =	S/A Drive Mechanism
(a) =	SADM/APM Off	APM =	HGA Pointing Mechanism
(b) =	canonical position (SADM) resp. skewed canonical position (APM)		
(c) =	SADM/APM in hold position		
(d) =	SADM/APM tracking		

(*) in any Mode where gyros are used, it is possible for the Ground to pre-select either a single IMP configuration or a 2 IMPs configuration (indicated in the column is the recommended number)

(**) in any Mode where wheels are used, it is possible for the Ground to pre-select either a 3 wheels configuration or a 4 wheels configuration (indicated in the column is the recommended number)

3.3. Experiment Modes

3.3.1. Alice Operational Modes

The Alice instrument will be dormant for much of the flight time out to rendezvous. After commissioning, except for an occasional self test, decontamination exercise, or calibration exercise and with the desire to operate during en-route flybys, the instrument will not be powered on.

During the rendezvous, drift phase, comet approach and navigation, nucleus mapping, SSP delivery, and run down phases, Alice will be operating in the modes described below.

Alice has several distinct operating states. It can only be in one particular state at a given time. The behavior of Alice is determined by its operating state, summarized below:

- safe state - instrument safed (HV off, door closed)
- safe dump state - dump science data, remaining safed
- checkout state - diagnostics, "manual" operation
- acquire state - acquiring science data
- hold state - holding acquired data , waiting for dump
- dump state - dumping science data

Alice begins in the safe state. It then transitions to the acquire state in response to an MultipleAcquireDump command. When the acquisition is complete it enters the hold state. Data is then dumped during the dump phase of the MultipleAcquireDump command. When the dump is complete, the state is changed to Dump, then returns to the hold state. A detailed explanation of Alice states is given in section 2.8 of the EID-B

.

In addition to the operating states, there are three acquisition modes. The acquisition mode controls how the detector data is stored when acquiring data in the acquire state. The three acquisition modes are summarized below:

- image histogram - creates x-y histogram of detector events
- pixel list - stores list of pixel event x-y addresses
- count rate - stores list of event count over time

The mode used to acquire data is determined by a parameter of the MultipleAcquireDump command. Detailed descriptions of acquisition commands are given in section 2.8 of the EID-B.

The MultipleAcquireDump telecommand controls a typical complete science acquisition sequence. The execution consists of a number (typically 10) identical cycles. Each cycle consists of an acquire phase followed by a dump phase. The acquire phase collects detector events in one of three science acquisition modes (see above). After the start of this phase, Alice enters the acquire state, setting the high voltage and detector discriminator levels and configuring the acquisition memory (assuming there are no safety conditions to prevent operation). Alice then remains in the acquire state, collecting the data until the command specified acquisition time has elapsed. After acquiring, a dump phase is started that may´consist of up to eight separate windowed dumps of the acquired data. An idle period may be included in the command definition before the next cycle starts.
Note that while acquiring data, Alice is not dumping data. Likewise, while dumping data, no data is acquired. This is due to the simple design of Alice which can only perform one high level function at a time. Despite this, Alice does carry on several low level functions all the time, in all states. The most important of these low level functions is the safety monitoring algorithm. Alice continuously monitors several inputs for the following possible safety conditions:

- dust alert
- high pressure (from ROSINA)
- bright object
- high voltage power supply anomaly

If any of these occur, regardless of what else Alice is doing, the safe state is entered, the aperture door is closed and the HVPS turned down or off. Each safety condition can be individually masked by command so that it does not cause a safety event. The safety algorithm can also be overridden by command if needed. Housekeeping data is also acquired on a periodic basis and formatted into housekeeping TM packets.

In addition to the safety algorithm and housekeeping data generation, Alice also decodes any incoming telecommands while in any state. This allows Alice to respond to a stop command or other commands while acquiring or dumping data.

3.3.2. MIRO Operational Modes

The MIRO instrument is configured to have several operational modes to optimise capability for different power availability. An engineering mode provides a low power mode to obtain housekeeping measurements only. Single and dual receiver continuum modes are available to obtain the radiometric brightness within the MIRO field-of-view from the millimeter and submillimeter channels and is useful for the investigation of the properties of surfaces such as those of the asteroids and comet nucleus. A spectroscopic mode allows for the spectrometer and the submillimeter-wave intermediate-frequency (IF) signal processing to be on as well as the corresponding continuum channel. This spectroscopic mode allows a sensitive detection of specific gases generated by the comet nucleus (and possibly the asteroids as well).
In the comet rendezvous stage of the mission, MIRO will initially turned on in continuum mode and begin nucleus sounding measurements. During the cometary and targeted mapping phases, a majority of the viewing will be in the one or two receiver/spectrometer modes to study outgassing processes, bulk composition, and coma formation. These phases will provide the highest spatial resolution for studying the nucleus. If limb sounding is feasible, it would enhance the minimum detectability of species, and allow greater resolution of the coma.

Following the mapping phase, MIRO plans to operate in the two receiver/spectrometer mode. During this phase, both nucleus and coma studies will be performed.

In detail, the MIRO instrument has 17 different operational modes. Each mode is characterized according to the amount of power consumed and maximum data rate produced by the instrument. There are 6 power modes and 6 data modes for MIRO. They combine to give the 17 modes are as follows:

Mode	Mode Description	Power Mode	Data Mode	Maximum Data Rate(Bits/sec)
1	CTS/Dual Cont	1	1	446
2	CTS/Dual Cont	1	2	890
3	CTS/Dual Cont	1	3	1335
4	CTS/Dual Cont	1	4	1780
5	CTS/Dual Cont	1	5	2224
6	CTS/Dual Cont	1	6	2670

Mode	Mode Description	Power Mode	Data Mode	Maximum Data Rate(Bits/sec)
7	CTS/SMM Cont	2	1	446
8	CTS/SMM Cont	2	2	890
9	CTS/SMM Cont	2	3	1335
10	CTS/SMM Cont	2	4	1780
11	CTS/SMM Cont	2	5	2224
12	CTS/SMM Cont	2	6	2670
13	Dual Cont	3	1	446
14	Dual Cont	3	2	890
15	SMM Cont	4	1	446
16	MM Cont	5	1	446
17	Engineering	6	1	446

When the instrument is initially powered on it will enter engineering mode upon receipt of a time update telecommand from the spacecraft. Engineering mode telemetry will be sent to the spacecraft within 1 minute following the time synchronization telecommand.

Engineering Mode

While running in engineering mode the MIRO software is collecting engineering data from 56 internal sensors. The sampling of these sensors is at a 5 Hz rate. All engineering measurements are 12-bit A/D converted values. The engineering mode telemetry is sent to the spacecraft in the form of a housekeeping telemetry packet. One engineering telemetry packet is generated every 11 seconds.

The engineering TM is also generated in the 16 other MIRO operational modes.

Millimeter Continuum Mode

While running in millimeter continuum mode the MIRO software has powered up the millimeter continuum portion of the electronics. Millimeter continuum data is collected at a 20 Hz. rate. All continuum data consist of 16-bit values. The millimeter continuum data is nominally packet into science telemetry packets every 10 seconds. A ‘summing value’ parameter can cause the MIRO software to sum either 1, 2, 5, 10 or 20 separate continuum values prior to putting them into the telemetry packet. This feature can reduce the data rate to as little as one millimeter continuum packet every 200 seconds.

Sub-Millimeter Continuum Mode

Sub-millimeter continuum mode is very similar to millimeter continuum mode except a different set of electronics is powered on. The data collection and packing is identical to millimeter continuum mode. Millimeter and sub-millimeter continuum data are contained in separate science telemetry packets. A field in the source data header identifies which type of science data is contained in the telemetry packet.

Dual Continuum Mode

In dual continuum mode the millimeter and sub-millimeter continuum are being collected simultaneously. When running in dual continuum mode, the summing value parameter mentioned earlier is applied to both sets of data. This causes the same amount of millimeter and sub-millimeter data to be generated.

CTS / Sub-Millimeter Continuum Mode

This mode adds the collection of chirp transform spectrometer (CTS) data. The CTS is programmed by the MIRO software to run for an initial sub-integration period of approximately 5 seconds. An internal LO frequency generator is then switched and another 5 second period is observed. These pairs of observations are repeated with the respective results being summed over time. Selectable integration periods are 30, 60, 90 and 120 seconds. The data from the 2 LO frequencies are then subtracted from each other.

The CTS returns a total of 4096 channels of data. The 4096 data values can be further reduced by application of a smoothing function whereby data from several channels are combined and weighted to produce fewer final channels. Smoothing window sizes are 1, 5, 7 and 9 channels. A mask is applied to the CTS data and only 12 bits of each resulting measurement is returned.

CTS data collection and the LO frequency switching is coordinated with the collection of continuum data. Exactly 100 continuum samples are taken during each CTS scan. Upon receipt of the data on the ground it is known at which LO frequency all of the continuum measurements were made at.

If the CTS has just been powered on an internal calibration of the CTS is performed. This consists of loading the 4 CTS sum of square tables with a linear ramping pattern. A 10,000 cycle integration is then performed and the resulting data read out. The data is then averaged to yield the mid-point of the table. The resulting mid-point values for each table are downlinked in telemetry packets for monitoring over time.

CTS / Dual Continuum Mode

This is similar to CTS / SMM continuum mode except that the millimeter data is also collected.

Mode Transitions

It is possible to change the software operating mode from/to any valid mode. A mode change command is issued to the MIRO software. The mode change command contains 4 controlling parameters:

1. Power mode (the 6 defined above)
2. CTS integration period (30, 60, 90 or 120 seconds)
3. CTS smoothing value
4. Continuum summing value (1, 2, 5, 10 or 20)

The process of changing from one operational mode to another is begun via a graceful shutdown of the current mode. If the CTS is running as part of the current mode, then the current CTS integration period is allowed to complete. The telemetry data associated with the current scan, as well as the accumulating continuum data, are then flushed out. The software is then shut down.

If the CTS is not operating then the graceful shutdown is much simpler. If continuum data is being collected then the current 5 second (≤ 100 samples, dependent on summing value) collection cycle is allowed to complete prior to shutting down the software. If engineering mode is the current mode then no graceful shutdown is required as engineering collection continues through all mode transitions.

After the graceful software shutdown is complete, any required power state changes are made. This could result in numerous components either being powered on or off depending on the current mode and the commanded mode.

The start of each mode, except for engineering only mode, begins with an instrument calibration. The instrument calibration views the hot target for 30 seconds, the cold target for 30 seconds, and finally the space target for 30 seconds. CTS data collected during calibration is not subtracted based on LO frequency. Both LO data sets are returned. The continuum summing value in place when the mode is changed is controls the rate of continuum collection during the instrument calibration.

When the instrument calibration is complete the nominal processing mode is begun. The MIRO instrument will remain in nominal processing until it receives a mode change command or approximately 30 minutes have elapsed. After 30 minutes another instrument calibration is performed. Instrument calibration is performed with every mode change and every 30 minutes except when running in engineering only mode.

Data Rates Within Modes

Depending on all the parameters specified in the mode change command the MIRO software can generate a variety of telemetry data rates in the different power modes. Nearly all MIRO telemetry packets have been designed to be 430 bytes in size. Collected telemetry data is then trickled out over time depending on the allowable data rate. The rate is specified as a fixed number (maximum) of 430 byte telemetry packets to be sent by the MIRO software to the spacecraft every 8 seconds. The net result is that MIRO has a total of 17 operation modes when you define mode to be a combination of power and data rate.

3.3.3. VIRTIS

Virtis contains two scientifically complementary but operationally independent instruments: VIRTIS-H and VIRTIS-M. Both instruments work most of the time in parallel. In addition, the Virtis Main Electronic Module (VIRTIS-ME) can have its own modes.

Virtis modes are identified by the "VIRTIS Mode Id" contained in the HK telemetry packets. This parameter has three fields for each subsystem of the instrument (ME, VIRTIS-M and -H). A VIRTIS Mode is a unique combination of these 3 fields. However, several VIRTIS Modes have common properties and hence are classified as belonging to the same Mode Group.
This is a naming convention to address without ambiguity general statements which are valid in different modes (e.g., “all Science modes” means “all modes of the Science Mode Group”). The Modes Groups are listed below:

- Off
- Safe
- Idle
- Cool-down
- Annealing
- Calibration

- Science
- Test
- Development (used only by S/W developers and not described further)

A visualisation of the transitions between modes is given in figure 3-1a representing the general VIRTIS state diagram.

In principle all VIRTIS-M operative modes can be used in combination with almost all VIRTIS-H operative modes as the two channels are fully independent. However, in practice, of the overall allowed combinations we can identify a reduced number according to a series of constraints (here V-X and V-Y represent VIRTIS-H and VIRTIS-M indifferently) imposed by logical considerations and/or by H/W constraints. These constraints are applicable to steady state conditions and not during transitions.

- If ME mode is Off, Safe, Development or Test, then both PEMs are Off.
- If V-X mode is Cool_Down, V-Y mode can be Off or Cool_Down.
- If V-X mode is Annealing, V-Y mode can only be Off.
- If V-X mode is Idle, V-Y mode can only be Off or Idle.
- If V-X mode is one of Science modes, V-Y mode can only be Off, User Defined, Test or one of the Science modes.

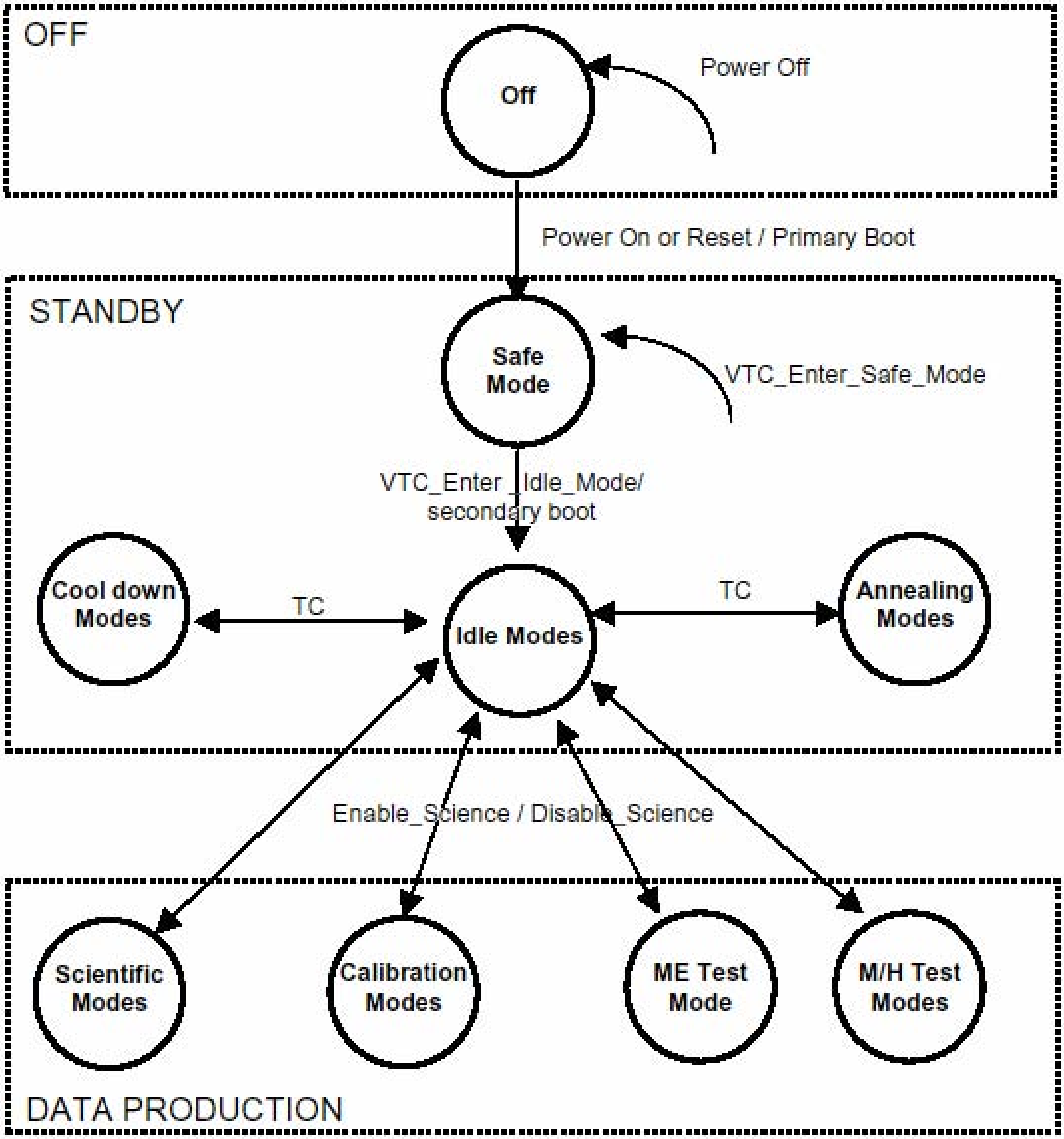


Figure 3-1a: VIRTIS Mode Transitions

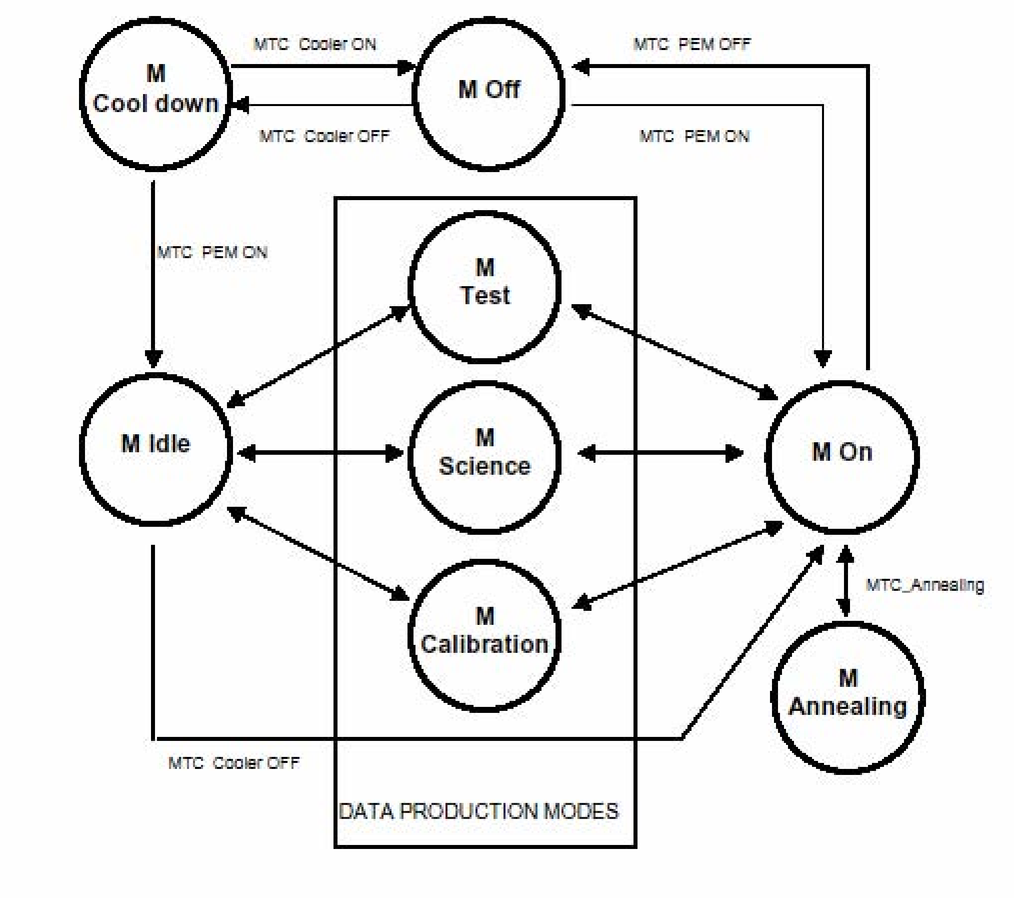


Figure 3-1b: Mode Transitions for VIRTIS-M

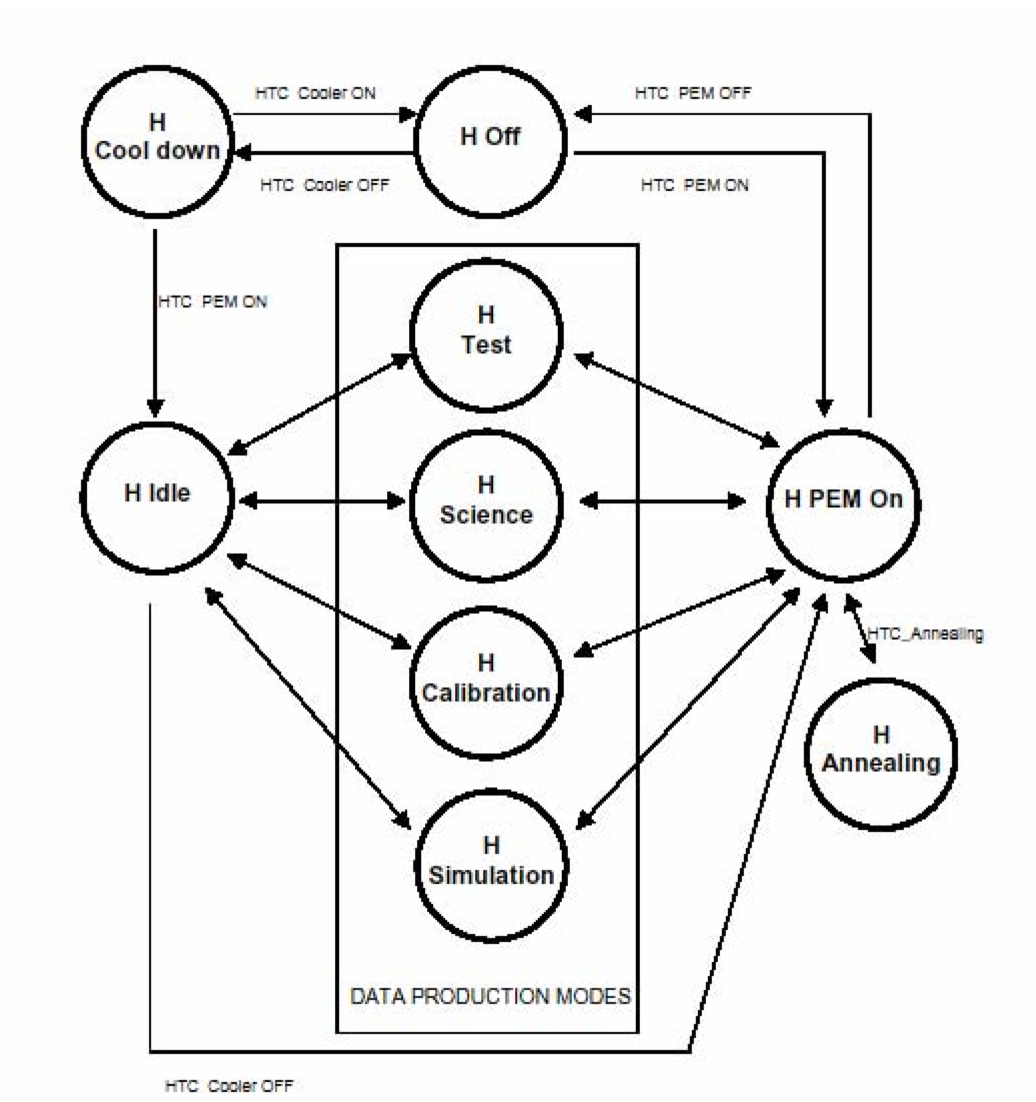


Figure 3-1c: Mode Transitions for VIRTIS-H

3.3.4. OSIRIS Operational Modes[1]

The operational modes of OSIRIS and the possible routes through the operational mode tree are shown in Figure 3-1d. Mode transitions, dependencies and allowed actions are given in Table 3-2a.

[1] Reference: OSIRIS User Manual, RO-RIS-MPAE-SP-025, iss. 1

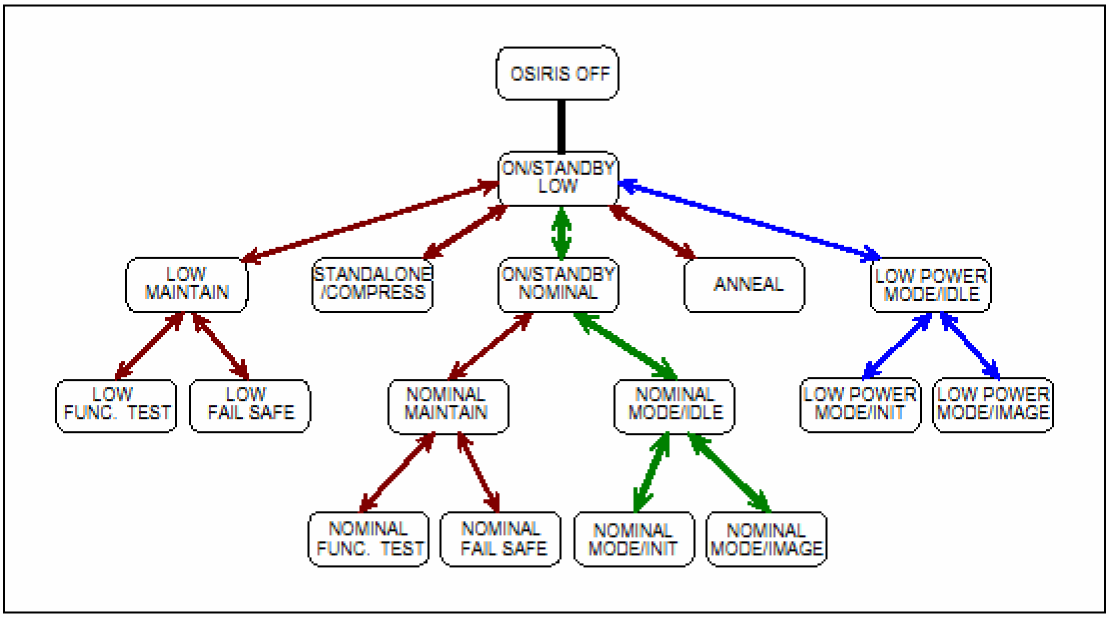


Figure 3-1d: OSIRIS Operational Modes

Initial status	No. of branches	Final states	Transition needed	Allowed actions in final state
OSIRIS OFF	1	ON/STANDBY LOW	MMB off DPU on DIB-A clocked DIB-B off NAC CRB off WAC CRB off MCB on PCM on op heaters on	Move to ON/STANDBY HIGH, LOW POWER MODE/IDLE, ANNEAL, STANDALONE/COMPRESS, LOW MAINTAIN, OSIRIS OFF
ON/STANDBY LOW	6	ON/STANDBY NOMINAL	Power mode 10 DIB-B on	Move to NOMINAL MAINTAIN, NOMINAL MODE/IDLE, ON/STANDBY LOW
		LOW POWER MODE/IDLE	Power mode 2 no transition req.	Move to LOW POWER/INIT, LOW POWER MODE/IMAGE, ON/STANDBY LOW
		ANNEAL	Power mode 20-21 no transition req.	Move to ON/STANDBY LOW Heat NAC CCD Heat WAC CCD
		LOW MAINTAIN	Power mode 5 no transition req.	Move to LOW FUNC. TEST, LOW FAIL-SAFE, ON/STANDBY LOW
		STANDALONE/COMPRESS	Power mode 25 MMB on	Move to ON/STANDBY LOW
		OSIRIS OFF	MMB off DPU off DIB-A off DIB-B off NAC CRB off WAC CRB off MCB off PCM off op heaters off	Go to bed. Non-op heater line is ON.
ANNEAL	1	ON/STANDBY LOW	CCD heaters off Power mode 1	Move to LOW POWER MODE/IDLE, ANNEAL, LOW MAINTAIN, ON/STANDBY NOMINAL, STANDALONE/COMPRESS, OSIRIS OFF
LOW POWER MODE/IDLE	3	LOW POWER MODE/INIT	Power mode 3	Move to LOW POWER MODE/IDLE Initialize NAC FWM Initialize WAC FWM Open NAC front door Open WAC front door

Initial status	No. of branches	Final states	Transition needed	Allowed actions in final state
				Close NAC front door Close WAC front door Move NAC FW1 Move NAC FW2 Move WAC FW1 Move WAC FW2
		LOW POWER MODE/IMAGE	Power mode 4 NAC or WAC CRB/SHE on Set read-out amplifier chain A or B	Move to LOW POWER MODE/IDLE Make exposure with or without calibration lamps in slow mode.
		ON/STANDBY LOW	Power mode 1	Move to LOW POWER MODE/IDLE, ANNEAL, LOW MAINTAIN, ON/STANDBY NOMINAL, STANDALONE/COMPRESS, OSIRIS OFF
LOW MODE/INIT	1	LOW MODE/IDLE	Power mode 2 No transition req.	Move to LOW MODE/INIT, LOW MODE/IMAGE, ON/STANDBY LOW
LOW MODE/IMAGE	1	LOW MODE/IDLE	Power mode 2 NAC CRB/SHE off WAC CRB/SHE off	Move to LOW MODE/INIT, LOW MODE/IMAGE, ON/STANDBY LOW
ON/STANDBY NOMINAL	3	NOMINAL MAINTAIN	Power mode 12 MMB on	Move to ON/STANDBY NOMINAL, NOMINAL FUNC. TEST, NOMINAL FAIL-SAFE Software upload
		NOMINAL MODE/IDLE	Power mode 30 MMB on	Move to NOMINAL MODE/INIT, NOMINAL MODE/IMAGE, ON/STANDBY NOMINAL
		ON/STANDBY LOW	Power mode 1 DIB-B off	Move to LOW POWER MODE/IDLE, ANNEAL, LOW MAINTAIN, ON/STANDBY NOMINAL, STANDALONE/COMPRESS, OSIRIS OFF
STANDALONE /COMPRESS	1	ON/STANDBY LOW	MMB off Power mode 1	Move to LOW POWER MODE/IDLE, ANNEAL, LOW MAINTAIN, ON/STANDBY NOMINAL, STANDALONE/COMPRESS, OSIRIS OFF
NOMINAL MAINTAIN	3	ON/STANDBY NOMINAL	MMB off Power mode 10	Move to NOMINAL MAINTAIN NOMINAL MODE/IDLE, ON/STANDBY LOW
		NOMINAL FUNC. TEST	Power mode 15-17 NAC CRB/SHE on or WAC CRB/SHE on or both	Move to NOMINAL MAINTAIN Full functional test programmes
		NOMINAL FAIL-SAFE	Power mode 14 NAC CRB/SHE on or WAC CRB/SHE on	Move to NOMINAL MAINTAIN Activate NAC shutter fail-safe Activate WAC shutter fail-safe Activate NAC FDM fail-safe Activate WAC FDM fail-safe
NOMINAL FUNC. TEST	1	NOMINAL MAINTAIN	Power mode 12 NAC CRB/SHE off WAC CRB/SHE off	Move to ON/STANDBY NOMINAL, NOMINAL FUNC TEST, NOMINAL FAIL-SAFE Software upload
NOMINAL FAIL-SAFE	1	NOMINAL MAINTAIN	Power mode 12 NAC CRB/SHE on or WAC CRB/SHE on	Move to ON/STANDBY NOMINAL, NOMINAL FUNC TEST, NOMINAL FAIL-SAFE Software upload
NOMINAL MODE/IDLE	3	NOMINAL MODE/INIT	Power mode 31 No transition req.	Move to NOMINAL MODE/IDLE Initialize NAC FWM Initialize WAC FWM Open NAC front door Open WAC front door Close NAC front door Close WAC front door Move NAC FW1 Move NAC FW2 Move WAC FW1 Move WAC FW2
		NOMINAL MODE/IMAGE	Power mode 32-36 NAC or WAC or both CRB/SHE on	Move to NOMINAL MODE/IDLE Make exposure with or without calibration lamps in any mode through any read-out chain(s). Full mechanism availability.
		ON/STANDBY NOMINAL	Power mode 10 MMB off	Move to NOMINAL MAINTAIN, NOMINAL MODE/IDLE

Initial status	No. of branches	Final states	Transition needed	Allowed actions in final state
NOMINAL MODE/INIT	1	NOMINAL MODE/IDLE	Power mode 30 No transition req.	Move to NOMINAL MODE/INIT, NOMINAL MODE/IMAGE, ON/STANDBY NOMINAL
NOMINAL MODE/IMAGE	1	NOMINAL MODE/IDLE	Power mode 30 NAC CRB/SHE off WAC CRB/SHE off	Move to NOMINAL MODE/INIT, NOMINAL MODE/IMAGE, ON/STANDBY NOMINAL
LOW MAINTAIN	3	ON/STANDBY LOW	MMB off Power mode 1	Move to LOW MAINTAIN LOW MODE/IDLE, ON/STANDBY LOW
		LOW FUNC. TEST	Power mode 6-7 NAC CRB/SHE on or WAC CRB/SHE on or both	Move to LOW MAINTAIN Full functional test programmes
		LOW FAIL-SAFE	Power mode 9 NAC CRB/SHE on or WAC CRB/SHE on	Move to LOW MAINTAIN Activate NAC shutter fail-safe Activate WAC shutter fail-safe Activate NAC FDM fail-safe Activate WAC FDM fail-safe
LOW FUNC. TEST	1	LOW MAINTAIN	Power mode 5 NAC CRB/SHE off WAC CRB/SHE off	Move to ON/STANDBY LOW, LOW FUNC TEST, LOW FAIL-SAFE Software upload
LOW FAIL-SAFE	1	LOW MAINTAIN	Power mode 5 NAC CRB/SHE on or WAC CRB/SHE on	Move to ON/STANDBY LOW, LOW FUNC TEST, LOW FAIL-SAFE Software upload

Table 3-2a: OSIRIS Mode Transitions

3.3.5. Consert Operational Modes

3.3.5.1. Modes

Init mode: after switch-on and up to reception of SC Time update

Wait Mission Table Mode: after *Init Mode* and until reception of a valid mission table

Wait tuning Mode: after *Wait Mission Table Mode* and until time for start of tuning is reached.

Tuning phase Mode : after *Wait tuning Mode* and until completion of tuning activities (reception of signal from Lander)

Wait Sounding Mode : After *Tuning Phase Mode* and until time for start of sounding is reached.

Sounding Mode : After *Wait Sounding Mode* and until completion f the predefined number of soundings.

End Sounding Mode : After *Sounding Mode* and until Switch-off.

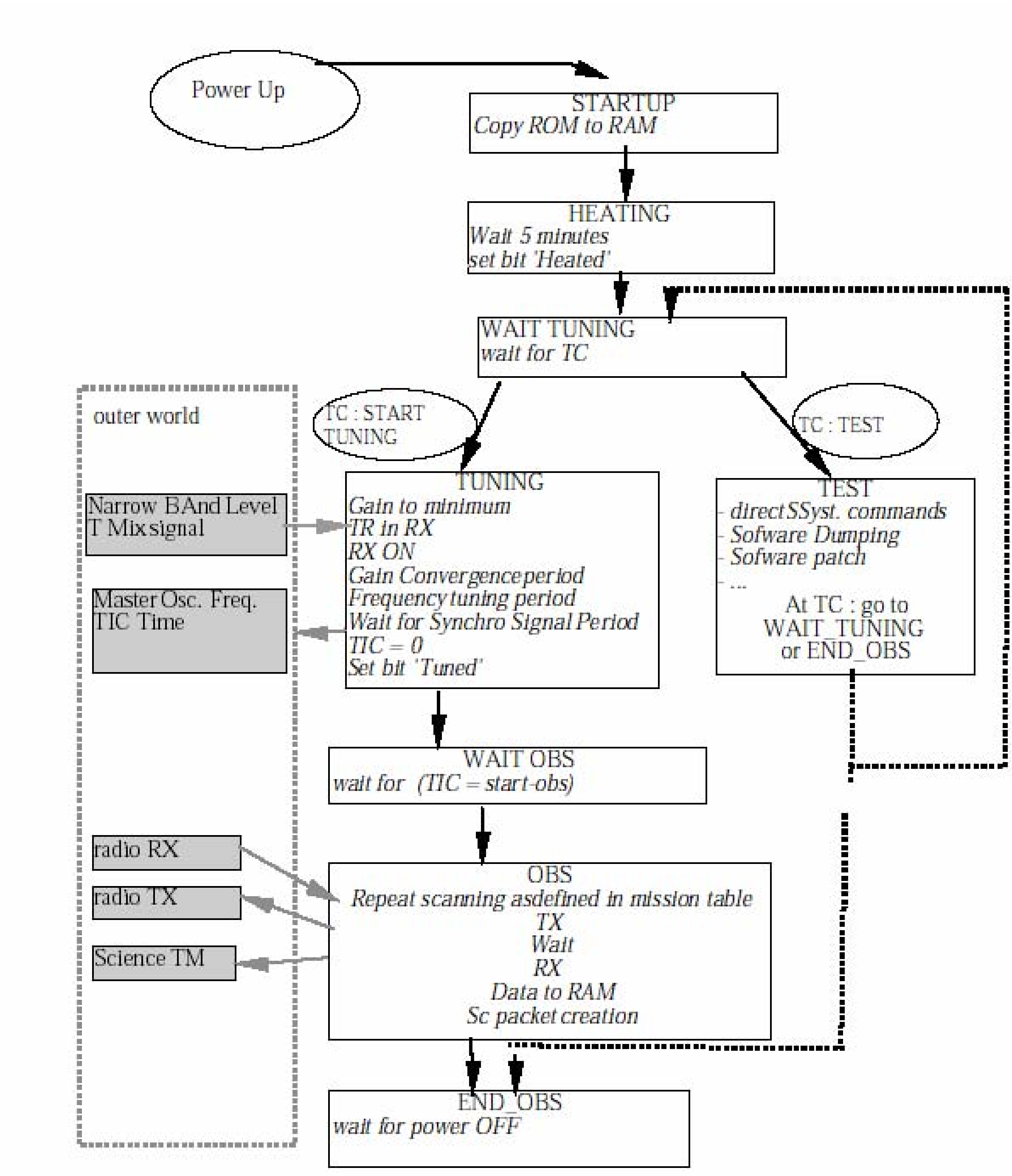


Figure 3-2: Consert Modes of Operation

3.3.5.2. Measurement Strategy

Modes of operations within one sounding measurement cycle :

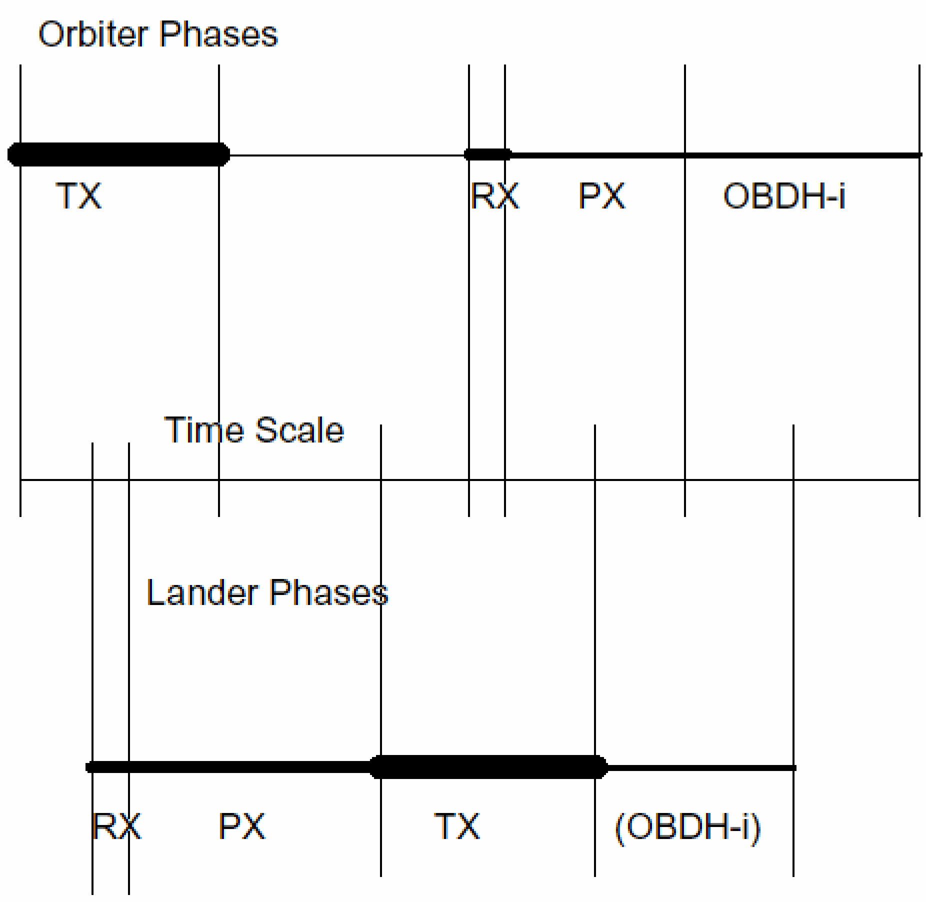


Figure 3-3: Consert Measurment Cycle

TX	Transmit Phase	209 ms
PX	Processing Phase	104ms (Lander only)
RX	Receiving Phase	26ms
OBDH-i	On Board Data Handling Interface Phase to OBDH (duration according to data rate)	

3.3.6. COSIMA Operational Modes[1]

Start (safe)

[1] Reference: COSIMA User Manual, iss. 2.2

When the instrument is switched on or rebooted, it goes to the Start mode. In this mode only the CPU board and low-voltage power supply of the instrument are operational. Only the software residing in PROM is loaded. This allows command execution, housekeeping telemetry generation, and RAM patch/dump. In this mode the software is loaded from the EEPROM or from the DMS. From the starting mode the instrument switches to the Check-up mode, which is also safe. The switch is performed in about a minute after instrument power on.

Check-up (safe)

In Check-up mode only the CPU board and low-voltage power supply of the instrument are operational. The whole software has been loaded in RAM. Cosima does a health check and reports its status. If it does not receive any commands for TBD time, it will fall into Idle mode.

Idle (safe)

During the Stand-by mode only the CPU board and low-voltage power supply of the instrument are operational. Cosima does periodically some HK measurements, else the processor is in the idle loop consuming lowest possible power. The instrument switches to other modes from here by telecommand or according to the task queue. If something goes wrong during any other modes, all instrument parts except the CPU board and the low-voltage power supply are switched off, and the instrument returns to the Idle (or Check-up) mode. The instrument may be in Idle mode while collecting dust.

Move target

During the Move target mode the CPU board, the low-voltage power supply, and the target manipulator are operational. During this mode the targets can be moved to different positions (expose, Cosiscope, clean, analyze, storage, chemistry station). From this mode Cosima may switch to any other mode, except Start, or it can fall into Idle mode.

Search target with COSISCOPE

During the Search target with COSISCOPE mode the CPU board, the low-voltage power supply, and COSISCOPE are operational. Cosiscope takes a picture of the target in front of it, calculates the positions of the grains, and returns the results in telemetry. From this mode Cosima may switch to any other mode, except Start, or it can fall into Idle mode.

Clean feature

During the Clean feature mode, the CPU board, the low-voltage power supply, and the ion gun are operational. Also the target manipulator can be operational if needed. The cleaning mode is used for cleaning the feature before measurement in order to sputter away any contaminants. From this mode Cosima may switch to any other mode, except Start, or it can fall into Idle mode.

Analyze feature

During the Analyze mode all instrument parts except Cosiscope are operational. The Analyze mode is used for feature characterization and analysis (produces spectra). From this mode Cosima may switch to any other mode, except Start, or it can fall into Idle mode.

Tip-clean

During the Tip-clean mode the CPU board, the low-voltage power supply, and the ion gun are operational. The mode is used for cleaning the ion source tip in order to refresh the ion emitter. From this mode Cosima may switch to any other mode, except Start, or it can fall into Idle mode.

Chemistry station

During the Chemistry station mode the CPU board, the low-voltage power supply, and the target manipulator are operational. The target in the chemistry station is heated, the TMU motors do not move. From this mode Cosima may switch to any other mode, except Start, or it can fall into Idle mode.

Summary of operating modes and needed resources

Experiment mode	Power usage	Average data rate	Functional use
Start	8.4 W	100 bits/s	Booting the instrument
Check-up	14.6 W	100 bits/s	Self-check of the instrument
Idle	11.4 W	30 bits/s	Waiting, dust collection
Move target	24.2 W(short peak)	70 bits/s	Moving targets to different positions.
Search target - COSISCOPE	22.0 W (short peak)	512 bits/s	Searching target for features using COSISCOPE
Clean feature	20.3 W	30 bits/s	Cleaning a target with the ion beam
Analyze feature	18.5 W	512 bits/s	Measuring feature spectra
Tip-Clean	20.3 W	30 bits/s	Cleaning the ion source tip to refresh the ion emitter
Chemistry station	17.1 W	30 bits/s	Heating a target for chemical purposes

All data except science data will be available in telemetry blocks with the first possible poll. The science data will be included in blocks every 16 seconds, if capacity admits (see chapter 2.3.1.4 of COSIMA UM). Data will always be generated at a steady rate, there will be no bursts. For example in Analyze feature mode the size of the data block produced every 16 seconds will be ≈ 2 Kbytes (512 bits/s * 16s).

Note! The remains of the data of the previous mode may be sent to the DMS while COSIMA has already switched to the next mode. This may result at start in a higher average data rate than typical to that particular state.

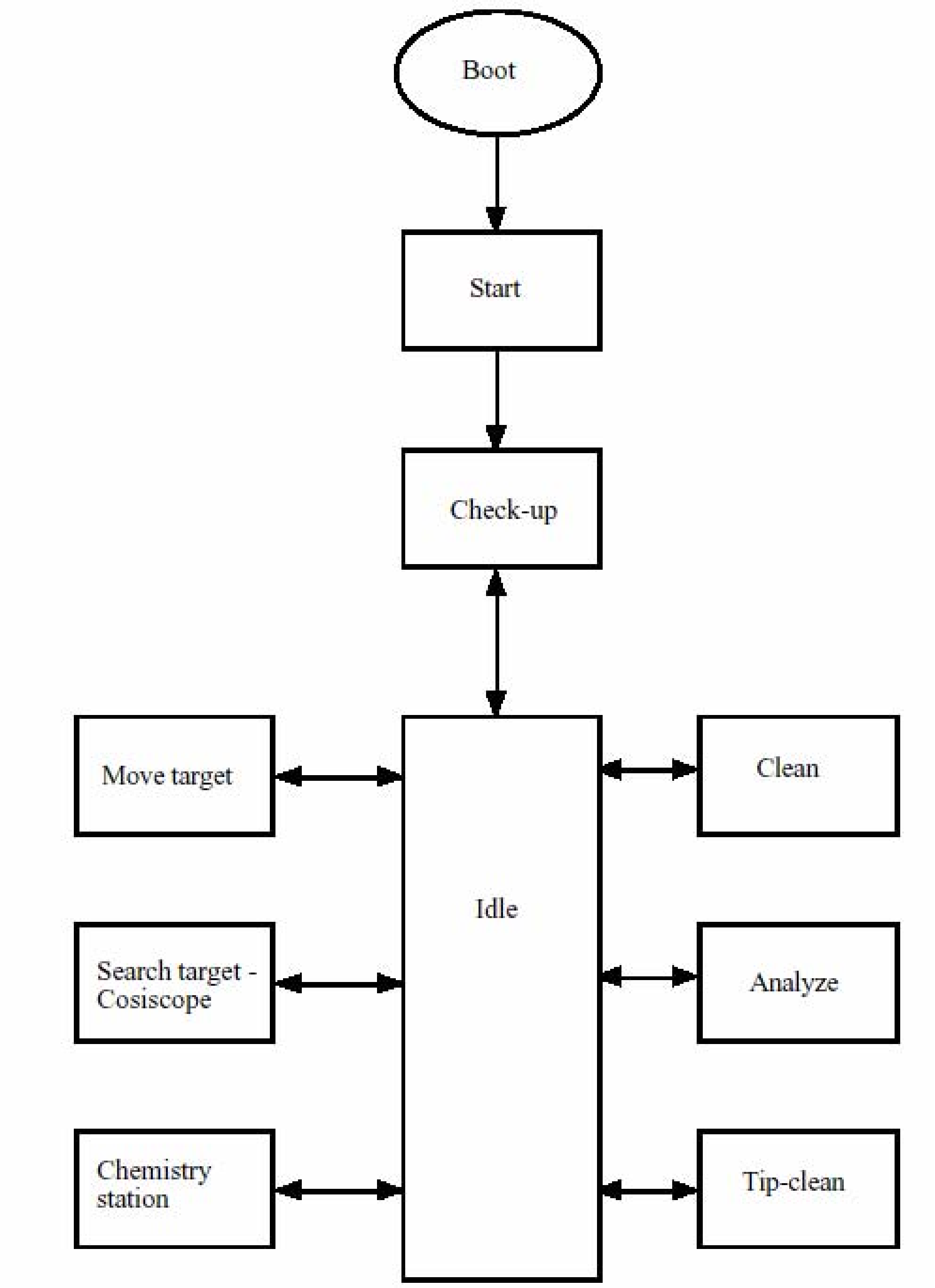


Figure 3-3a: COSIMA Mode Transition Diagram

3.3.7. MIDAS Operational Modes

The science operations concept foresees that a certain facet of the dust collector wheel is exposed to the ambient dust flux. After the exposure the shutter will be closed and the wheel turns by a certain angle to transport the facet underneath the scanning head.

The baseline MIDAS operations will involve data collection simultaneously with the processing, compression and transmission of collected images. It is likely that some images will be reduced to simple statistical parameters for transmission (for example the number and sizes of the dust grains) while others will be studied at full resolution.

There will be several modes, such as standard mode, test mode, calibration mode and a mode to exercise the piezo-electric devices.

The instrument is designed to work in an autonomous mode and will thus not require excessive operational support.

The division of telemetry between the transmission of full images and feature vectors will vary with the mission timeline. Early in the mission mainly full images and no feature vectors will be transmitted. In this phase also the on-board image processing capabilities will be verified.

With increasing dust flux towards the later phases of the mission, and after successful verification of the on-board processing capabilities on real samples, an increasing percentage of image data will be replaced by summary information in the form of feature vectors. The exact fraction of feature vectors will depend on the available telemetry capacity and the actual image acquisition rates which themselves depend on the dust environment encounted in the mission.

Detailed Mode Description

Operating modes are grouped into two levels:

- Level 1 (high level mode commands; examples: scan one area, process one image)
- Level 2 (single mechanism activation or single S/W task; example: facet selection, background subtraction)

The further characterisation of the instrument state is made by parameters describing the modes.

In technical mode (=level 1 mode) the level 2 modes are controlled by commands which activate the instrument on detailed level.

<u>Level 1 Modes</u>

- Kernel
- Standby
- Scan
- Processing and science data transfer

- Prepare passive exposure
- Terminate passive exposure
- Standby with exposure (prepare exposure, then standby + open shutter + listening to broadcast packets, then terminate)
- Self-test (predefined sequences, parameters define which mechanisms are included in the test)
- Technical

Examples for Level 2 Modes

- Baseplate unlock
- Wheel rotation
- Linear movement
- Shutter operation
- Prepare scan
- Line scan
- Full scan
- Image processing
- Software patch
- Full upload

Experiment Mode	Power Usage (W)	Data Rate (kbit/s)	Functional Use
Kernel	8.3	0.005	
Standby	8.3	0.005	
Scan	18.4	0.01	
Processing and Science	8.3	0.2	
Data Transfer			
Prepare Passive	10.2	0.01	
Exposure			
Terminate Passive	10.2	0.01	
Exposure			
Standby With	8.3 (- 12.0)	0.005	
Exposure			
Self-test	18.4	0.2	
CSSC Calibration	18.4	0.2	

Experiment Mode	Power Usage (W)	Data Rate (kbit/s)	Functional Use
Technical	8.3 - 18.4	0.005 - 0.2	Ground use and contingencies only
Baseplate Unlock	18.5	0.01	
Other Level 2 Modes with Mechanisms	12.0 - 18.4	0.01	

Table 3-2b: MIDAS Mode Definition

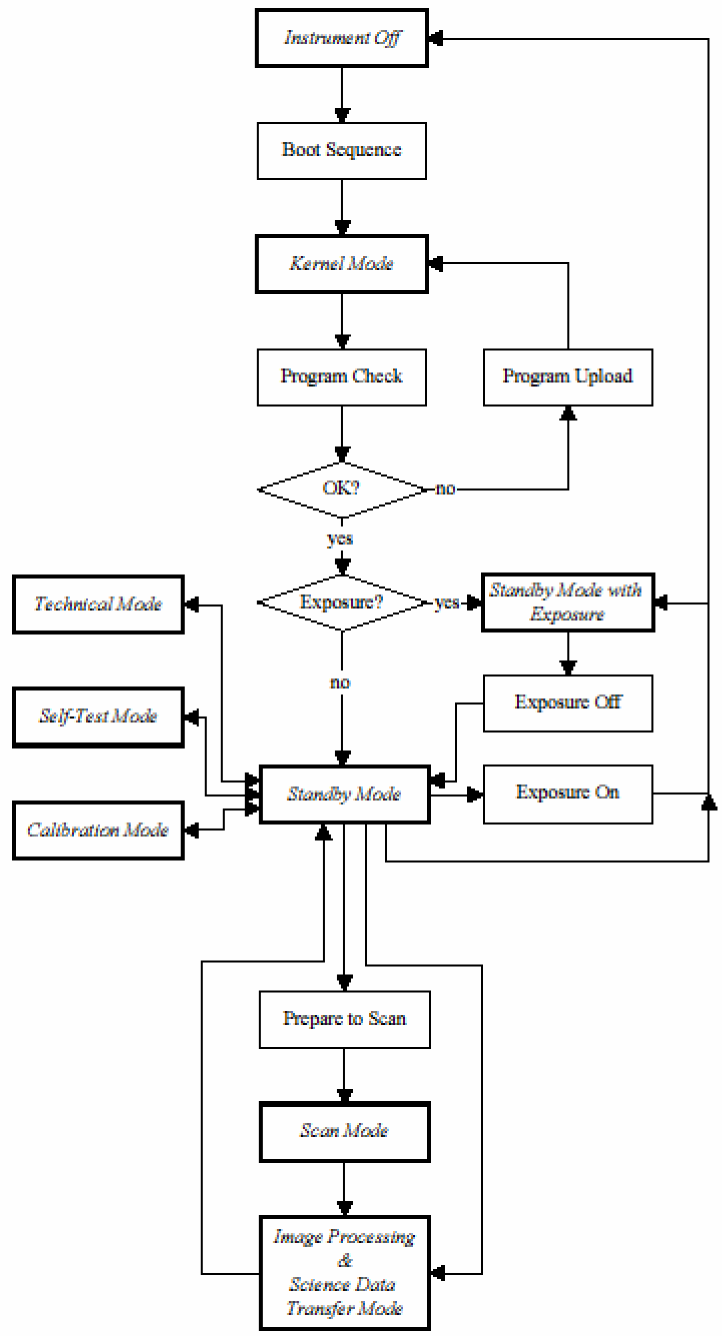


Figure 3-3b: MIDAS Mode Transition Diagram

3.3.8. ROSINA Operational Modes

ROSINA is one of the instruments which should provide scientific data during the whole mission. It is important that the instrument is switched on as soon as possible and left on as long as possible to gain insight into the physics and chemistry of the evolving comet during its journey towards the sun. The main look direction is towards the comet. Because the RTOF is the high sensitivity sensor this is the first one to be turned on while approaching the comet. This sensor is also used for the asteroid flyby's.

Each sensor is independent from each other, except that COPS is required be be on whenever DFMS and/or RTOF are switched on. Simultaneous operation of the full RTOF and DFMS is not foreseen for power reasons. Transition into emergency modes is possible from all instrument modes.

The allowed ROSINA sensor mode configurations are specified in the following table:

No.	Experiment Mode	DPU	DFMS	RTOF	COPS	Power (W)	Data Rate(bits/s)
0	Instrument off	Off	off	off	off	0	0
D1	DPU Booting	on	off	off	off	6	0
D2	DPU Standby	on	off	off	off	4.5	25
D3	DPU Emergency	on	off	off	off	4.5	500
D4	DPU Ground Test	on	off	off	off	6	500
D5	DPU S/W patch	on	off	off	off	6	500
S1	RTOF Standby	on	off	stby	Micro	20.5	25
E1	RTOF Emergency	on	off	on	Micro	20.5	500
G1	RTOF ground test	on	off	stby	off	25	30k
1L	RTOF Low Power	on	off	on	Micro	29	1k
1G	RTOF Gas	on	off	on	Micro	32	1k
1I	RTOF ion	on	off	on	Micro	29	500
1	RTOF Full (Gas and Ion)	on	off	on	Micro	42	1.5k
S2	DFMS Standby	on	stby	off	Micro	25	25
E2	DFMS Emergency	on	on	off	Micro	25	500
G2	DFMS Ground Test	on	stby	off	off	25	18k
2	DFMS Normal	on	on	off	Micro	28	1k
3	DFMS Narrow	on	on	off	Full	31	1k
S4	RTOF + DFMS Standby	on	stby	stby	Micro	36.5	25
E4	RTOF + DFMS Emergency	on	on	on	Micro	36.5	500
G4	RTOF +DFMS Ground test	on	stby	stby	stby	32.5	46k
4	RTOF Single + DFMS	on	on	on	Full	52	2k
S5	COPS Standby	on	off	off	stby	8	25
E5	COPS Emergency	on	off	off	on	8	500
G5	COPS Ground test	on	off	off	stby	8	500

No.	Experiment Mode	DPU	DFMS	RTOF	COPS	Power (W)	Data Rate(bits/s)
5M	COPS Microtips	on	off	off	Micro	9	25
5	COPS Full	on	off	off	Full	11	25

Table 3-3: ROSINA Modes

DPU Modes

Mode	Sub-mode	28V	Experiment	HV	Activated by	Typical time	Used in phase	Desription/ Frequency of activation
DPU Booting	Initial booting	On	Off	Off	S/C	10s	Ground test	Ground test Mode
	DPU Patching	On	Off	Off	S/C	N/A	All phases	Software download
DPU Standby	Normal	On	Off	Off	S/C or DPU	N/A	All phases	All the Instruments are switched Off excepted the DPU
DPU Instrument	Pressure Monitoring	On	COPS On	-	DPU	10s	All phases	Monitoring of pressure and gas parameters
	Instruments Mode	On	COPS On/Off DFMS On/Off RTOF On/Off	Off / On	DPU	N/A	All phases	All the sensor modes
DPU Emergency	Pressure Alert	On	Off	Off	DPU	N/A	All phases	All the sensors are switched Off
	Emergency	On	TBD	TBD	DPU	N/A	All phases	Emergency handling for all the Instruments TBD
DPU Ground Test	DPU Memory Test	On	Off	Off	S/C	N/A	Ground test	Test sequence during ground test
	Instruments Test	On	Off / On	Off / On	DPU	N/A	Ground test	Test sequence during ground test
DPU Transition		On	On/Off	On / Off	DPU	N/A	All phases	Transitions of all the Instruments Mode

DFMS

DFMS has several parameters in order to measure mass spectra of ions or neutrals between two given mass numbers, with a high or low mass resolution, with adjustable electron emission current and energy. It has three different detector systems with different detector modes in order to accommodate the different density regimes of the mission. The main unit operational modes are given below. Full control of all sensor modes is within the DPU. Data compression is achieved by integration over several spectra depending on data rate.

Mode	Submode	28V	HV	Filament	Cover	Ion source heater	GCU	Activated by	Typical time	Used in phase	Description / Frequence of activation
S2 Standby	Cover initial opening	Off	Off	Off	Pyro firing	Off	Off	S/C	N/A	Commissioning in LEO	Breaking of vacuum seal
	Safe mode	On	off	off	open	off	off	S/C or DPU	N/A	All phases	Standby during turn on/turn off sequences
	High Pressure mode	On	off	off	closed	off	off	S/C or DPU	N/A	All phases	Safe mode during thruster firing and high pressure alert
	Ion Source cleaning	On	off	off	open	on	off	DPU	1 h	All phases	Regular cleaning of ion source by heating, 1/week (TBC)
2 Normal	Noise	On	On	On	open	off	off	DPU	10 s	All phases	Background measurement of detectors, every few minutes
	Background	On	On	On	Partially open	off	off	DPU	5 min	All phases	Background measurement of sensor by blocking off cometary material, < 1/day
	High res.	On	On	On	open	off	off	DPU	10 s/ mass	All phases	Normal high resolution mode, mass spectrum of one mass number per measurement
	Low res	On	On	On	open	off	off	DPU	10 s / 8	All phases	Normal low resolution
									masses		mode, mass spectrum of eight mass numbers per measurement
	Intercalibration	On	On	On	open	off	off	DPU	10 min	All phases	Intercalibration of all three detectors (LEDA, CEM, Faraday), 1 /day
	In-flight calibration	On	On	On	open	off	on	DPU	30 min	All phases	In-flight calibration with gas calibration unit, 1/week
3 Narrow angle	High res.	On	On	On	open	off	off	DPU	N/A	Special S/C mode	Normal high resolution mode, mass spectrum of one mass number per
	Low res.	On	On	On	open	off	off	DPU	N/A	Special S/C mode	Normal low resolution mode, mass spectrum of eight mass numbers per measurement

Mode	Submode	28V	HV	Filament	Cover	Ion source heater	GCU	Activated by	Typical time	Used in phase	Description / Frequence of activation
G2 Ground test	Normal	On	off	Off	closed	off	off	DPU	N/A	Ground test	Test sequence during ground test if no vacuum pump is attached
	Special test	On	On	On	closed	off	off	DPU	2 h	Special ground test	Test sequence during ground test if vacuum pump is attached

The power consumption of DFMS is composed of five main components, namely of the standby power (low voltage converters and main controller), of the analyzer part, of the filament, of the ion source heater and of the cover motor. The power consumption of DFMS is more or less independent of the detector used. It does vary neither with low or high resolution nor with the zoom optics. The following table shows the five contributions:

	Power (W)
Standby mode (LVPS, MC)	16
Analyzer Part	1
Filament	2
Ion source heater[1]	10
Cover motor	2

The power used in each mode can therefore be calculated. A normal measurement mode (including noise mode or calibration mode) needs 19 W; a background mode with cover 21 W, the ion source heater needs 26 W.

RTOF

RTOF has several parameters in order to measure mass spectra of ions or neutrals between two given mass numbers, with a high or low mass resolution, with adjustable electron emission current and energy. It has two channels, one optimized for neutrals (Storage Source SS), one optimized for ions (Ortho Source (OS)) with two different data acquisition system. Both channels, however, can also be used vice-versa. The main operational modes are given below. Full control of all sensor modes is within the DPU. Data compression is achieved by integration over several spectra and 2D wavelet compression depending on data rate.

Mode	Sub-mode	28 V	HV	Filament Gas	ETS/ETS_L	Cover	Ion source heater	GCU	Activated by	Typical time	Used in phase	Description / Frequence of activation
S1 Standby	Cover initial opening	Off	Off	Off	Both off	Pyro firing	Off	Off	S/C	N/A	Commissioning in LEOP	Breaking of vacuum seal
	Safe mode	On	off	off	Both off	open	off	off	S/C or	N/A	All phases	Standby during turn on /turn off

[1] not run in parallel to analyzer part, filament or cover motor

Mode	Sub-mode	28 V	HV	Filament Gas	ETS/ETS_L	Cover	Ion source heater	GCU	Activated by	Typical time	Used in phase	Description / Frequence of activation
									DPU			sequences
	High Pressure mode	On	off	off	Both off	closed	off	off	S/C or DPU	N/A	All phases	Safe mode during thruster firing and high pressure alert
	Ion Source cleaning	On	off	off	Both off	open	on	off	DPU	>1 h	All phases	Regular cleaning of ion source by heating, 1 /week (TBC)
1L Low Power	Noise	On	On	On	ETS	open	off	off	DPU	10 s	All phases	Background measurement of detectors, every few minutes
	Background	On	On	On	ETS	Partially open	off	off	DPU	5 min	All phases	Background measurement of sensor by blocking off cometary material, < 1/day
	Measurement	On	On	On	ETS	open	off	off	DPU	100s/mass spectrum	All phases	Normal mass spectrum mass1-500 amu/e
	In-flight calibration	On	On	On	ETS	open	off	on	DPU	30 min	All phases	In-flight calibration with gas calibration unit, 1/week
1G Gas	Noise	On	On	On	ETS	open	off	off	DPU	N/A	All phases	Background measurement of detectors, every few minutes
	Background	On	On	On	ETS	Partially open	off	off	DPU	5 min	All phases	Background measurement of sensor by blocking off cometary material, < 1/day
	Measurement	On	On	On	ETS	open	off	off	DPU	100s/mass spectrum	All phases	Normal mass spectrum mass1-500 amu/e
	In-flight calibration	On	On	On	ETS	open	off	on	DPU	30 min	All phases	In-flight calibration with gas calibration unit, 1/week
1I Ion	Noise	On	On	Off	ETS_L	open	off	off	DPU	N/A	All phases	Background measurement of detectors, every few minutes
	Background	On	On	Off	ETS_L	Partially open	off	off	DPU	5 min	All phases	Background measurement of sensor by blocking off cometary

Mode	Sub-mode	28 V	HV	Filament Gas	ETS/ETS_L	Cover	Ion source heater	GCU	Activated by	Typical time	Used in phase	Description / Frequence of activation
												material, < 1/day
	Measurement	On	On	Off	ETS_L	open	off	off	DPU	100s/mass spectrum	All phases	Normal mass spectrum, ions, mass 1-500 amu/e
1 RTOF full	Noise	On	On	on	ETS and ETS_L	open	off	off	DPU	N/A	All phases	Background measurement of detectors, every few minutes
	Background	On	On	on	ETS and ETS_L	Partially open	off	off	DPU	5 min	All phases	Background measurement of sensor by blocking off cometary material, < 1/day
	Measurement	On	On	on	ETS and ETS_L	open	off	off	DPU	100s/mass spectrum	All phases	Normal mass spectrum, ions and gas, mass 1-500 amu/e
G1 Ground test	Normal	On	off	Off	ETS and ETS_L	closed	off	off	DPU	N/A	Ground test	Test sequence during ground test if no vacuum pump is attached
	Special test	On	On	On	ETS and ETS_L	closed	off	off	DPU	2 h	Special ground test	Test sequence during ground test if vacuum pump is attached

COPS Operational modes:

<u>Neutral Sensor</u>

The pressure measurements with the neutral gauge essentially consists in a single mode where the ion current is measured each time the gauges are operated.

3.3.8.1. Mission Phases and Instrument Operations

Following are the special requirements for the different mission phases:

Commissioning Phase near Earth

The covers of RTOF and DFMS should only be opened after the spacecraft has had sufficient time to outgas. Also the main orbit and attitude correction maneuvers of the spacecraft which use a lot of thruster firing should be finished by the time the covers are opened for the first time (appr. 70 days after launch, TBC). Before cover opening the ambient pressure as recorded by COPS MICROTIPS OR FILAMENT has to be below 10^{-6} mbar (TBC). After cover opening enough time has to elapse (~days), TBC) to allow an outgassing of the sensors before power is turned on. To accelerate outgassing of the DFMS ion source the ion source heater will be used. All three sensors should be checked out separately. For this operation near real-time commanding and science data are needed.

Hibernation / Planet fly-by's

Before going into hibernation the covers of RTOF and DFMS should be closed. ROSINA should be turned on during the Mars fly-by to measure the martian exosphere. The measurement modes will be similar to the asteroid fly-bys. If feasible the planet fly-bys should be used to heat up the spacecraft experiment platform (turn it towards the sun) to outgas it so as not to let the dirt get sticky.

Asteroid Fly-By's

A few days (>5, TBC) prior to the asteroid fly-by's the COPS MICROTIPS OR FILAMENT, the RTOF and the DFMS (TBC) have to be commissioned. The filaments need a slow and careful conditioning before the actual fly-by and the instrument has to perform a thorough measurement of the background (outgassing of the spacecraft). The data rate however can be small during this period. During the actual fly-by the RTOF should be fully operating at the highest possible data rate to gather mass spectra with high spatial resolution. If power and available bit rate permit the DFMS will be used to complement RTOF by looking at specific molecules in a low mass resolution mode. The sensors will be operated throughout the asteroid fly-bys in the same measurement modes (gas channel RTOF, low resolution DFMS). That means no commanding will be necessary.

Comet Approach

After reaching the neighbourhood of the comet, it is mandatory that the instrument is switched on as soon as possible to study outgassing and cometary activity at large heliocentric distances. At these distances the expected cometary gas densities are low and S/C outgassing and instrument background must be reduced to the lowest possible level. This requires exposure of the experiment platform to sunlight for several days to accelerate degassing of adsorbed gases. This degassing process should be monitored by COPS MICROTIPS OR FILAMENT. The covers of the two sensors should be opened when S/C outgassing has been sufficiently reduced as determined by the COPS MICROTIPS OR FILAMENT. The first sensor to be switched on will be the RTOF because it has a larger sensitivity than the DFMS. RTOF has a power savings mode where only the channel which is adapted to low densities will be operated which should allow an early turn on. Where this switch-on occurs will be determined by available spacecraft power and telemetry. DFMS and COPS should be turned on as soon as feasible from the power point of view. During commissioning the DFMS ion source will be degassed by the ion source heater for several days. Careful conditioning of the filaments and use of the inflight calibration system have to be included in the commissioning phases.

Regarding telemetry, cometary gas densities will be low at large heliocentric distances, requiring very long integration periods and monitoring of spacecraft outgassing. Thus, telemetry requirements may be significantly lower than later when the gas densities are larger.

Mapping Phase

During the mapping phase of the mission, the instrument will be used to survey the nucleus surface. To search for active areas on the nucleus surface, where volatiles are at or near the surface and to search for suitable landing places for the SSP, a survey of the gas density around the nucleus at an altitude of about one nuclear radius is required. The intensive study of the gas density, composition and dynamics must be continued during the entire mapping and close survey phase to achieve the science goals. It will also require use of the narrow FOV of the DFMS which must be directed towards the nucleus.

Escort to Perihelion

After the SSP has been deployed and during the escort to perihelion phase, the gas production rate will increase. The increased production will allow accurate measurements at large cometocentric distances. In this phase the RTOF will serve as survey instrument, measuring a very large mass range whereas the DFMS will concentrate on individual masses to get a full mass resolution for critical mass peaks (e.g. mass 28 amu).To study the release of gas from grains (extended sources), and to get insight into the complex coma chemistry and the interaction between gas and dust, several radial excursions from about one nuclear radius to at least 1000 km with extended stays at large distances may be required. These excursions must be interspersed with detailed investigation of the sunward near nucleus hemisphere of the coma. The observations of the outgassing behavior of active areas during terminator crossings and in the shadow will be a diagnostic tool for the morphology of the nuclear surface regions in these areas. These observations require stays above the dawn and dusk terminator regions and occasional observations of the nightside of the coma.

To measure minor constituents of the gas and to get isotope ratios for a large number of species it is essential to have very long integration periods. Depending on the actual gas flow field in the vicinity of the nucleus, it may also be necessary to operate the instrument for extended periods of time while it is not pointed at the nucleus. Angular scans using the narrow FOV of the DFMS will be required for studying individual gas sources on the nucleus.

Instrument check-out and inflight calibration

A detailed check out of the entire instrument will be made during the initial turn on in the cometary neighborhood (TBD). An inflight calibration program will be activated every TBD week. The program will encompass internal calibration of the different ion detectors of the DFMS, RTOF and COPS and ion source and analysis operation modes as well as an absolute calibration of the overall sensitivity using the calibrated gas release system.

Interferences

Operation of the ACS thrusters interferes with the operation of the instrument and could even cause permanent damage. It is therefore mandatory that the instrument is put in a safe mode before the thrusters are operated. The instrument will have several types of safe modes depending on which thrusters on the S/C will be used and depending on the length and detailed time profile of thruster use. The instrument can only be turned on again TBD minutes after the thrusters are turned off. It will be necessary that a suitable signal is provided to the instrument TBD min. prior to thruster operations containing all the necessary information. An end of thruster operation signal is also necessary so the instrument can resume operation after a suitable time period to allow dispersion of any thruster gas contamination. Several hours may be necessary after instrument turn off to reach stable background conditions.

As an additional safety measure, the COPS MICROTIPS OR FILAMENT will be used as a monitor of ambient conditions and will signal the mass spectrometer to turn off if ambient pressure should increase above a preset limit, for instance due to a cometary outburst during the near comet phases of the mission or episodic S/C outgassing. If the pressure exceeds 10^{-4} mbar (TBC) the COPS MICROTIPS OR FILAMENT will also be turned off.

3.3.9. GIADA Operational Modes

The GIADA experiment modes are summarised in Table 3-4. The mode transitions are depicted in Figure 3-3c. The physical quantities measured in the different modes are summarised in Table 3-5. The general timeline worksheet is reported in Table 3-6 and Figure 3-4 for the nominal mission scenario.

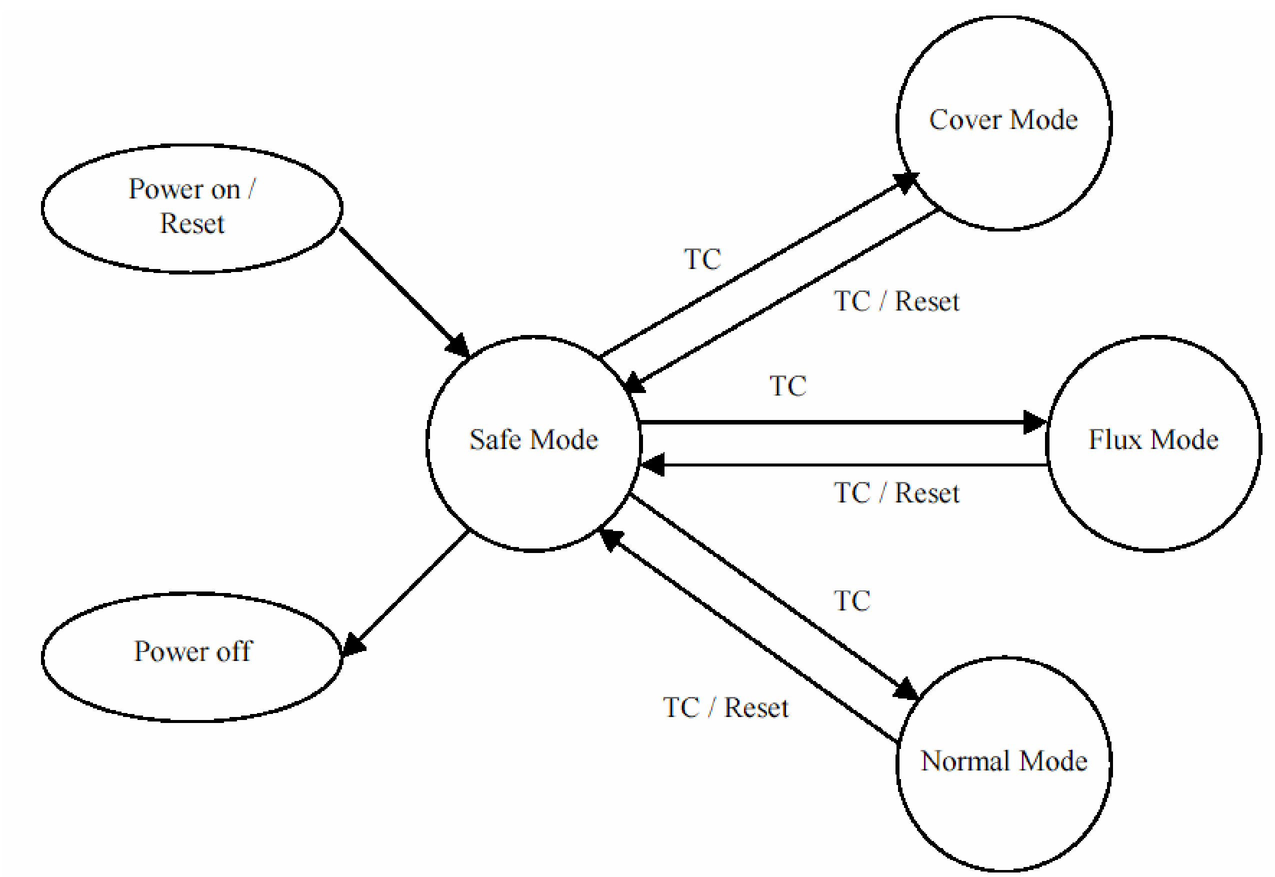


Figure 3-3c: GIADA Mode Transition Diagram

Mode	**Active Sub-system**	**Power requirement** ([1])(W)
Safe	ME	4.5
Normal	GDS+IS+5 MBS's (Normal)+EL	20.7 (22.4 W acc. to test results)
Flux([1])	5 MBS's (Normal) + ME	10.7
Cover ([4])	ME + Cover motor	24.7 <33.6 ([3])

Table 3-4: GIADA Experiment Modes

([1]) At S/C; efficiency = 0.75; Short peak power = 28 W; this short peak power is only at power-on. At power-on GIADA will go in Safe Mode. GIADA will not exhibit this short peak power when switching from any other mode to Safe mode.

([3]) Long peak power; this long peak power, caused by the Frangibolt device, will be applicable only at the first opportunity after the launch

Mode	Measured quantity	Sub-system
Safe		ME
Normal	Dust flux and fluence	5 MBS's + GDS + IS
	Scalar velocity of single grains	GDS + IS
	Momentum of single grains	IS
	Grain scattering properties	GDS
Flux	Dust flux and fluence	5 MBS's
Cover		

Table 3-5: Measured physical quantities

Mission phase	Duration	GIADA operating mode	Data volume (Mwords)	(bps)
commissioning to comet app.	9.5 years	Testing (at least once per non-hibernation period)	very low	very low
nucleus mapping	82 days	Flux ([1,2])	2.0	5/160
coma observation	7 months	Normal ([1,2])	76.0	200

([1]) Heating mode for each MBS (4000 Bytes) foreseen once per month

([2]) Testing mode required at the beginning of operations and regularly during normal operation for instrument health checking.

Table 3-6: General timeline worksheet

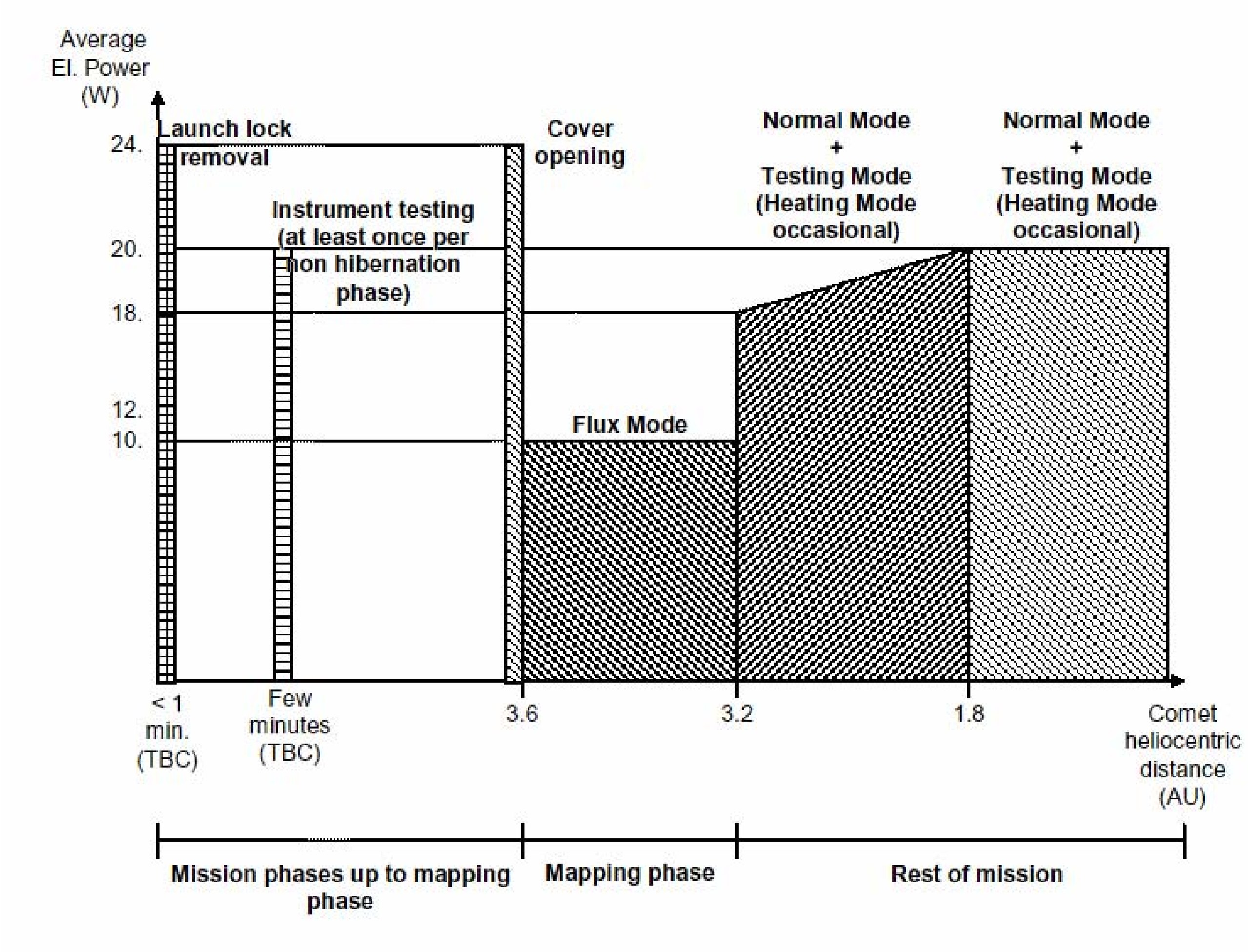


Figure 3-4: Timeline of GIADA operation

3.3.10. RPC Operational Modes

The RPC package is set of five individual sensors, each measuring different parameters of the cometary plasma. Each sensor can be operated in a variety of different modes. To make the operation of the package easier and to inhibit a too large number of individual modes, operational macro modes (OMM) are defined which allow to handle available power and telemetry resource requirements.

Detailed individual sensor modes will be described later.

The following OMMs are distinguished:

- OMM 0: Hibernation mode
- OMM 1: Maintenance mode
- OMM 2: Calibration mode
- OMM 3: Normal mode

- OMM 4: Burst mode
- OMM 5: Flyby mode

These OMMs are described in detail in the following subsections. Internally, other sub-modes are defined, corresponding power and telemetry requirements or mission phases. External and internal modes are distinguished by status information transmitted in the housekeeping telemetry.

3.3.10.1. Hibernation mode: OMM 0

In this Mode 0 all sensors of the RPC as well as the PIU are switched-off. No data are taken.

Power requirements:

None ; required heater power : ICA 2.2 W
IES 0.5 W

Telemetry requirements:

None

3.3.10.2. Maintenance mode: OMM 1

In this mode none of the sensors is taking scientific data. The PIU and MAG are in operation and deliver house keeping data to the telemetry. This mode is to monitor the PIU and RPC status during the cruise phase.

Power requirements: 2800 mW primary

Telemetry requirements: 54.0 bit/s

3.3.10.3. Calibration mode: OMM 2

In this mode each of the different sensors is switch-on individually for check-out and in-flight calibration purposes. As house-keeping data are handled via the MAG sensor telemetry MAG is taking data continuously during this mode.

Power requirements: 6284 mW primary maximum power with MAG, PIU, and ICA on

Telemetry requirements: 3651 bits/s maximum with MAG, PIU, and LAP on

3.3.10.4. Normal mode: OMM 3

In this mode normal science operation during the comet drift, approach, mapping, lander delivery, and escort phase is performed. All sensors and the PIU are preferred to be operational in this mode. However, to accommodate the limited power and telemetry resources several sub-modes are defined. Following modes are planned:

Mode 31:

All sensors and the PIU are operational

Power requirement: 16339 mW nominal primary

Tele. requirements: 392.7 bit/s normal

Mode 32:

ICA off; all other sensors and PIU operational

Power requirement: 12855 mW nominal primary

Tele. requirement: 289.5 bit/s normal

Mode 33:

LAP and MIP off; IES, MAG, ICA, PIU on

Power requirement: 10796 mW nominal primary

Tele. requirement: 276.7 bit/s normal

Mode 34:

IES and MIP off; ICA, LAP, PIU, and outboard MAG on

Power requirement: 9634 mW nominal primary

Tele. requirement: 285.7 bit/s normal

Mode 35:

IES and LAP off; ICA, MIP, MAG, and PIU on

Power requirement: 8477 mW nominal primary

Tele. requirement: 276.7 bit/s normal

Mode 36:

LAP, MIP, ICA, IES off; MAG, and PIU on

Power requirement: 2800 mW nominal primary

Tele. requirement: 120 bit/s normal

Mode 37:

IES, ICA off; MAG, MIP, LAP, and PIU on

Power requirement: 8343 mW nominal primary

Tele. requirement: 236 bit/s normal

3.3.10.5. Burst modes: OMM 4

All RPC sensors can be operated in very high-time resolution modes, that is all sensors can be operated in a burst mode. The telemetry requirements are within the normal telemetry rates provided sufficient s/c memory is available. The detailed commanding and memory operation is TBD and strongly depends on the scientific questions to be studied. Burst mode telemetry and power requirements are sensor specific. The requirements are, maximum PIU telemetry included:

SENSOR	POWER [MW]	Max DATA RATE [BIT/S] (Burst Mode)
LAP	5310	2253
MIP	4153	304
IES	6472	257
ICA	5444	1027
MAG	2800	1344
PIU	1175	1344
RPC total	16339	5239

It should be noted that these figures are not additative, but include the individual sub-experiment power and bitrates as well as the PIU overhead.

3.3.10.6. Flyby mode: OMM 5

During the Earth, Mars, and asteroid flyby the RPC package is expected in the operational macro mode 31. However, the specific modes are TBD depending on power and telemetry available.

The bitrate of each individual sensor in different modes are summarized in the following table:

	MINIMUM [BIT/S]	NORMAL [BIT/S]	MAXIMUM [BIT/S] (Burst Mode)
PIU	54.0	54.0	54.0
IES	5.3	53.5	257.0
ICA	5.2	103.2	1023.0
LAP	1.6	62.5	2253.0
MIP	16.5	61.5	312.0
MAG	2.1	66.0	1344.0

Table 3-7: RPC Operational Modes and Bitrates

The power and telemetry requirements for the different operational macro modes are summarized in the following table.

OPERATIONAL MACRO MODE		POWER [mW]	TELEMETRY RATE [Bit / s]
Hibernation	OMM 0	0	0
Maintenance	OMM 1	2800	54.0
Calibration	OMM 2	6284	3651.0
Normal	OMM 31	16339	392.7
	OMM 32	12855	289.5
	OMM 33	10796	276.7
	OMM 34	9634	285.7
	OMM 35	8477	276.7
	OMM 36	2800	120.0
	OMM 37	8343	236.0
Burst	OMM 4	16339	5239.0
Flyby	OMM 5	16339	392.7

Table 3-8: RPC Operational Macro Modes Summary

3.3.10.7. Operational Concept

The choice of the mode is due to mission phase, available power and telemetry as well as scientific requirements. Appropriate instrument commanding is required. The selection and initiation of the modes and sub-modes are under the control of the RPC PI-spokesman after consultation with the RPC team.

A more detailed preferred operational concept is described in section 6 or related EID-B. The sequence of sub-modes during operational phases is TBD and depends on power and telemetry available. In any case modes 31, 32, and 33 are preferred, as no switch-off of the IES high voltage power supply is necessary. Mode 36 is designed for the delivery phase, when both the orbiter and the lander magnetometers are required to operate simultaneously.

3.3.11. RSI Operational Modes

RSI operations will start on (TBD) for the cometary science objectives. The start for the asteroid science operations and the solar corona science operations is TBD. Operations requirements may be found in Volume VI of the EID-B.

3.3.11.1. Operational Radio Link Modes

Two-way radio link: frequency reference source is the hydrogen maser of the ground station (TBC). S-band uplink at 2.1 GHz with telecommanding; dual-frequency coherent and simultaneous downlink at S-band (2.3 Ghz) and X-band (8.4 Ghz). X-band with telemetry modulation.

One-way radio link: frequency reference source is the Ultra Stable Oscillator on board of the spacecraft. Dual-frequency coherent and simultaneous downlink at S-band and X-band. X-band with telemetry modulation.

<u>Two-way link:</u>

- S-band up
- S,X-band down simultaneous
- Doppler and ranging simultaneous
- Ranging measurements at begin and end of track with length TBD

<u>One-way link:</u>

- S,X-band down coherent and simultaneous

- Doppler

A sketch of the RSI radio link configurations can be found in Figure 3-5 and Figure 3-6.

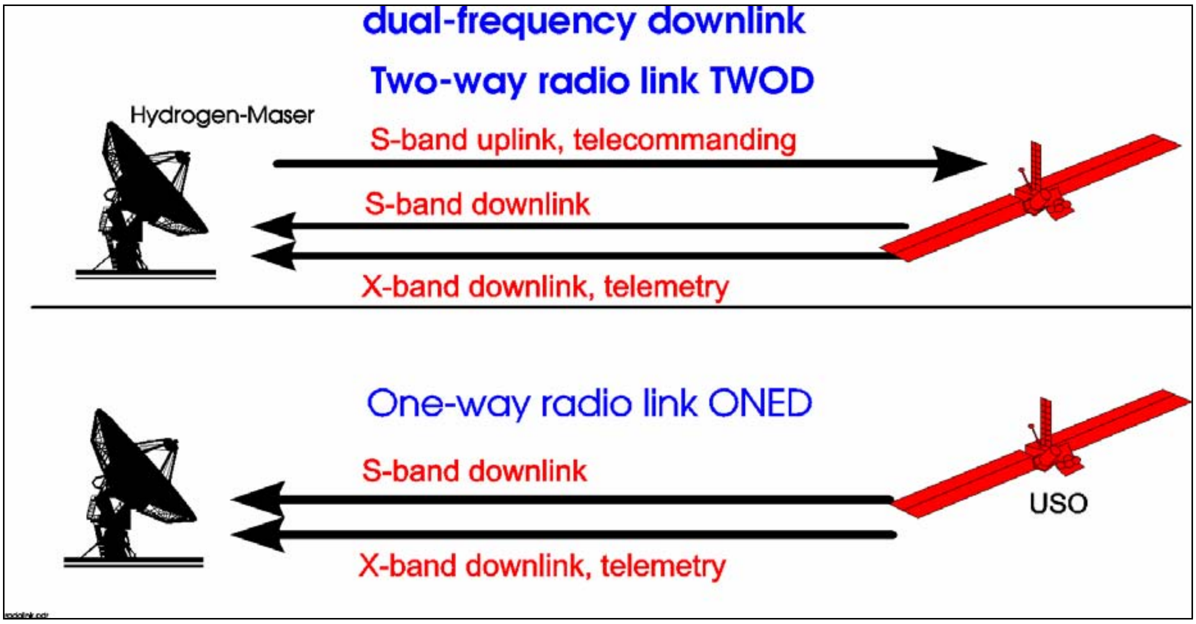


Figure 3-5: Spacecraft Configurations TWOD and ONED

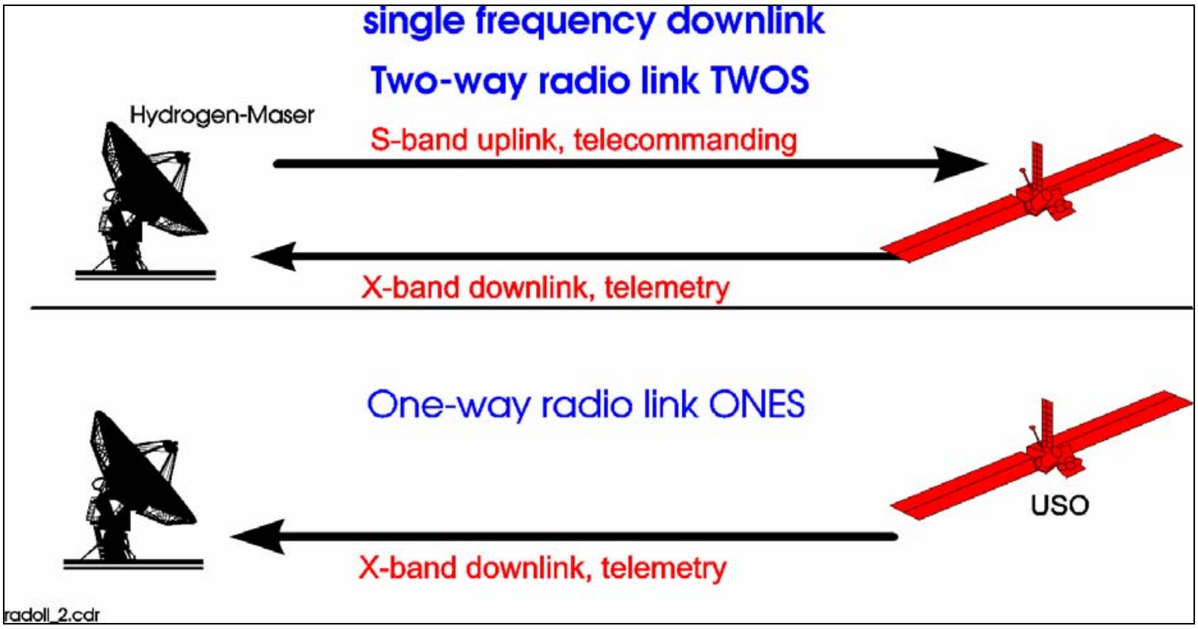


Figure 3-6: Spacecraft Configurations TWOS and ONES

3.3.11.2. Spacecraft Configuration

Exp.Mode Space Segment	Acronym	Power (W)	Functional Use
One-way single downlink frequency	ONES	2.1 USO	X-band downlink, USO bistatic radar
One-way dual-frequency	ONED	2.1 USO 25 (tbc) S-band	S- & X-band downlink Occultations Solar Corona (optional)
Two-way single frequency	TWOS	-	S-band uplink, X-band downlink Early prime mission phases
Two-way dual-frequency	TWOD	25 (tbc) S-band	S-band uplink, dual-frequency downlink Routine operations

Z:\projects\tables\rsi_mode.doc\Z2 17.07.98 08:25

Table 3-9: Spacecraft Configuration Modes

Note: Above table could not be updated due to editing problems. The update is:

- replace 2.1 USO by 6.2 USO in 2 places
- delete (tbc) in 2 places

3.3.11.2.1. Routine RSI Operations

RSI routine measurements (two-way Doppler and range) will be obtained at all times when the spacecraft is tracked for navigation and data return. The routine operational mode is the TWOD (see Table 3-9) mode: S-band uplink, coherent and simultaneous dual-frequency (S-band and X-band) downlink via the HGA. This takes advantage of the superior stability of the ground station frequency reference source generated by the ground station hydrogen masers. One tracking session will consist of roughly a fourteen-hour pass at the ground station in New Norcia in 2012/2013 (tbc for Churyumov-Gerasimenko). Dual frequency ranging data may be acquired at a rate TBD at the beginning and the end of a tracking pass.

3.3.11.2.2. Gravity Mapping Campaign

The Gravity Mapping Campaign (GMC) has to be carried out at distances of about two nucleus radii in such a way that global coverage is achieved. The duration of this campaign depends on the rotational rate of the nucleus. Preliminary estimates yield a duration of two weeks or more. To avoid perturbations by gas and dust outflow interactions with the orbiter which might mask the contributions of higher order gravity coefficients, the GMC should be performed as early as possible after reaching the close orbit. During the GMC, continuous tracking (24-hours daily coverage) is required. Thruster activity should be avoided as far as possible. High-inclination orbits (orbits almost in the plane-of-sky) should be avoided during the GMC. The spacecraft configuration is the TWOD mode.

3.3.11.2.3. Occultation Experiments

The gas, plasma and dust environment of the innermost coma (within the orbit of Rosetta about the nucleus) can only be sounded prior and after occultation of the spacecraft by the nucleus. These occultation experiments require orbits with inclinations of $\approx 90°$ with respect to the plane-of-sky.

In order to obtain favourable occultation geometries, the orbit about the nucleus should be changed such that a series of occultations can be predicted (Occultation Campaigns). These Occultation Campaigns should be repeated every month or every two months (TBD).

Because the revolution period of Rosetta about the nucleus is in the order of days, the operational mode has to be switched to the one-way simultaneous coherent dual-frequency downlink mode (ONED) approximately ten to twenty hours (TBD) prior to occultation. This reflects a radial coverage of the innermost coma within the Rosetta orbit (plasma; dust grains) with a sufficient baseline prior and after occulation. The regular two-way mode (TWOD) will be re-established a sufficient time (again in order of ten to twenty hours) after the occultation.

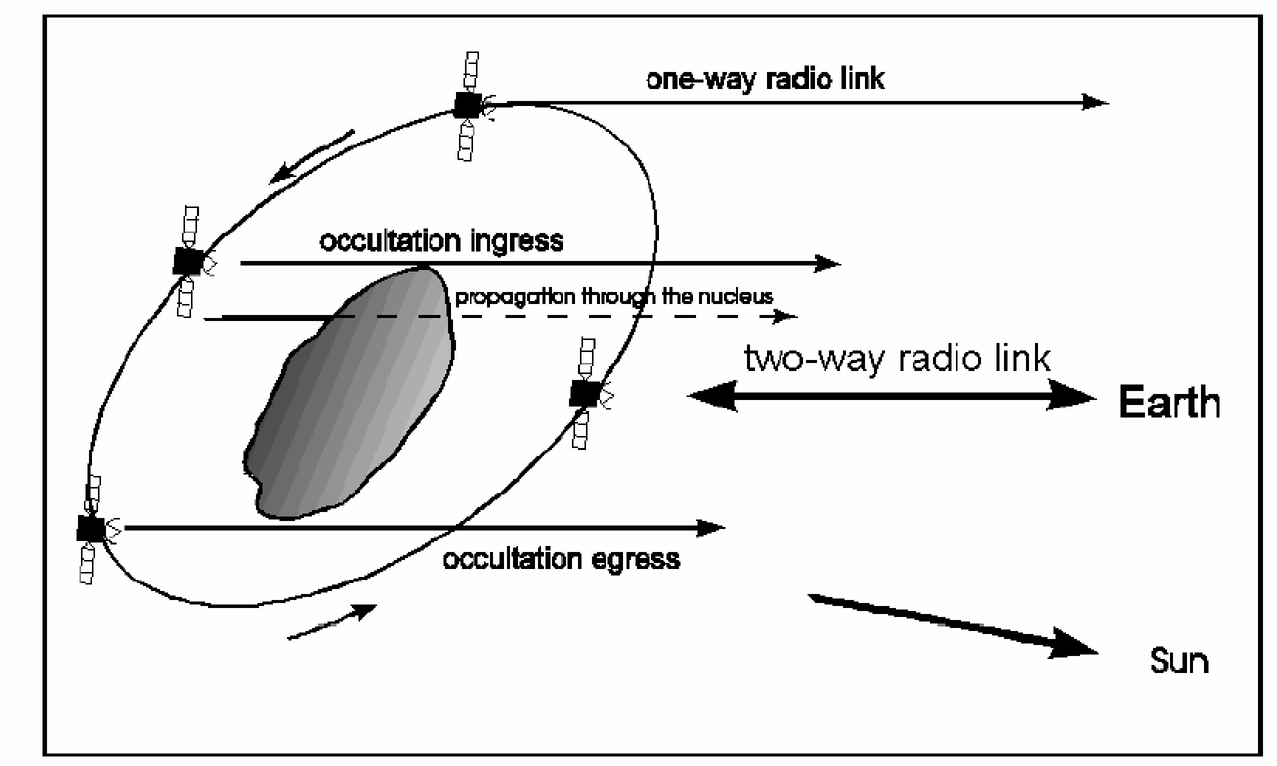


Figure 3-7: Occultation Campaign

View onto the orbit plane containing the direction to Earth. Ten to twenty hours before occultation by the nucleus as seen from Earth, the one-way downlink is established. The regular TWOD downlink is re-established again ten to twenty hours after occultation.

3.3.11.2.4. Bistatic Radar Observations

Bistatic radar observations require the HGA to be pointed toward the comet surface. Therefore, the only geometrical configuration that would permit simultaneous reception of the direct downlink signal and its forward scattered radar echo is at Earth occultation, where the angle of incidence $i \approx 90°$. Other values of i, including the range near the probable Brewster angle Φ_B, can be attained only

at times when it is possible to depoint the Rosetta HGA from Earth. The S/C will operate in the one-way mode ONES.

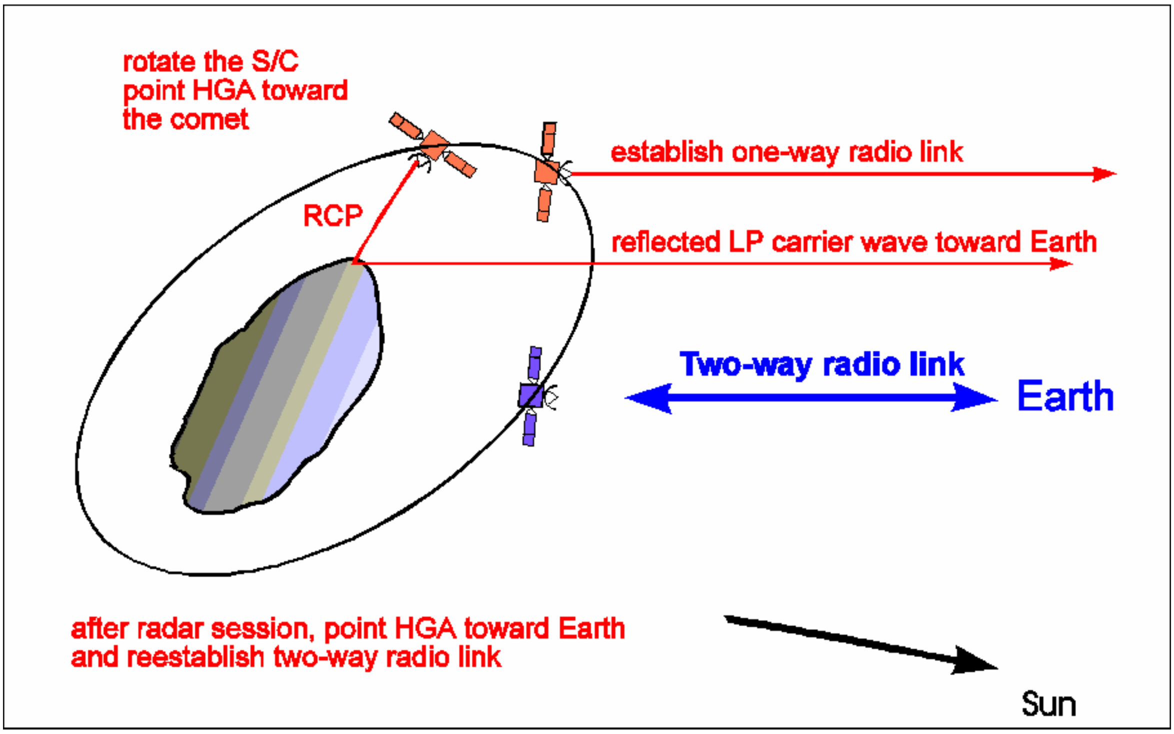


Figure 3-8: Bistatic radar configuration

(after establishing the one-way downlink the HGA is pointed toward the nucleus surface. After the radar session, the HGA is repointed toward the Earth and the two-way radio link is re-established.)

3.3.11.2.5. Asteroid Fly-bys

The operational mode during the asteroid flybys is the routine two-way link TWOD mode. The S/C should not rotate during the close fly-by. All thruster activities should be avoided during a sufficiently long period before and after closest approach, to ensure accurate orbit arc determinations. ~~The probable selection of Siwa as one of the new target asteroids will allow the determination of its mass and bulk density even up to flyby distances of 10,000 km with sufficient accuracy.~~

3.3.11.2.6. Solar Corona Sounding

In order to perform a solar corona sounding experiment, the radio subsystem of the orbiter should be fully operational (with the HGA pointing toward Earth) during the times given in Table 3-10 (~~based on orbital elements for Rosetta from 1994~~updated according to the mission calendar; it should be noted that this might be limited by the hibernation). The radio subsystem should operate in the two-way mode TWOD, thus enabling dual-frequency ranging measurements. Tracking passes should be conducted as often as possible (preference of a 18 hours to 24 hours daily coverage).

DC power availability in ~~C4 - C6~~some of these phases might not be sufficient to operate a dual-frequency downlink. Furthermore due to the distance spacecraft/Earth of approximately 5.5 AU, the RF transmission power at S-band might also not be sufficient to receive an adequate signal-to-noise ratio at the ground station.

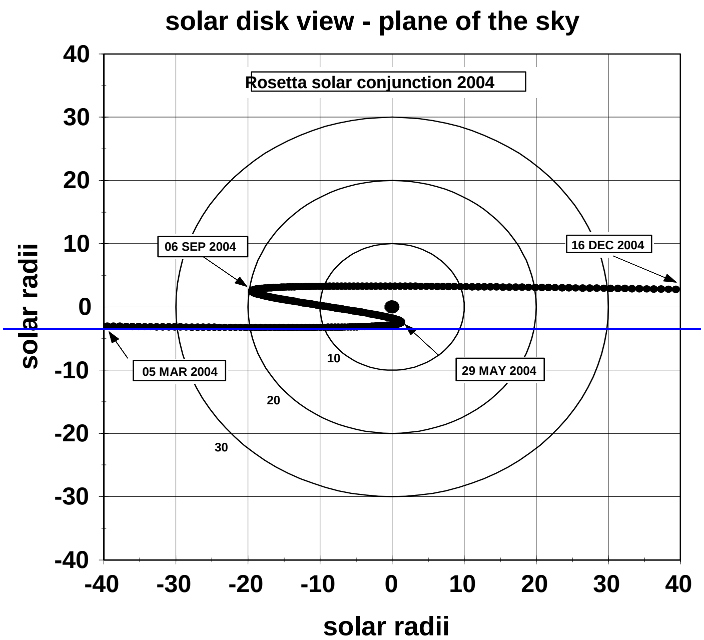
~~Conjunction geometries of the first solar conjunction (C1) and the conjunctions during the prime mission at the comet (C6 and C7) can be found in Figure 3-9 and Figure 3-11.~~

3.3.11.2.7. Search for Gravitational Radiation

For the search for gravitational radiation, a sufficiently long period of time (3 to 4 weeks) of continuous Doppler tracking could be scheduled when the spacecraft is in cruise and near solar opposition. The opposition dates are given in Table 3-11.

The operational mode during solar oppositions would be the routine two-way mode TWOD.

DC power availability for ~~O1-O3~~some of these phases might not be sufficient to operate a dual-frequency downlink.



~~**Figure 3-9: C1 conjunction geometry**~~

~~Positions of Rosetta in 2004 projected onto the plane-of-sky within 40 solar radii at both limbs of the Sun (10 degree elongation). Tick marks are one day.~~

Conjunction	Entry Date	Exit Date	Closest Approach	S/C-Earth-Sun Angle ± 10°[1]
C1	16.03.2006	17.05.2006	< 3 R	±40 $R_{\odot}$
C2	18.12.2008	22.01.2009	< 2 R	±40 R
C3	04.10.2010	01.11.2010	< 6 R	±40 R
C4	03.11.2011	28.11.2011	< 3 R	± 40 R
C5	21.11.2012	15.12.2013	< 10 R	± 40 R
C6	11.12.2013	04.01.2014	< 16 R	± 40 R

Table 3-10: Solar Conjunctions of the Rosetta Spacecraft (S/C-Earth-Sun Angle < 10°)

Opposition	Date	Heliocentric Distance
O1	25.04.2008	1.55 AU
O2	21.10.2009	1.12 AU
O3	02.05.2011	4.37 AU
O4	22.05.2012	5.27 AU
O5	12.06.2013	5.09 AU
O6	10.07.2014	3.75 AU

Table 3-11: Oppositions of the Rosetta Spacecraft

3.4. Autonomy and Fault Management Concept

The mission profile and operational concept demand a very high degree of on-board autonomy. On one hand this refers to the S/C capabilities in support of nominal operations, and on the other hand to its cleverness for failure detection, isolation, and recovery, which is of particular importance for the success of the mission.

[1] corresponds to 40 solar radii

Robustness against failures in H/W, S/W, or ground control is the main objective, when designing a spacecraft for this mission. An overview of the basic failure detection concept is shown in the following table.

Failure	**Subsystems**					
Managem. Level	**Instruments**	**Power S/S**	**Thermal Control S/S**	**TT&C**	**AOCMS and RCS**	**DMS**
Level 3: Independent system surveil-lance		battery discharge alarm			attitude anomaly alarm	~~attitude anomaly alarm,~~ handling of system alarms by Reconfiguration Module
Level 2: Subsystem surveillance by DMS	define HK pa-rameters to be surveyed and possible recovery monitor health signal	SA power availability surveillance for battery discharge, over-charge and over-discharge	heater function surveillance and redundancy switching	TC Link Monitor and Recovery TX/RX health checks	surveillance of PM health by means of essential HK packet generation, attitude, mode changes, time-out control, manoeuvres, tank pressures, reconfiguration in case of failures	On-board Monitor system reconfigu-ration after mainbus undervoltage surveillance of AOCMS PM health by surveying SCET in AOCMS essential HK
Level 1: Checks on processor level	perform S/W FDIR (if possible) provide health signal TBD (under responsibility of PIs)				- S/W FDIR of AOCMS and STR and Nav. Camera processors - undervoltage surveillance - parallel check-out of red. processor	S/W FDIR of DMS and SSMM processors, watchdog and undervoltage surveillance parallel check-out of red. processor
Level 0: Subsystem internally and units	TBD (under responsibility of PIs)	hot redundant, LCLs, FCLs, battery over-charge/discharge protection, reconnection logic	hot red. heaters controlled by thermostats	hot red. receivers	perform sensor and actuator FDIR and plausibility checks, HGA/SA drive FDIR, RCS surveillance,	hot red. decoders link checks

Table 3-12: Overview to System Failure Detection Concept

This table addresses only globally the available surveillances. Especially for the AOCMS and DMS related functions it is referred to the Avionics User Manual [RD3] and [RD25].

This table, however, shows the hierarchical structure of the on-board FDIR, which aims for isolation and recovery of any failure at the lowest possible level.

On Level 0 this is ensured partly by hardware (e.g. LCLs for mainbus protection, thermostat controlled redundant heaters) and partly by software (e.g. sensor consistency checks, link checks). This is to ensure that nominal operations can be continued, when only a local problem has been identified. This will be resolved by simple isolation of the failed equipment, by hot redundancy, or by software controlled local reconfiguration, instead of entering a back-up mode and interrupting mission product generation.

On Level 1 the consequences will be more severe, if the processors of DMS or AOCMS are concerned. This must lead in any case to a transition into Safe Mode, because the failed processor may have left the system in a critical state. In this case the recovery to a safe configuration will be accomplished on-board after processor reconfiguration and ground action is awaited. More details about the on-board actions and exceptional situations, where the system has to react differently (e.g. at deep space hibernation ~~wake-up~~ or separation sequence the current activities have to be resumed) can be found in the System Autonomy Software URD: [RD4], section 2.5 and in [RD3].

On Level 2 the DMS plays its role as the master of the system. The On-board Monitor is capable of checking housekeeping parameters of any equipment against limits or event messages and perform corrective actions. The parameters and corrective actions can be tailored to the actual needs. In case the AOCMS processor is found suspect, this will lead to a reconfiguration of both processors followed by Safe Mode.

On Level 3 the system alarms are in action, which deal with the most essential parameters for S/C safety, the attitude and solar power availability. They will capture failures, which have not been detected on lower levels for whatever reasons. In fact these system alarms have an internal hierarchy in the following way:

- the AOCMS attitude anomaly alarm should be the first to trigger; it uses the Sun sensors on the solar arrays and triggers at a programmable offset from Sun of typically 10° to 15°; if this offset is exceeded, the AOCMS changes to the first level back-up mode SKM to reacquire Sun pointing of the solar arrays and subsequent Earth reacquisition in Safe Mode; no processor reconfiguration is performed in this case

- ~~in the DMS a similar attitude anomaly alarm is set to a wider limit; if this is reached the AOCMS processor is also suspected and the system enters Safe Mode with both processors reconfigured~~

- if the battery discharge alarm triggers, the DMS and AOCMS are both suspected and the system enters Safe Mode with both processors reconfigured.

~~These system alarms in principle protect also against 'intelligent software failures', where for instance the AOCMS thinks it is doing all right, but it is not. However, when this happens during a Delta-V manoeuvre, the DMS attitude anomaly alarm for instance would trigger rather late and only in two axes, suchit could be that the Delta-V may have gone so wrong that the mission is lost. Therefore it may be proposed to use the RF uplink beam to the HGA as an additional sensor during manoeuvres. The DMS On-board Monitor would continuously watch the HGA/RX AGC signal and stop the manoeuvrve if it disappears. This implies, however, the need for ground availability at least for the larger manoeuvres.~~

Operator failures will either lead to triggering of one of the above surveillances with subsequent recovery or lead to loss of contact, e.g. when wrong ephemerides have been uplinked causing mispointing of the HGA. This can be corrected from ground, possibly needing DSN uplink via LGA. Ultimately, there would come the on-board program TC Recovery into action (after programmable time-out for command reception), which would start searching for the Earth (for details see under System Contingency Procedures).

3.5 Operational Constraints

Note: Constraints, which are applicable to individual procedures only, are not repeated here. They are contained only in the corresponding procedures of the System or Avionics part.

3.5.1 Constraints on Attitude

- ALICE: Sun-pointing of < 11° not allowed, i.e. Sun shall remain outside a cone of 11° from the S/C Z-axis, when ALICE cover is open
- COSIMA: The Sun shall not be in the UFoV (± 10 deg) when the Shutter is open. Ref.: Instrument EID-B Section 6.3.1.1. This translates into ± 10° w.r.t. S/C +Z-axis.
- GIADA:
  - cover to be closed (OBCP) if temperature exceeds limit (cold or hot).
  - For angles between Sun and +Z-axis down to 11 deg, no thermal problems will affect GIADA, according to the performed thermal analysis (EID-B). The thermal behaviour below 11° is not described, therefore it is assumed as a precaution that such attitudes shall be avoided.
  - During instrument operation the angle between –Y direction and the sun direction has to be > 80° in the (X-Y) plane and >65° in the (Y-Z) plane to avoid sun radiation entering the GIADA1 module through the laser exit aperture (ref. Instrument EID-B Section 6.3.1).
- MIRO: no Sun in FoV when MIRO is operating (5° around +Z)
- Osiris (ref: OSIRIS UM)
  - In general, the Wide Angle Camera (WAC) shall not be used and shall have its front door closed when the Sun is less than 90 deg from the boresight for a time depending on the angle between sun and +Z axis. Typically for an angle of 30° 4h of operation are allowed (ref. OSIRIS UM, §4.5.1). The WAC shall not point to within 10 degrees of the Sun with its front door open under any circumstances unless the Sun is obscured from view.
  - The Narrow Angle Camera (NAC) shall not be used and shall have its front door closed when the Sun is less than 45° from the boresight. In particular cases, if requested by the PI, NAC could be exceptionally used for Sun incidence angles between 45° and 12°, for approximately 30 minutes, depending upon the distance of the sun and the sun incidence angle.
  - The NAC shall not point to within 11° of the Sun with its front door open under any circumstances unless the Sun is obscured from view (e.g. when we enter eclipse).
- VIRTIS: the UFoV of ± 10° w.r.t. S/C +Z-axis should be avoided even if VIRTIS is not operating. This applies only if the cover is open. During operations the sun avoidance angle is ± 45° w.r.t. S/C +Z-axis.
  For sun angles between 45° and 10° w.r.t. S/C +Z-axis serious degradation of the scientific performance is expected up to the degree where no IR operation is possible

- Mars Express in-flight experience and straylight measurements with star tracker EQM have indicated a STR acquisition problem when Sun is within 65° of boresight for distances of 1 AU and 45° of boresight for distances above 2 AU.
- STR-B may be affected by Sun reflections from the Virtis radiator rim
  - for Sun angles < - 80° in X/Z plane, counting from +X
  - for Sun grazing on -Y side wall > 5° (from lower hemisphere, incl. AOCMS deadband)

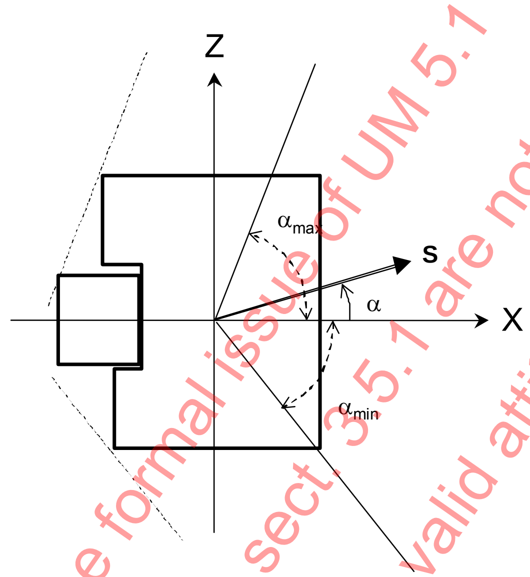
  A STR S/W patch is available at ESOC which will reduce the sensibility to straylight of the STR in case problems will occur at initial acquisition. Furthermore it is recommended to characterise the straylight behaviour of the STR and NAVCAM in flight during CVP.
- NavCam: For Sun distances ≤ 1 AU, the NavCam optical head inside the baffle may get too hot if it is illuminated by the Sun (whether operational or not):
  - Sun avoidance angle ≥ 20° about boresight, at ≤ 1 AU Sun distance
- Thrusters on -Z-side (Delta-V thrusters, modules 9 to 12, refer to FCP-SY0370) may become too hot for small Sun distances:
  - for Sun distances ≤ 0.97 AU, the Sun shall be at least 70° away from the -Z-axis; smaller angles are allowed only for a limited duration (temperatures need to be monitored)
  - for Sun distances of 0.97 to 1.8 AU the Sun shall be at least 40° away from the -Z-axis; smaller angles are allowed only for a limited duration (temperatures need to be monitored)
- Solar array position: It is recommended to maintain the solar array at a positive angle whenever possible (i.e. pointing above +X-axis).

  This means that attitudes, that require the solar array to be rotated downwards, shall be used only when really necessary, like for Delta-V manoeuvres, payload pointing, and asteroid fly-by. If it cannot be avoided, the array rotation should be limited to -50° (lower end for MGA strobing range), if possible from power and spacecraft safety point of view. Spacecraft safety in this respect means, that for Delta-V manoeuvres the linear range sun-pointing surveillance must remain active and therefore the solar array offset from sun-pointing must not be larger than 10° in manoeuvre attitude (linear range sun-pointing threshold is set to 16°). On the other hand, in wheel-based modes the linear range sun-pointing surveillance may be disabled temporarily to allow larger offsets.

  Reason for this recommendation: Considering the possibility that one of the solar panels blocks at a certain position (in the vicinity of which then the sane panel has to be kept), then it would be preferable that this happens in the positive pointing range, where the Lander thermal constraints on the attitude are not so severe than in the negative range.
- Solar incidence on the +/-Y side walls: max 5° at 1 AU Sun distance; this angle can be increased to 40° at 1.25 AU sun distance for pure S/C operation, i.e. without P/L; at 1.9 AU sun distance the angle is 30° for S/C operation and limited P/L operation. Both additional conditions are covered in RO-DSS-TN-1140 ("Thermal Analysis of Special Mission Cases"). If special cases in between are required, they have to be thermally assessed depending on the actual conditions.
- During Delta-V manoeuvres the linear range sun-pointing surveillance must remain active and therefore the solar array offset from sun-pointing must not be larger than 10° in manoeuvre attitude (linear range sun-pointing threshold is set to 16°). This means that the

solar incidence on the +/-Y side walls must not be greater than 10° during Delta-V manoeuvres.

- Due to high heat absorption at the LVA ring when the Sun is at SAA = -80°, the –Z propellant tank may reach its temperature limit if the Sun distance is below 1.15 AU and in addition the full P/L is operational. This is a matter of days, however.
- SSP Constraints



Maximum and minimum Solar Aspect Angles
for nominal attitude (β ~ 0).

D. Stramaccioni SCI-PRS

The Lander shall be shaded against sunlight during the Cruise Phases, the asteroid detection phases and during the comet approach and observation phases.

This means in the above picture: α_{max} is 85° and α_{min} is -55°

A margin for attitude control deadband and errors of 5° to these limits shall be observed.

During the launch phase, Delta-V manoeuvres, and asteroid flyby phases the following possible exceptions are allowed:

- Solar radiation onto –Z side of the Lander baseplate for duration less than the equivalent of 24 hours of perpendicular sun illumination at 1 AU is allowed. After illumination, a cool-off period longer than 4 times the equivalent illumination duration (perpendicular at 1 AU) must be allowed. During the 'barbecue' manoeuvre of the launch coast phase, the cool-off period is meant to take place after completion of the coast phase.
- Solar radiation onto the Solar Generator at heliocentric distances larger than 1 AU is allowed.
- Solar radiation onto the solar absorbers on the +Z side of the Lander for a duration of less than the equivalent of 25 minutes of perpendicular sun-illumination at 1 AU is allowed. A cool-off period of 40 hours must be allowed after illumination. During the 'barbecue' manoeuvre of the launch coast phase, an illumination with an angle of less than 12.5° from the plane of the solar absorbers is allowed. The cool-off period is meant to take place after completion of the coast phase.

Table 3-12a below summarizes the attitude constraints for nominal operation of the payload and S/C equipment during mission and emergency actions executed on-board in case of Safe Mode.

Unit	Attitude Constraint for nominal mission operation[1]	Emergency actions executed on-board in case of Safe Mode	used during Asteroid fly-by
ALICE	sun avoidance angle is 11° about s/c +Z-axis when instrument cover is open	Safe Mode OBCP calls Instrument Safing OBCP[2] to ensure payload safety; LCL Off command in SIT (System Initialisation Table)	yes
COSIMA	sun avoidance angle is 10° about s/c +Z-axis when instrument cover is open	LCL Off command in SIT	no
GIADA	sun avoidance angle > 11° about +Z-axis during instrument operation for thermal reasons sun avoidance angle > 80° wrt -Y-axis in the xy-plane during instrument operation sun avoidance angle > 65° wrt -Y-axis in the yz-plane during instrument oration	Safe Mode OBCP calls Instrument Safing OBCP to ensure payload safety; LCL Off command in SIT[3] (System Initialisation Table)	no
MIRO	none	LCL Off command in SIT	yes
OSIRIS	sun avoidance angle ≥90° about +Z-axis during WAC instrument operation a specific time. The allowed operation time depends on the angle between sun and +Z axis and is typically 4h for an angle of 30° (see OSIRIS UM, §4.5.1) sun avoidance angle > 45° about +Z-axis when NAC instrument cover is open and instr. is operated. NAC could be used for approx. 30 minutes for sun incidence angles between 45° and 12° under PI request sun avoidance angle > 11° about +Z-axis when NAC/WAC instrument cover is open	Safe Mode OBCP calls Instrument Safing OBCP to ensure payload safety; LCL Off command in SIT (System Initialisation Table)	yes
RPC	none	LCL Off command in SIT	yes
VIRTIS	sun avoidance angle ≥10° about +Z-axis when instrument is operating. When instrument cover is closed => no constraint When instrument cover is open => constraint applies	LCL Off command in SIT	yes
SSP	sun avoidance angle ≥5°+5° margin away from +Z-axis towards +X-axis and ≥ 35°+5° margin away from -Z-axis towards +X-axis	LCL Off command in SIT	no
STR/NAVCAM	sun avoidance angle > 65° about boresight at 1 AU sun avoidance angle > 45° about boresight above 2 AU	Switch off performed by AOCMS S/W	yes
NAVCAM	non-operational NAVCAM: sun avoidance angle ≥ 20° about boresight, at ≤ 1 AU Sun distance	Switch off performed by AOCMS S/W	yes
-Z Thrusters (No. 9 to 12)	Near Sun the Delta-V thrusters may get too hot: • for Sun distances ≤ 0.97 AU, the Sun shall be at least 70° away from the -Z-axis • for Sun distances of 0.97 to 1.8 AU the Sun shall be at least 40° away from the -Z-axis	Safe attitude is established	
STR-B	Avoid Sun reflections into STR-B from Virtis radiator rim, until characterised during CVP • ≥ -80° in X/Z plane, counting from +X • Sun grazing on -Y-side ≤ 5° (lower hemisphere)	Switch off performed by AOCMS S/W	
radiators on +/-Y side walls	Solar incidence on the +/-Y side walls: • max 5° at 1 AU Sun distance • 40° at 1.25 AU Sun distance for pure S/C operation, i.e. without P/L • 30° at 1.9 AU Sun distance for S/C operation and limited P/L operation	Safe attitude is established with Sun in X/Z-plane	

[1] constraints which would lead to a performance degradation are not listed

[2] for details see System Level OBCP URD RO-DSS-RS-1019

[3] for details see System Autonomy Requirements Software URD RO-DSS-RS-1016

Unit	Attitude Constraint for nominal mission operation[1]	Emergency actions executed on-board in case of Safe Mode	used during Asteroid fly-by
Delta-V attitude	The solar array offset from sun-pointing must not be larger than 10° in Delta-V manoeuvre attitude (because the linear range sun-pointing surveillance must be active with the threshold set to 16°). This means that the solar incidence on the +/-Y side walls must not be greater than 10° during Delta-V manoeuvres.	Safe attitude is established	
-Z propellant tank	When the sun is at SAA = -80°, the –Z propellant tank may reach its temperature limit if the Sun distance is below 1.15 AU and in addition the full P/L is operational. This is a matter of days, however.	Safe attitude is established	

Table 3-12a: Summary of attitude constraints

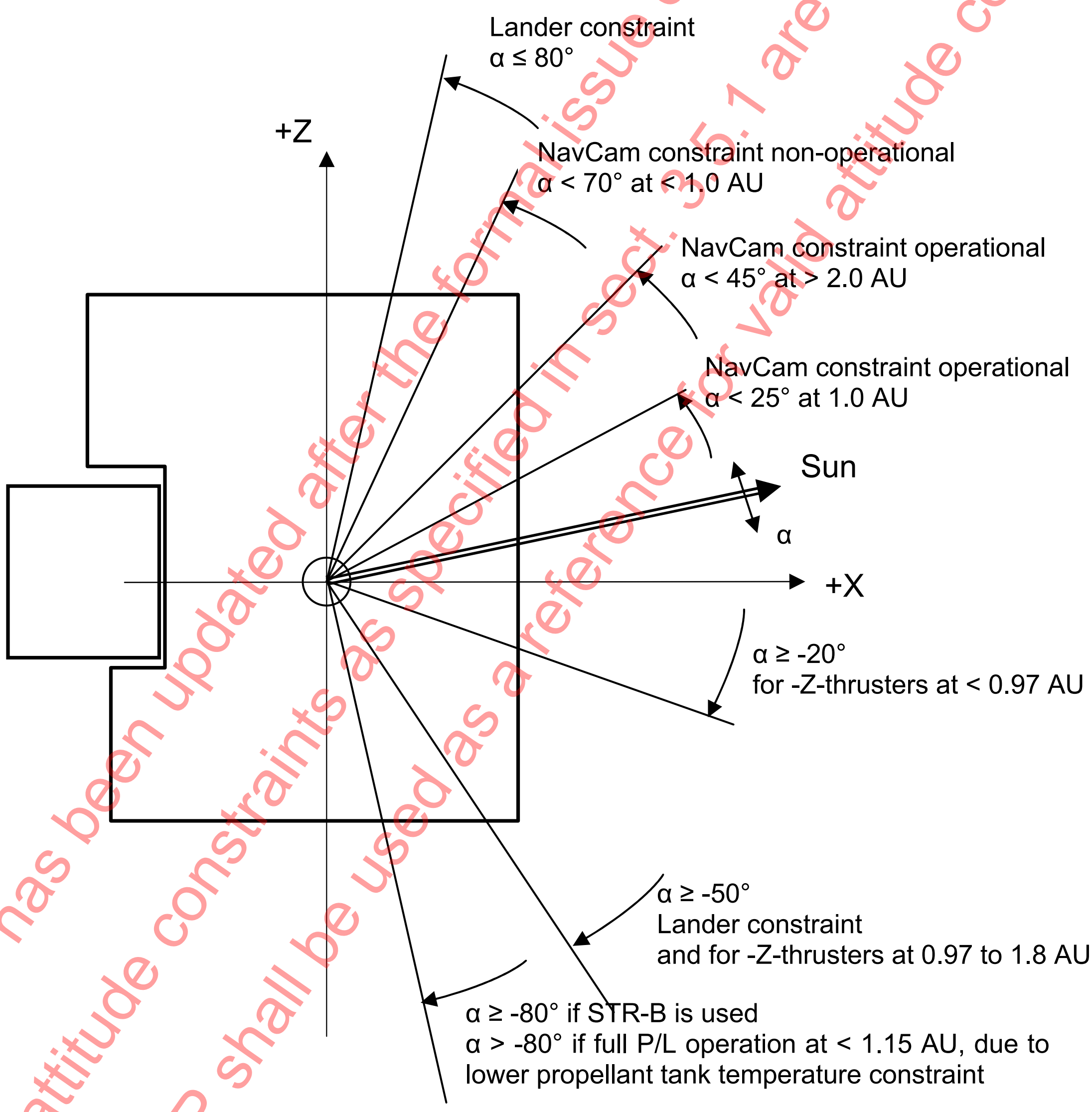


Fig. 3-1: Main Attitude Constraints from Spacecraft and Lander

<u>Attitude Measurement prior to Delta-V Manoeuvres, when STR-B is blinded</u>

When the spacecraft has been re-orientated to its Delta-V orientation, the attitude shall be measured by one of the STRs to validate the orientation.

There is only one exception to this requirement, as described below.

Suppose, the Delta-V manoeuvre orientation is such that the Sun is below -80°, i.e. $-90° \leq \alpha < -80°$ (-90° is a logical limit: if the angle is < -90°, the spacecraft would be re-orientated by 180° around the Z axis), and for the attitude measurement only STR-B is available, which is probably blinded in this attitude by solar reflections from the Virtis radiator (see constraints above).

Then two options are available in order to measure the spacecraft attitude. The preferred option is to perform the delta-V as a dogleg, the dogleg being designed such that, for each leg, the Sun is at $\alpha \geq -80°$.

If this is not possible due to the fuel penalty, then the following option may be used.

Firstly, the slew from the current attitude to the delta-V attitude shall be split into two slews as follows:

The first slew shall bring α to -80°, and shall include a possible out-of-X/Z-plane component of the Sun vector (offset must be ≤ 5° on -Y-side, otherwise blinding of STR-B). The second slew will be purely a rotation around the spacecraft –Y axis to bring α to the value required for the Delta-V. The magnitude of this second slew will be ≤ 10°.

At the end of the first slew, the spacecraft attitude shall be verified using STR-B. Also, the SADM angle measurements and the SAS_{+Y} and SAS_{-Y} measurements shall be recorded. In addition, the APME azimuth and elevation angle measurements and the HGA X-band carrier downlink signal strength shall be recorded. Note for the carrier signal strength measurement, the TM must be temporarily stopped.

At the end of the second slew, if the spacecraft attitude can be measured using STR-B, this shall be done. If STR-B is blinded, however, then the spacecraft attitude shall be checked as follows: The SADM angle measurements and the SAS_{+Y} and SAS_{-Y} measurements shall be recorded. The change in Sun position with respect to the spacecraft attitude at the end of the first slew should correspond to the magnitude of the second slew around the –Y axis. This change should be seen as a change in the SADM angle measurements, with negligible change in the SAS measurements. In addition, the APME azimuth and elevation angle measurements and the HGA X-band carrier downlink signal strength shall be recorded. The change in Earth position with respect to the spacecraft attitude at the end of the first slew should correspond to the magnitude of the second slew around the –Y axis. This change should be seen as a change in the HGA elevation angle. The HGA azimuth angle and the X-band carrier downlink signal strength should be the same as at the end of the first slew.

This scheme ensures that the Delta-V orientation is correct, even if the STR-B is blinded in the Delta-V orientation.

3.5.2 Power Constraints in Deep Space

3.5.2.1 General Strategy

In the phases with Sun distances above approximately 4.0 AU the decreasing solar array power forces the use of economical strategies for certain operations. Thereby the situation after the deep space hibernation phase is much more severe. From radiation degradation analysis it has been derived that after DSHM at 4.5 AU about 65 W less solar array power will be available compared to 4.5 AU before DSHM. This corresponds to about 13% of the power needed at that distance.

In the deep space phases the general operational concept is the following:

- minimise the overall power consumption by switching off all equipment not directly needed during the current operation
- additionally, for certain operations with high extra power demand, perform a power sharing strategy by switching off some TCS heaters; as a consequence this puts a time limit on such operations
- operate equipment like RWs and SSMM in reduced power mode
- for autonomous operations, which are not directly under ground control, like in Safe Mode, the ground can set a Low Power Flag as invocation parameter in the call of the Safe Mode OBCP (which is loaded in the System Init Table) at the appropriate time in the mission, according to the current Sun distance. This flag will be checked by the OBCP; if the flag is set, the Safe Mode downlink will be performed in power sharing strategy and the SSMM is set into stand-by mode (memory modules remain powered, but memory controllers are switched off).

As a safety precaution the battery discharge alarm shall remain enabled all the time. This will allow for nominal short (< 4 min) peak power demands to be satisfied by the batteries, e.g. for RW offloading, but will trigger a system alarm and transition to Safe Mode in case of a creeping battery discharge due to a wrong power configuration e.g. because of a missed command. If for such a case a processor reconfiguration is not desired, it is possible to use the monitoring of the MEA Voltage to trigger transition into Safe Mode before the battery discharge alarm triggers (see Handling of On-board Monitoring, RO-DSS-TN-1155).

The guidelines given below are based on conservative power budget considerations, with the aim to maintain as far as possible a power margin of about 10%. During flight the actually available power shall be determined at certain points in the mission by searching for the PCU maximum power point and calibrating the readings from the reference cells, see procedures to 'Verify SA Thermal Model, FCP-TS0270'. With this knowledge a reduced margin could be accepted.

The operational strategies, which are possible for power saving, are summarised in the following Table.

Operation	Power Saving Strategy in Low Power Situation	Remarks
normal downlink operation, S- and X-Band	power sharing with TCS tank heaters during downlink operation, allowed max. downlink duration about 10 hours per day (only 3 hours per day if also the SSP heater is switched off) AOCMS in Gyroless Ephemerides Pointing during downlink SADE off APME on only as long as needed for position update, else off	The operational strategy for downlink operation with power sharing are described in FCP-SY0200 'Station Pass Management'
operations for comet detection with NavCam	not to be performed together with downlink operation data storage in SSMM for later downlink power sharing with TCS tank heaters during this operation, allowed max. downlink duration about 10 hours per day (only 3 hours per day, if also the SSP heater is switched off) SADE on only during slews and for short position updates if needed APME off one gyro only if slews are performed for comet search	General power sharing strategy is described in TCS Procedure FCP-SY0370 'Thermal Control Management'
SSMM operation	used in minimum power configuration, i.e. one Memory Module only with one converter	10 GB storage capacity with 1 MM; for SSMM; configuration see DMS S/S procedures
RW and gyros operation	RW torque and speed limits set to restrict steady state consumption to less than 20W per wheel; timely off-loading generally only one gyro should be used, whenever possible and during X-Band downlink: gyroless mode; during Delta-V manoeuvres two gyros can be used	Procedure for torque and speed limitation see in AOCMS S/S procedures; RW transient peak power demands during mode transitions (TTM to WDP) or offloading are to be supported by the batteries
SADE and APME operation	activated only when needed for position update and not simultaneously (ground task) during slews the SADE can stay off, if the SA offset from Sun stays below 15° (the power loss at 15° offset is smaller than the SADE consumption)	
Safe Mode	use of two gyros shall always be authorised for the transition to Safe/Survival Modes; when necessary, the use of reaction wheels can be inhibited (use of wheels set to "not allowed" in SGM EEPROM); before return to wheel based mode under ground control, the P/L heater LCLs 8, 13, 18, and 1 gyro have to be switched off (this is needed only after DSHM).	

Operation	Power Saving Strategy in Low Power Situation	Remarks
	Intermittent S-Band downlink with power sharing in a 12 hour cycle, when the 'Low Power Flag' is set: 5 hours downlink on with tank heaters off, followed by 7 hours downlink off with tank heaters on; the SSMM is set to standby mode, when the 'Low Power Flag' is set: memory modules remain powered, but memory controllers are switched off APME and SADE off most of the time (AOCMS deep space flag set to "True" in SGM EEPROM), for position update the AOCMS S/W performs autonomously the following (not simultaneously): SADE: 2 min on every day APME: 2 min on every day	
Survival Mode X-Band	power sharing with TCS tank heaters during X-Band downlink in deep space; by invocation parameter in the call of the 'Recovery from Survival Mode' OBCP. It can be selected if the downlink shall be activated continuously or only for 10h.	This OBCP is called from ground, see procedure CRP-SY0020 'Recovery from Survival Mode'

3.5.2.2 Special Cases

3.5.2.2.1 DSHM Entry[1]

At a Sun distance of 4.6 AU (latest DSHM entry) the power constraints result in the following:

- the necessity of appropriate sequencing of the individual operations, i.e. equipment like APME, SADM, RWs, second Gyro, S- or X-Band transmitter can not be operated at any time; especially the usage of APM and SADM must be handled differently in some cases compared to the autonomous activities in AOCMS mode transitions
- the RW torques and speeds during the slew must be limited such that the power consumption per wheel does not exceed about 22 W; this corresponds to a usable torque level of e.g. 0.03 Nm at 15 Nms (the required 44° slew can be made easily within 1 hour)
- during certain operations (slew phase, downlink, etc.) the tank heaters have to be switched off to provide sufficient power margin; these heaters can be switched off for about 10 hours per day
- even with the tank heaters switched off it is not always possible to maintain the downlink

In the last section of procedure FCP-SY0160 power budget tables are included, showing the equipment configuration and the currently predicted power situation at each step of the procedure. This budget, and consequently also the operational procedure, is based on the following assumptions:

[1] Referenz: procedure FCP-SY0160

- power margin maintained > 10%
- available power at 4.6 AU is, with SAA 5°: 608 W, with SAA 30°: 532 W, according agreed power calculation tool
- the SSMM is in Stby mode up to shortly before spin-up, then it is operational up to final entry

The power budget tables have to be updated during the mission depending on whether a 20 W load failure really has occurred or not and depending on the really available solar array output power. The really available solar array output power can be determined only in deep space, using procedure FCP-TS0270, "Verify Solar Array Thermal Model". Based on the result, it has to be verified by power budget calculation, that there is always sufficient power margin available throughout the complete operation. Under this condition it is also considered acceptable to reduce the required power margin to for example 5%. This could result in some simplification of the strategy.

3.5.2.2.2 DSHM Exit and Recovery[1]

At a Sun distance of 4.5 AU the power constraints result in the following:

- the necessity of appropriate sequencing of the individual operations, i.e. equipment like SSMM, APME, SADM, RWs, S- or X-Band transmitter can not be operated at any time; especially the usage of APM and SADM must be handled differently compared to the autonomous activities in AOCMS mode transitions; in procedure FCP-SY0170 this is the case for the transition WDP to GSP, where the APM and SADM are autonomously switched on by the AOCMS, and have to be switched-off again shortly afterwards by MTL command; they are not needed at that time, because the guidance strategy for SHM and the target mode GLEP is the same
- the RW torques and speeds must be limited such that the power consumption per wheel does not exceed about 18 W; this corresponds to a usable torque level of e.g. 0.01 Nm at 20 Nms
- during certain operations the tank heaters have to be switched off to provide sufficient power margin; these heaters can be switched off for about 10 hours cumulated per day; this switching is handled by the Safe Mode OBCP and therefore considered safe
- if the power margin turns out to be too low in some cases (as determined in the Power Test) also the SSP heater may have to be switched off in addition to the tank heaters; this is allowed only for 3 hours per day; this SSP heater switching is not part of the Safe Mode OBCP, therefore it would have to be handled by the Short MTL with back-up commands from ground for safety reasons
- the use of the SSMM is foreseen only when the last gyro has been switched off (AOCMS in GLEP); this means that there are no OBCPs for Link Configuration available other than the OBCPs for Safe Mode and Recovery from Survival Mode

In the last section of procedure FCP-SY0170 power budget tables are included, showing the equipment configuration and the currently predicted power situation at each step of the pro-

[1] Referenz: procedure FCP-SY0170

cedure. This budget, and consequently also the operational procedure, is tailored to maintain always a power margin of > 10%.

The power budget tables have to be updated during the mission depending if an uncorrectable LCL or load failure has occurred and depending on the really available solar array output power as determined during the Power Test. Based on the result, it has to be verified by power budget calculation, that there is always sufficient power margin available throughout the complete operation. Under this condition it is also considered acceptable to reduce the required power margin to for example 5%. This could result in some simplification of the strategy.

3.5.2.2.3 Recovery from Safe and Survival Mode[1][2]

Above 4.0 AU Sun distance certain precautions shall be taken to avoid battery discharge, until the real solar array output power is better known by performing procedure FCP-TS0270.

After DSHM the available power is a lot less than before, due to radiation effects. Therefore power saving strategies have to be applied probably down to below 4.0 AU (subject to a power test after DSHM).

Flags in Safe- and Survival Mode

In order to observe the power constraints, various flags must be set appropriately for Safe Mode and for Survival Mode. From current power predictions, the situation is as shown in the following three figures.

Variables not handled by Flags (but also included in the following figures)

<u>Use of SSMM</u>

Above 4.15/3.74 AU Sun distance (before/after DSHM) the SSMM shall be operated only with 1 MM active.

<u>PL PDU LCLs 8A, 13A, 18A</u>

These payload heater LCLs are switched on by the SIT, as well as the corresponding cycling OBCP KSBF6458. They have to be on when the RWs are off. They are in the SIT also in phases where the use of RWs is allowed, because this does not ensure that they are indeed on. When the RWs are confirmed to be running, these heaters can be switched off.

[1] Referenz: procedure CRP-SY0010

[2] Referenz: procedure CRP-SY0020

Sun-spacecraft distance | **SAFE MODE** | Array power | **SURVIVAL MODE** | Sun-spacecraft distance

4.60 AU — **608 W** — **4.60 AU**

Safe Mode (4.60 AU)

AOCMS_COMMON.Set_Deep_Space_Flag = TRUE.
Safe Mode OBCP: LOW POWER flag = TRUE.
RWA_ORB.Enable_Wheels_Use = TRUE.

WORST CASE POWER CONSUMPTION IN SAFE MODE		
S/C configuration	**Steady state**	**Recovery operations**
SADE/APME	Intermittently ON	
SSMM	Standby mode	
Tank heaters	At entry, TM is ON and heaters are OFF. Power then switched between these. Worst case is with TM OFF and heaters ON.	
S-band TM D/L (21 bps via HGA)		
RWs (3)	ON (up to 18W each)	
P/L heaters 8, 13, 18	ON	
STR SW heater	ON	
Gyros	2 are ON	
STR	ON	
Power required with 10% margin	*600 W*	*600 W*

Worst case power needed with 10% margin = 600 W
Worst case power margin at 4.60 AU = 11.5%

Survival Mode (4.60 AU)

WORST CASE POWER CONSUMPTION IN SURVIVAL MODE		
S/C configuration	**Steady state**	**Recovery operations**
X-band TM D/L (64 bps via MGA)	OFF	CONTINUOUS LINK flag = FALSE (worst case is with X-band TM D/L ON and tank heaters OFF)
Tank heaters	ON	
S-band carrier D/L	ON	OFF
STR SW heater	OFF	ON
SADE	ON	
STR	OFF	ON
P/L heaters 8, 13, 18	ON	
Gyros	2 are ON	
SSMM	As Safe Mode LOW POWER flag, i.e. in Standby mode.	
RWs and APME	OFF	
Power required with 10% margin	*532 W*	*589 W*

Worst case power needed with 10% margin = 589 W
Worst case power margin at 4.60 AU = 13.5%

4.46 AU — **643 W** — **4.46 AU**

Safe Mode (4.46 AU)

AOCMS_COMMON.Set_Deep_Space_Flag = TRUE.
Safe Mode OBCP: LOW POWER flag = FALSE.
RWA_ORB.Enable_Wheels_Use = TRUE.

WORST CASE POWER CONSUMPTION IN SAFE MODE		
S/C configuration	**Steady state**	**Recovery operations**
SADE/APME	Intermittently ON	
SSMM	1 memory module ON	
Tank heaters	ON	
S-band TM D/L (21 bps via HGA)	ON	
RWs (3)	ON (up to 18W each)	
P/L heaters 8, 13, 18	ON	
STR SW heater	ON	
Gyros	2 are ON	
STR	ON	
Power required with 10% margin	*640 W*	*640 W*

Worst case power needed with 10% margin = 640 W
Worst case power margin at 4.46 AU = 10.5%

Survival Mode (4.46 AU)

WORST CASE POWER CONSUMPTION IN SURVIVAL MODE		
S/C configuration	**Steady state**	**Recovery operations**
X-band TM D/L (64 bps via MGA)	OFF	CONTINUOUS LINK flag = TRUE (worst case is with X-band TM D/L ON and tank heaters ON)
Tank heaters	ON	
S-band carrier D/L	ON	OFF
STR SW heater	OFF	ON
SADE	ON	
STR	OFF	ON
P/L heaters 8, 13, 18	ON	
Gyros	2 are ON	
SSMM	As Safe Mode LOW POWER flag, i.e. 1 memory module ON.	
RWs and APME	OFF	
Power required with 10% margin	*545 W*	*643 W*

Worst case power needed with 10% margin = 643 W
Worst case power margin at 4.46 AU = 10%

4.28 AU — **692 W**

Safe Mode (4.28 AU)

AOCMS_COMMON.Set_Deep_Space_Flag = FALSE.
Safe Mode OBCP: LOW POWER flag = FALSE.
RWA_ORB.Enable_Wheels_Use = TRUE.

WORST CASE POWER CONSUMPTION IN SAFE MODE		
S/C configuration	**Steady state**	**Recovery operations**
SADE/APME	ON	
SSMM	1 memory module ON	
Tank heaters	ON	
S-band TM D/L (21 bps via HGA)	ON	
RWs (3)	ON (up to 18W each)	
P/L heaters 8, 13, 18	ON	
STR SW heater	ON	
Gyros	2 are ON	
STR	ON	
Power required with 10% margin	*692 W*	*692 W*

Worst case power needed with 10% margin = 692 W
Worst case power margin at 4.28 AU = 10%

Fig. 3-10: Power Settings for Safe Mode and Survival Mode before DSHM

Sun-spacecraft distance | **SAFE MODE** | **Array power** | **SURVIVAL MODE** | **Sun-spacecraft distance**

4.17 AU — **723 W**

AOCMS_COMMON.Set_Deep_Space_Flag = FALSE.
Safe Mode OBCP: LOW POWER flag = FALSE.
RWA_ORB.Enable_Wheels_Use = TRUE.

WORST CASE POWER CONSUMPTION IN SAFE MODE		
S/C configuration	**Steady state**	**Recovery operations**
SADE/APME	ON	
SSMM	1 memory module ON	
Tank heaters	ON	
S-band TM D/L (21 bps via HGA)	ON	
RWs (3)	ON (up to 27W each)	
P/L heaters 8, 13, 18	ON	
STR SW heater	ON	
Gyros	2 are ON	
STR	ON	
Power required with 10% margin	*723 W*	*723 W*

Worst case power needed with 10% margin = 723 W
Worst case power margin at 4.17 AU = 10%

4.15 AU — **731 W** — **4.15 AU**

AOCMS_COMMON.Set_Deep_Space_Flag = FALSE.
Safe Mode OBCP: LOW POWER flag = FALSE.
RWA_ORB.Enable_Wheels_Use = TRUE.

WORST CASE POWER CONSUMPTION IN SAFE MODE		
S/C configuration	**Steady state**	**Recovery operations**
SADE/APME	ON	
SSMM	All memory modules ON	
Tank heaters	ON	
S-band TM D/L (21 bps via HGA)	ON	
RWs (3)	ON (up to 27W each)	
P/L heaters 8, 13, 18	ON	
STR SW heater	ON	
Gyros	2 are ON	
STR	ON	
Power required with 10% margin	*731 W*	*731 W*

Worst case power needed with 10% margin = 731 W
Worst case power margin at 4.15 AU = 10%

WORST CASE POWER CONSUMPTION IN SURVIVAL MODE		
S/C configuration	**Steady state**	**Recovery operations**
X-band TM D/L (64 bps via MGA)	OFF	CONTINUOUS LINK flag = TRUE (worst case is with X-band TM D/L ON and tank heaters ON)
Tank heaters	ON	
S-band carrier D/L	ON	OFF
STR SW heater	OFF	ON
SADE	ON	
STR	OFF	ON
P/L heaters 8, 13, 18	ON	
Gyros	2 are ON	
SSMM	As Safe Mode LOW POWER flag, i.e. all memory modules ON.	
RWs and APME	OFF	
Power required with 10% margin	*553 W*	*651 W*

Worst case power needed with 10% margin = 651 W
Worst case power margin at 4.15 AU = 23.6%

Fig. 3-10 (cont'd): Power Settings for Safe Mode and Survival Mode before DSHM

Sun-spacecraft distance — **SAFE MODE** — **Array power** — **SURVIVAL MODE** — **Sun-spacecraft distance**

SAFE MODE — 4.50 AU (Array power 540 W)

AOCMS_COMMON.Set_Deep_Space_Flag = TRUE.
Safe Mode OBCP: LOW POWER flag = TRUE.
RWA_ORB.Enable_Wheels_Use = FALSE.
To complete SHM:
- Switch OFF P/L heaters 8, 13, and 18.
- Switch from 2 gyros to 1 gyro.
- Set RWA_ORB.Enable_wheels_Use = TRUE.

WORST CASE POWER CONSUMPTION IN SAFE MODE

S/C configuration	Steady state	Recovery operations
SADE/APME	Intermittently ON	
SSMM	Standby mode	
Tank heaters	At entry, TM is ON and heaters are OFF. Power then switched between these. Worst case is with TM OFF and heaters ON.	
S-band TM D/L (21 bps via HGA)		
RWs (3)	OFF	ON (up to 18W each)
P/L heaters 8, 13, 18	ON	OFF
STR SW heater	ON	
Gyros	2 are ON	1 is ON
STR	ON	
Power required with 10% margin	*537 W*	*540 W*

Worst case power needed with 10% margin = 540 W
Worst case power margin at 4.50 AU = 10%

SURVIVAL MODE — 4.50 AU

WORST CASE POWER CONSUMPTION IN SURVIVAL MODE

S/C configuration	Steady state	Recovery operations
X-band TM D/L (64 bps via MGA)	OFF	CONTINUOUS LINK flag = FALSE (worst case is with X-band TM D/L ON and tank heaters OFF)
Tank heaters	ON	
S-band carrier D/L	ON	OFF
STR SW heater	OFF	ON
SADE	ON	Power switched between these. Worst case is with STR ON and SADE OFF.
STR	OFF	
P/L heaters 8, 13, 18	ON	
Gyros	2 are ON	
SSMM	As Safe Mode LOW POWER flag, i.e. in Standby mode.	
RWs and APME	OFF	OFF
Power required with 10% margin	*532 W*	*566 W*

Worst case power needed with 10% margin = 566 W
Worst case power margin at 4.50 AU = 5%

Note that this is actually pessimistic as it is based on radiation degradation of the solar arrays for 10.5 years. In fact, the correct duration for radiation degradation is 3620 days (9.9 years). In this case, the expected array power is 565 W. Therefore, the worst case power margin at 4.5 AU is actually 9.8%.

SAFE MODE — 4.32 AU (Array power 577 W)

AOCMS_COMMON.Set_Deep_Space_Flag = TRUE.
Safe Mode OBCP: LOW POWER flag = TRUE.
RWA_ORB.Enable_Wheels_Use = FALSE.
To complete SHM:
- Switch OFF P/L heaters 8, 13, and 18.
- Set RWA_ORB.Enable_wheels_Use = TRUE.

WORST CASE POWER CONSUMPTION IN SAFE MODE

S/C configuration	Steady state	Recovery operations
SADE/APME	Intermittently ON	
SSMM	Standby mode	
Tank heaters	At entry, TM is ON and heaters are OFF. Power then switched between these. Worst case is with TM OFF and heaters ON.	
S-band TM D/L (21 bps via HGA)		
RWs (3)	OFF	ON (up to 18W each)
P/L heaters 8, 13, 18	ON	OFF
STR SW heater	ON	
Gyros	2 are ON	
STR	ON	
Power required with 10% margin	*537 W*	*577 W*

Worst case power needed with 10% margin = 577 W
Worst case power margin at 4.32 AU = 10%

SURVIVAL MODE — 4.26 AU (Array power 589 W)

WORST CASE POWER CONSUMPTION IN SURVIVAL MODE

S/C configuration	Steady state	Recovery operations
X-band TM D/L (64 bps via MGA)	OFF	CONTINUOUS LINK flag = FALSE (worst case is with X-band TM D/L ON and tank heaters OFF)
Tank heaters	ON	
S-band carrier D/L	ON	OFF
STR SW heater	OFF	ON
SADE	ON	
STR	OFF	ON
P/L heaters 8, 13, 18	ON	
Gyros	2 are ON	
SSMM	As Safe Mode LOW POWER flag, i.e. in Standby mode.	
RWs and APME	OFF	
Power required with 10% margin	*532 W*	*589 W*

Worst case power needed with 10% margin = 589 W
Worst case power margin at 4.26 AU = 10%

Fig. 3-11: Power Settings for Safe and Survival Mode after DSHM

SAFE MODE | **Array power** | **SURVIVAL MODE**

Sun-spacecraft distance

4.21 AU — 600 W

AOCMS_COMMON.Set_Deep_Space_Flag = TRUE.
Safe Mode OBCP: LOW POWER flag = TRUE.
RWA_ORB.Enable_Wheels_Use = TRUE.

WORST CASE POWER CONSUMPTION IN SAFE MODE		
S/C configuration	**Steady state**	**Recovery operations**
SADE/APME	Intermittently ON	
SSMM	Standby mode	
Tank heaters S-band TM D/L (21 bps via HGA)	At entry, TM is ON and heaters are OFF. Power then switched between these. Worst case is with TM OFF and heaters ON.	
RWs (3)	ON (up to 18W each)	
P/L heaters 8, 13, 18	ON	
STR SW heater	ON	
Gyros	2 are ON	
STR	ON	
Power required with 10% margin	*600 W*	*600 W*

Worst case power needed with 10% margin = 600 W
Worst case power margin at 4.21 AU = 10%

4.04 AU — 643 W — 4.04 AU

AOCMS_COMMON.Set_Deep_Space_Flag = TRUE.
Safe Mode OBCP: LOW POWER flag = FALSE.
RWA_ORB.Enable_Wheels_Use = TRUE.

WORST CASE POWER CONSUMPTION IN SAFE MODE		
S/C configuration	**Steady state**	**Recovery operations**
SADE/APME	Intermittently ON	
SSMM	1 memory module ON	
Tank heaters	ON	
S-band TM D/L (21 bps via HGA)	ON	
RWs (3)	ON (up to 18W each)	
P/L heaters 8, 13, 18	ON	
STR SW heater	ON	
Gyros	2 are ON	
STR	ON	
Power required with 10% margin	*640 W*	*640 W*

Worst case power needed with 10% margin = 640 W
Worst case power margin at 4.04 AU = 10.5%

WORST CASE POWER CONSUMPTION IN SURVIVAL MODE		
S/C configuration	**Steady state**	**Recovery operations**
X-band TM D/L (64 bps via MGA)	OFF	CONTINUOUS LINK flag = TRUE (worst case is with X-band TM D/L ON and tank heaters ON)
Tank heaters	ON	
S-band carrier D/L	ON	OFF
STR SW heater	OFF	ON
SADE	ON	
STR	OFF	ON
P/L heaters 8, 13, 18	ON	
Gyros	2 are ON	
SSMM	As Safe Mode LOW POWER flag, i.e. 1 memory module ON.	
RWs and APME	OFF	
Power required with 10% margin	*545 W*	*643 W*

Worst case power needed with 10% margin = 643 W
Worst case power margin at 4.04 AU = 10%

3.86 AU — 692 W

AOCMS_COMMON.Set_Deep_Space_Flag = FALSE.
Safe Mode OBCP: LOW POWER flag = FALSE.
RWA_ORB.Enable_Wheels_Use = TRUE.

WORST CASE POWER CONSUMPTION IN SAFE MODE		
S/C configuration	**Steady state**	**Recovery operations**
SADE/APME	ON	
SSMM	1 memory module ON	
Tank heaters	ON	
S-band TM D/L (21 bps via HGA)	ON	
RWs (3)	ON (up to 18W each)	
P/L heaters 8, 13, 18	ON	
STR SW heater	ON	
Gyros	2 are ON	
STR	ON	
Power required with 10% margin	*692 W*	*692 W*

Worst case power needed with 10% margin = 692 W
Worst case power margin at 3.86 AU = 10%

Fig. 3-11 (cont'd): Power Settings for Safe and Survival Mode after DSHM

Sun-spacecraft distance | **SAFE MODE** | **Array power** | **SURVIVAL MODE** | **Sun-spacecraft distance**

3.76 AU — **723 W**

AOCMS_COMMON.Set_Deep_Space_Flag = FALSE.
Safe Mode OBCP: LOW POWER flag = FALSE.
RWA_ORB.Enable_Wheels_Use = TRUE.

WORST CASE POWER CONSUMPTION IN SAFE MODE		
S/C configuration	**Steady state**	**Recovery operations**
SADE/APME	ON	
SSMM	1 memory module ON	
Tank heaters	ON	
S-band TM D/L (21 bps via HGA)	ON	
RWs (3)	ON (up to 27W each)	
P/L heaters 8, 13, 18	ON	
STR SW heater	ON	
Gyros	2 are ON	
STR	ON	
Power required with 10% margin	*723 W*	*723 W*

Worst case power needed with 10% margin = 723 W
Worst case power margin at 3.76 AU = 10%

3.74 AU — **731 W** — **3.74 AU**

Safe Mode, 3.74 AU:

AOCMS_COMMON.Set_Deep_Space_Flag = FALSE.
Safe Mode OBCP: LOW POWER flag = FALSE.
RWA_ORB.Enable_Wheels_Use = TRUE.

WORST CASE POWER CONSUMPTION IN SAFE MODE		
S/C configuration	**Steady state**	**Recovery operations**
SADE/APME	ON	
SSMM	All memory modules ON	
Tank heaters	ON	
S-band TM D/L (21 bps via HGA)	ON	
RWs (3)	ON (up to 27W each)	
P/L heaters 8, 13, 18	ON	
STR SW heater	ON	
Gyros	2 are ON	
STR	ON	
Power required with 10% margin	*731 W*	*731 W*

Worst case power needed with 10% margin = 731 W
Worst case power margin at 3.74 AU = 10%

Survival Mode, 3.74 AU:

WORST CASE POWER CONSUMPTION IN SURVIVAL MODE		
S/C configuration	**Steady state**	**Recovery operations**
X-band TM D/L (64 bps via MGA)	OFF	CONTINUOUS LINK flag = TRUE (worst case is with X-band TM downlink ON and tank heaters ON)
Tank heaters	ON	
S-band carrier D/L	ON	OFF
STR SW heater	OFF	ON
SADE	ON	
STR	OFF	ON
P/L heaters 8, 13, 18	ON	
Gyros	2 are ON	
SSMM	As Safe Mode LOW POWER flag, i.e. all memory modules ON.	
RWs and APME	OFF	
Power required with 10% margin	*553 W*	*651 W*

Worst case power needed with 10% margin = 651 W
Worst case power margin at 3.74 AU = 23.6%

Fig. 3-11 (cont'd): Power Settings for Safe and Survival Mode after DSHM

AOCMS (TC): AOCMS_COMMON.Set_Deep_Space_Flag
FALSE ⇒ After entry to SHM-HP, the APME and SADE are permanently ON.
TRUE ⇒ After entry to SHM-HP, the APME and SADE are ON intermittently.
Verified by TM: AOCMS_COMMON.Is_Deep_Space

AOCMS (TC): RWA_ORB.Enable_Wheels_Use
FALSE ⇒ SHM stops in SHM-HP. RWs are not powered.
TRUE ⇒ SHM completes (finishes in SHM-EPP). RWs are powered following exit from SHM-HP.
Verified by TM: RWA_ORB.is_the_use_of_wheels_alwd

AOCMS (TC): SKM_MGR.Set_ES_Rot_Sign
+1 ⇒ The array is rotated in SKM-ESP (SAR) such that the array normal, pointing to the sun, is in the +X +Z quadrant.
-1 ⇒ The array is rotated in SKM-ESP (SAR) such that the array normal, pointing to the sun, is in the +X -Z quadrant.
Verified by TM: SKM_MGR.sa_rot_sign

AOCMS (TC): SKM_MGR.Set_ES_Flag
TRUE ⇒ Transition to strobing is allowed despite a SADE failure (applies throughout the mission, apart from certain manoeuvres at a sun-spacecraft distance > 2.8 AU).
FALSE ⇒ Transition to strobing is not allowed in the case of a SADE failure.
Verified by TM: SKM_MGR.is_ES_alwd_despite_sade_fail

AOCMS (TC): SKM_MGR.Set_mga_strobing_Flag
TRUE ⇒ Strobing is allowed (applies throughout the mission up to a sun-spacecraft distance of ≤ 4.7 AU).
FALSE ⇒ Transition to strobing is not allowed (applies for a sun-spacecraft distance of > 4.7 AU).
Verified by TM: SKM_MGR.is_mga_strobing_alwd

Safe Mode OBCP invocation parameter: LOW POWER flag
FALSE (1) ⇒ SSMM is ON.
Tank heaters are ON continuously. S-band TM D/L (21.3 bps via HGA) is ON continuously.
TRUE (0) ⇒ SSMM is in STANDBY mode.
Tank heaters and S-band TM D/L (21.3 bps via HGA) are cycled (heaters are OFF with D/L ON for 5 hours; then, heaters are ON with D/L OFF for 7 hours).

Safe Mode OBCP invocation parameter: MGA STROBING flag
This flag is not used by the Safe Mode OBCP itself, but is transferred to the Survival Mode OBCP when the Survival Mode OBCP is called by the Safe Mode OBCP.
FALSE (1) ⇒ The Survival Mode OBCP connects the S-band receivers to LGA-F and LGA-R. In addition, it connects the S-band transmitter to LGA-R. (Transmitter 2 is used unless it has failed; then transmitter 1 is used).
TRUE (0) ⇒ The Survival Mode OBCP connects the S-band receivers to LGA-F and MGA. In addition, it connects the S-band transmitter to MGA. (Transmitter 2 is used unless it has failed; then transmitter 1 is used).

Survival Mode OBCP invocation parameter: MGA STROBING flag
FALSE (1) ⇒ The Survival Mode OBCP connects the S-band receivers to LGA-F and LGA-R. In addition, it connects the S-band transmitter to LGA-R. (Transmitter 2 is used unless it has failed; then transmitter 1 is used).
TRUE (0) ⇒ The Survival Mode OBCP connects the S-band receivers to LGA-F and MGA. In addition, it connects the S-band transmitter to MGA. (Transmitter 2 is used unless it has failed; then transmitter 1 is used).

Recovery from Survival Mode OBCP invocation parameter: CONTINUOUS LINK flag
FALSE (0) ⇒ X-band D/L and tank heaters are exclusive. Initially, the tank heaters are ON, the S-band carrier D/L is ON and the X-band carrier D/L is OFF. When the OBCP is called with this flag set to FALSE, the tank heaters are switched OFF, the S-band carrier D/L is switched OFF and the X-band carrier D/L is switched ON. This configuration is maintained for 10 hours, after which the initial configuration is again established (the tank heaters are ON, the S-band carrier D/L is ON and the X-band carrier D/L is OFF).
TRUE (1) ⇒ X-band D/L and tank heaters may be ON at the same time. Initially, the tank heaters are ON, the S-band carrier D/L is ON and the X-band carrier D/L is OFF. When the OBCP is called with this flag set to TRUE, the S-band carrier D/L is switched OFF and the X-band carrier D/L is switched ON. This configuration is maintained as long as needed by the recovery procedure.

Recovery from Survival Mode OBCP invocation parameter: DELAY TIME
If DELAY TIME is set to a certain value (for example, τ seconds), stop the spacecraft strobing motion τ seconds after receipt of the telecommand.
If DELAY TIME is set to the maximum value (FFFFFFFF), the strobing motion is not to be stopped.

Recovery from Survival Mode OBCP invocation parameter: TELEMETRY ON flag
FALSE (0) ⇒ The X-band 64 bps TM D/L is not switched ON.
TRUE (1) ⇒ The X-band 64 bps TM D/L is switched ON.

Figure 3-12: Definition of relevant flags

3.5.2.2.4 Delta-v in Deep Space[1]

The maximum Sun distance, at which manoeuvres are planned, is 4.4 AU. This worst case is considered in the Procedure FCP-SY0280.

Power constraints have to be observed, if the manoeuvre is to be performed at a Sun distance greater than typically 4.2 AU. Therefore, according to the nominal mission planning, the power constraints apply only to RVM1 and RVM2. For the subsequent comet approach manoeuvres the Sun distance is already well below 4 AU.

The power constraints result in the following:

- the necessity of appropriate sequencing of the individual operations, i.e. equipment like APME, SADM, RWs, second Gyro, S- or X-Band transmitter can not be operated at any time; especially the usage of APM and SADM must be handled differently in some cases compared to the autonomous activities in AOCMS mode transitions
- the required RW torques during the slews must be limited such that the power consumption per wheel does not exceed 25 W; this corresponds to a usable torque level of e.g. 0.03 Nm at 18 Nms (180° slew can be made within 1 hour)
- during certain operations (slew phase, downlink, etc.) the tank heaters have to be switched off to provide sufficient power margin; these heaters can be switched off for about 10 hours per day
- even with the tank heaters switched off it is not always possible to maintain the downlink
- 2 gyros are nominally used during the Delta-V manoeuvre for maximum S/C safety
- there are two occasions, in TTM and WDP, where power peaks from the RWs may cause a short battery discharge; the expected duration of these peaks is however well below the minimum duration at which the battery discharge alarm would trigger (which is 5 ± 1 min)

In the last section of procedure FCP-SY0280 power budget tables are included, showing the equipment configuration and the currently predicted power situation at each step of the procedure. This budget, and consequently also the operational procedure, is based on the following assumptions:

- power margin maintained > 10%
- available power at 4.4 AU is 651 W(at 10° SAA), according agreed power calculation tool
- the SSMM is operational

The power budget tables have to be updated during the mission depending on whether such a 20 W load failure really has occurred or not and depending on the really available solar array output power. The really available solar array output power can be determined only in deep space, using procedure FCP-TS0270, "Verify Solar Array Thermal Model". Based on the result, it has to be verified by power budget calculation, that there is always sufficient power margin available throughout the complete operation. Under this condition it is also considered acceptable to reduce the required power margin to for example 5%. This could result in some simplification of the strategy.

3.5.2.2.5 Handling of the Mechanisms in Deep Space

[1] Referenz: procedure FCP-SY0280

During certain AOCMS mode transition the usage of APME and SADE is automated in the AOCMS software. Due to the power constraints in deep space phases this usage must be modified in some cases by appropriate MTL commands. Where this is necessary is shown in the following Table for all AOCMS modes and mode transition during the complete operations sequence.

Mode/Mode Transition	Automated Usage of SADE/APME	Desired Usage	Insert MTL command	Remarks
NM GLEP	none (keeps previous mode=off)	off		ground commands a switch-on, position update, switch-off, only when necessary
NM FPAP	none	SADM off APME off/on/off	activate APME, position update, switch-off APME	to drive HGA to Earth pointing
NM FPAP => WDP	APME/SADE off	off		
NM WDP => FPAP	APME/SADE on	off	switch-off APME, switch-off SADE	
NM GSP => WDP	APME/SADE off	off		
NM WDP => GSP	APME/SADE on	APME off during slew SADE on during slew	APME off	
NM FPAP => FPSP	APME/SADE off	off		
NM FPSP => FPAP	APME/SADE on	off	switch-off APME, switch-off SADE	
NM GSP => FPAP	none	SADE off	switch-off SADE	
NM FPAP => GSP	none	APME off during slew SADE on during slew	APME off SADE on	
NM GSEP => GSP	none	APME off during slew SADE on during slew	APME off SADE on	
NM GSP => GSEP	none	SADE off	switch-off SADE	
NM GLEP => GSEP	none	off		
NM GSEP => GLEP	none	off		
NM WDP => GSEP	APME/SADE on	off	switch-off APME, switch-off SADE	
NM WOLP/off -> WOLP/on	none	off		
NM => **AFM**	APME/SADE on	APME off	switch-off APME	

Mode/Mode Transition	Automated Usage of SADE/APME	Desired Usage	Insert MTL command	Remarks
		SADE on	during near fly-by	
NM => TTM	APME/SADE off	off		
NM => NSH	APME/SADE off	off		
NM => OCM	APME/SADE off	APME on	switch APME on	because of i/f torques on APMM
NSH => TTM	none	off		
TTM => NM	none	off		
TTM => SPM	APME on	APME on		needed for autonomous position update after spin-up
TTM => OCM	none	off		
SPM	none	off	switch-off APME	after HGA position update, i.e. after about 1h10min from start of spin-up
OCM => TTM	none	off		
AFM => NM	none	off		
SAM SCP => SAP	SADE on			
SAM RRP => SCP	APME on			
SKM StAP => SAR (Solar Array Rotation)	APME/SADE on APME in canon. position and off			
SAM => SHM	none			
SKM => SHM	none			
SKM => SAM	none			
SHM => NM	none			

Table 3-13a: Usage of APME/SADE in AOCMS Mode Transitions

3.5.3 Other Power Constraints

3.5.3.1 MPPT/APR Voltage Level Setting

The APR voltage level setting fixes the operational voltage threshold of the converter on the constant voltage part of the solar array power curve. He can operate up to the selected voltage on the solar array power curve and when the selected level is reached the converter is not able to pass this point.

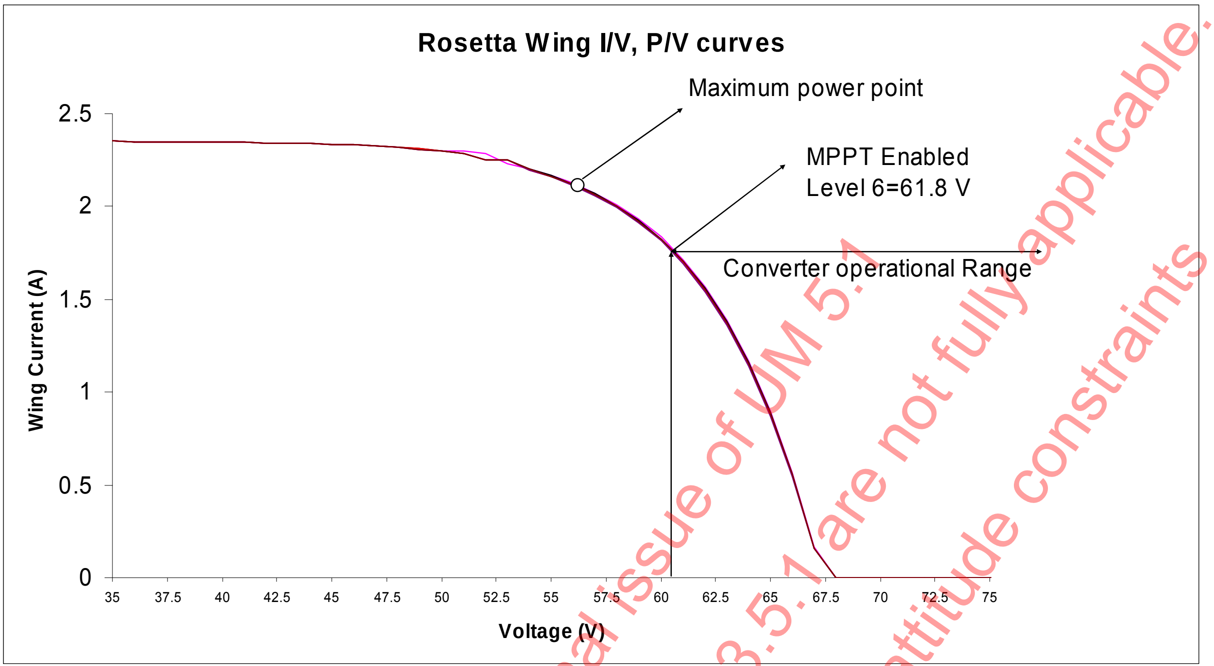


Figure 3-13: Solar Array Power Curve

If for example the voltage level 6 with MPPT enabled is selected the APR converter can only operate between 61.8 V and the open circuit voltage of 68 V. The solar array power between 61.8 V and the maximum power point is lost.

If the power at 61.8 V is not sufficient the remaining power will be taken from the batteries.

Since the battery power is limited they will be "FLAT" very quickly which results in a mainbus undervoltage.

In the worst case the voltage setting can be such that that the APR converter delivers no power. That is the case if the selected voltage level is higher than the solar array open circuit voltage.

Warning: A wrong APR voltage level setting can result in the loss of mission.

The only allowed voltage level is the level 0 MPPT enabled for the entire mission with the exception for the second CTS case where the voltage level is the level 0 MPPT disabled.

3.5.3.2 CTS Operation

For the CTS a maximum S/C power consumption of 1000 W is assumed. The critical factor is the voltage margin between the APR input voltage at 1000 W and the minimum APR regulation voltage of 33.215 V with the MPPT enabled voltage level 0 and 30.547 V with MPPT disabled, voltage level 0. There is no voltage margin requirement. A margin of 1 V is sufficient but a margin of 2 V is strongly recommended.

For the first CTS some days after launch the voltage margin, about 5 V, is sufficient with MPPT enabled.

At the second CTS, about 3.5 years after launch the voltage margin is in the order of 1.7 V with MPPT enabled voltage level 0. Therefore the MPPT should be disabled, voltage level 0, at sun distance of 0.91 AU to compensate for radiation uncertainties. At CTS exit the MPPT must be enabled again at sun distance of 0.91 AU with a voltage level 0.

For this CTS case CRP-SY0080 is applicable.

3.5.3.3 Various Power Related Constraints

Enable Battery Discharge Alarm[1]

The BDA must not be enabled during Launch phase and in DSHM.

If any operation is intended with use of batteries for longer than 4 min, the BDA has to be disabled before. Such operations are however not planned.

Disable Battery Discharge Alarm[2]

The BDA shall remain enabled in PCU and DMS all the time during the mission except during the launch phase and in DSHM.

Battery Discharge with Dummy Load[3]

Procedure FCP-PW0150 should not be executed in case one battery or one battery discharger already failed.

No battery discharge mode should be performed during this procedure.

Setting of Battery EOC Voltage Level[4]

A minimum of 50 W (about 0.5 A per battery) is required to charge the batteries in a reasonable time.

EOC Level 0 shall be used throughout the mission, corresponding to 89% SOC of the batteries. The battery voltage shall be monitored during the mission to ensure that it will never go above 25.2 V, see procedure FCP-PW0170.

Battery discharge due to high S/C power demand should be avoided.

Calibration of Solar Array Thermal Model[5]

The available power margin at begin of procedure FCP-TS0270 must be small enough, such that by sequentially adding power loads the discharge region is reached. As a first guess this is the case if the margin is approximately 100 W.

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[1] Referenz: procedure FCP-PW0090

[2] Referenz: procedure FCP-PW0100

[3] Referenz: procedure FCP-PW0150

[4] Referenz: procedure FCP-PW0170

[5] Referenz: procedure FCP-TS0270

In case software controlled heaters are used to increase the power demand (such as battery heaters and STR heaters) these heaters have to be taken out of software control to allow manual switching.

Osiris

Due to peak power constraints the operational heaters shall be switched off during front door and filter wheel mechanism activation. (ref: OSIRIS UM)

Commissioning of Power S/S & Power S/S Check-out during cruise

During execution of this procedure no load switching shall be performed (ref: fcp-pw0010/fcp-pw0020).

3.5.4 Thermal Constraints of Payload

There will be thermal constraints for the operation of the P/L towards the end of the mission. Below a sun distance of 1.4AU the P/L need to be operated with reduced power dissipation and some S/C orientation can not be achieved without violating the temperature limits. The relevant S/C attitudes where P/L operation is limited are when the sun is illuminating the P/Ls directly. However this means in principle that the P/L accommodated on the +Z S/C side is looking into the sun and on the dark side of the comet (see disscussion in RO-MMB-TN-3134)

No specific other constraints need to be implemented even not for the end of the mission. However some units may come close to their temperature limit during the last month of the mission, but for specific attitudes only.

Due to high heat absorption at the LVA ring when the sun is at SAA = -80°, the –Z propellant tank may reach its temperature limit if the Sun distance is below 1.15 AU and in addition the full P/L is operational. This is a matter of days, however.The WDE and RW2 may run hot too under specific operational conditions (e.g. high speed plus torque for longer duration; nominal operation including wheel off-loading are considered uncritical).

3.5.4.1 Midas[1]

For Midas thermal constraints at solar distances < 1.4 AU are expected. Thermal models predict that the upper operational temperature limit defined for MIDAS (+55°C) cannot be maintained by the spacecraft at solar distances <1.4 AU, when all payload elements are turned on.

In order to maintain the specified operating temperature, it may be necessary to operate the payload elements in the compartment containing MIDAS in time-sharing mode. These payload elements are RPC and RTOF.

The long thermal time constant of MIDAS of approx 10h in combination with the susceptibility to very small mechanical deformations induced by thermal inequilibrium requires, that several hours per thermal cycle are needed to achieve temperature stabilisation if temperature variations inside MIDAS of >1°C are reached.

[1] Referenz: MIDAS UM

Even with constant temperature at the thermal reference point, the heat internally produced by MIDAS requires to power on all internal converters of MIDAS well before (30 minutes, TBC) a scan operation can start.

3.5.4.2 VIRTIS

VIRTIS can operate in its nominal power mode until a temperature of 40°C at the TRP is reached. For higher temperatures the so called 70% power mode i.e. either VIRTIS-M or VIRTIS-H are running, is required.

Additionally VIRTIS-H should be operated only with the Main DHSU (main power) and VIRTIS-M should only be operated with the Redundant DHSU (redundant power).

3.5.5 Hardware Constraints

EEPROM: maximum number of write accesses is 10000, including ground operations; book-keeping required

Pressurant Tanks

- No pressurisation must start at a temperature lower than 18°C.
- The maximum temperature reached on the tank during pressurisation must not exceed 45°C.
- The minimum temperature reached on the tank during depressurisation must not be < –20°C.

Pyro Valves

As a consequence of a Mars Express Anomaly the following constraints shall be respected for all pyro firings

- Ensure that after each fire command the energy selection relay (batteries or main bus relay) is commanded OFF not later than 1 to 2 seconds after the fire command execution. This shall be ensured by putting the fire command and the energy de-selection command into one TC frame.
- Ensure that after commanding OFF the energy relay first the fire relay and thereafter the group arm relay is commanded OFF (reason: avoid failure propagation of energy selection relay failed closed to group arm relay, group arm relay is not capable to interrupt the 5A pyro current)
- Ensure that the mandatory relay status check is executed after each pyro firing and in case of a status inconsistency the contingency operation is continuing remaining pyro firings using the redundant pyro chain.

There are 8 main and 8 redundant pyro buffers in the S/S-PDU. Each buffer stores the firing current profile for one pyro. Main pyros are only stored in the main PDU side/buffer and redundant pyro firings are stored in the redundant side/buffer only. If a pyro fails there may be a need to access this current telemetry. However since only eight buffers are available it is necessary to reset the buffers before a ninth pyro is fired.

For each RCS operational mode there is a maximum of 6 pyros valves which are fired. Therefore, before the start of each operational mode e.g regulation or isolation, the buffers must be reset but will not need to be reset again unless there is a regulator failure which means 6 more pyros are fired.

Pressure Regulator

During isolation the inlet pressure must drop to approximately 70 bar (to prevent leakage through regulator outlet) but not below 50 bar before firing pyros in lines below regulator outlet.

3.5.6 High Gain Antenna Pointing Constraints

3.5.6.1 HGA Usable Pointing Range

The useable ranges of azimuth and elevation angles are limited by:

1. The mechanical limitation through the end stops
2. The software limits as specified in RO-DSS-RS-1037 (APME S/W URD)
3. The satellite shadowing effects (as presented in AST-G fax RO-DSS-0135/00 dated 26.01.00)
4. The thruster plume effects (Plume impingement analysis on the Rosetta S/C; MOS.NT.CT.3680142.00)

Point 1):
Is not addressed further herein.

Point 2):

In general, a software limit of 3° inside the mechanical limits has been specified in the updated APME URD (RO-DSS-RS-1037, issue 4)

Point 3):
The S/C shadowing effect has been repeated in the plot above together with a definition of the applicable nodes.

Point 4):
The basis for the thruster plume assessment is the “Plume impingement analysis on the Rosetta S/C” (MOS.NT.CT.3680142.00). It can be clearly seen from the presented plots, for some of the investigated cases, that the heat flux could be extremely high thus damaging the HGA. In addition, the plots of disturbance torque and forces indicate the potential for increased fuel usage due to:

- Reduced force on the –Z direction

- Disturbance torques around the Y-axis, necessitating OFF modulation of 2 of the axial thrusters and thus reduced specific impulse.

In the assessment of the useable elevation and azimuth angles the following assumptions have been made:

I. The maximum tolerable additional heat flux from the thrusters is about 2 kW/m2

II. Disturbance torques and forces during axial delta-V manoeuvres shall be limited to assure an acceptable propellant penalty.

III. In case of a single failure in the elevation or azimuth drive failure, it must still be possible to meet the mission objectives.

Point I: The area that can never be used during axial delta-V manoeuvres for thermal reasons (with the axial thrusters) is the "**red**" hatched area, i.e. the area above nodes 11 to 20 in the plot below.

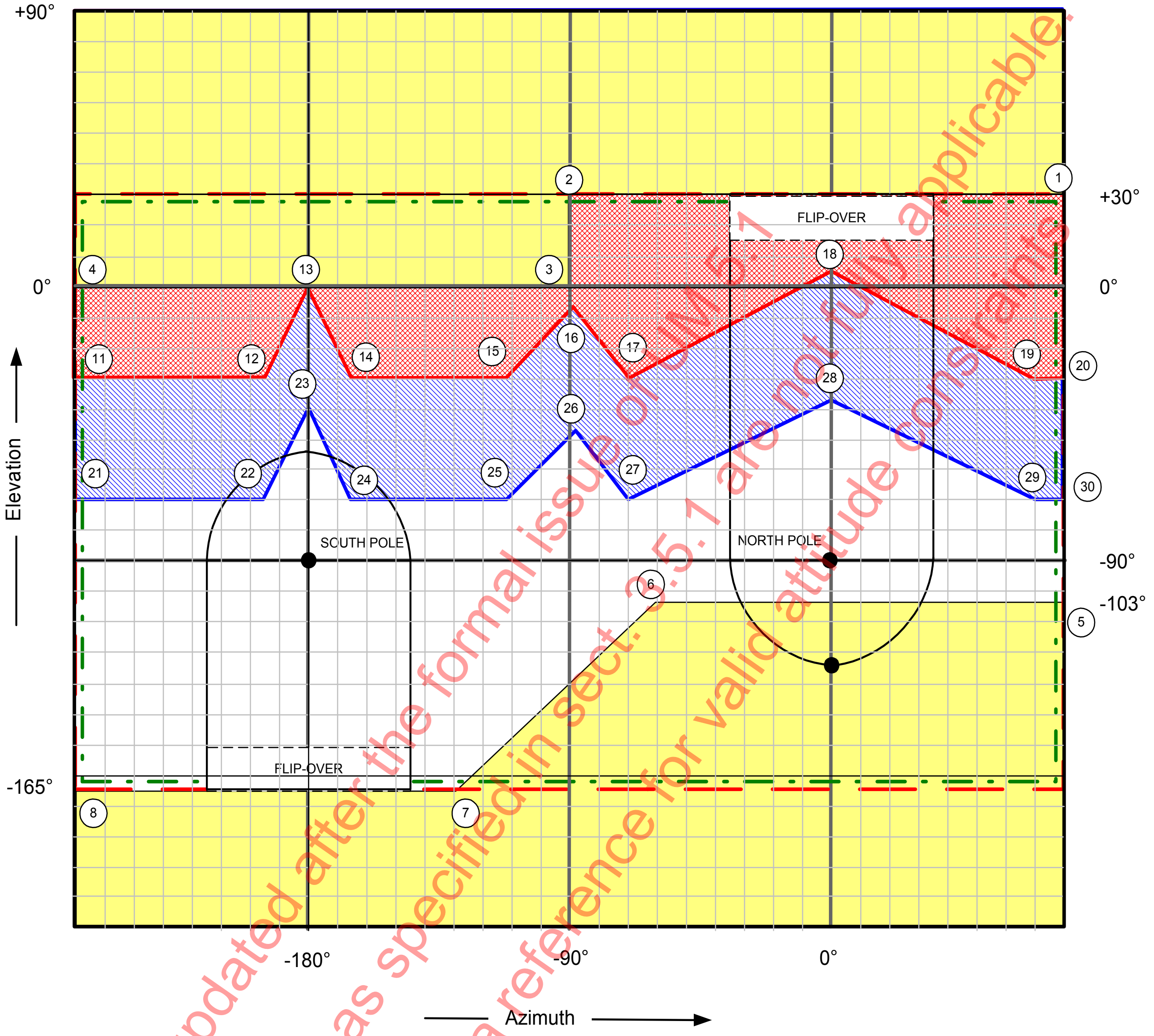
Point II: To reduce the disturbance torques and forces during any delta-V manoeuvre to an acceptable level, the antenna should be driven out in the non-shaded area during the axial delta-V manoeuvre.

Note that from a controller point of view, the disturbance torques are not considered to be a problem (except perhaps at an elevation angle of 30°) as the available control torques for X, Y and Z are 18 Nm, 23Nm and 21 Nm respectively.

Point III: The HGA drive mechanisms are redundant except for the mechanical part of each drive, i.e. the axis and the bearings.

If mechanical blockage of the azimuth or elevation drive mechanism, is considered to be a credible failure, it must be possible, at any time in the mission, to rotate the HGA into a safe orientation with the remaining drive mechanism. Safe orientation means to get at least out of the red area into the blue or white area.

The result of this assessment has been summarised in the plot shown below.



Critical areas due to shading effects or mechanical limits

Non accessible areas due to too high thermal flux from thrusters

Area of plume impingement resulting in propellant penalty

Mechanical hard limit
Azimuth: -260° - +80°
Elevation: -165° - +30°

Software limit (adjustable by telecommand)
Azimuth: -257° - +77°
Elevation: -162° - +27°

Figure 3-14: HGA useable azimuth and elevation angles

The nodes are as defined below:

Node	Azimuth	Elevation	Remarks
1	+80	+30	mechanical endstop
2	-90	+30	lower S/C body shadowing effect
3	-90	0	lower S/C body shadowing effect
4	-260	0	lower S/C body shadowing effect
5	+80	-103	upper S/C body shadowing effect (LGA, SAS)
6	-60	-103	upper S/C body shadowing effect (LGA, SAS)
7	-130	-165	HGA strut shadowing effect
8	-260	-165	mechanical endstop
9			not used
10			not used
11	-260	-30	excessive heat flux
12	-195	-30	excessive heat flux
13	-180	0	excessive heat flux
14	-165	-30	excessive heat flux
15	-110	-30	excessive heat flux
16	-90	-5	excessive heat flux
17	-70	-30	excessive heat flux
18	0	+5	excessive heat flux
19	70	-30	excessive heat flux
20	80	-30	excessive heat flux
21[1]	-260	-70	plume impingement loss
22	-195	-70	plume impingement loss
23	-180	-40	plume impingement loss
24	-165	-70	plume impingement loss
25	-110	-70	plume impingement loss
26	-90	-45	plume impingement loss
27	-70	-70	plume impingement loss
28	0	-35	plume impingement loss
29	70	-70	plume impingement loss
30	80	-70	plume impingement loss

Table 3-13: Azimuth and elevation limiting nodes

3.5.6.2 Constraints

- Up to the comet orbit, the red hatched area in Figure 3-14 may be entered but the elevation angle shall be restricted to ≤ 0°.

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[1] These limits are approximate as the plume impingement analysis did not specifically cover this case.

- When performing axial (turn and burn) delta-V manoeuvres, the HGA is not permitted to be within the red hatched area in Figure 3-14. Consequently, unless the HGA is nominally in the unshaded area of Figure 3-14 to maintain a TM downlink, it is driven to the position

  Elevation angle = -150°

  Azimuth angle = -180°

  to allow the burn to be performed with no high thermal flux and no plume impingement on the HGA. After the burn, the HGA is driven back to its initial position within the hatched area, in order to re-establish the TM downlink.

- In case of a single axis mechanical drive failure of the HGA, if the HGA was in the red hatched area before the failure, it can still be driven into the blue hatched area before a delta-V is performed. The worst case plume impingement impact then occurs at Elevation angle = Azimuth angle = 0°.

- During the comet orbit, the red hatched area in Figure 3-14 may be entered, but the elevation angle shall be restricted to +27°. Note that the physical limit is 30°, but a 3° margin is taken. Also, the limit of 27° can be adjusted, by telecommand, up to the end stop position.

- Procedures will be written on the basis that the elevation angle is constrained to be ≤ 0° prior to the comet orbit, and relaxed to ≤ 27° in comet orbit.

- The impact on the propellant budget, if the HGA is blocked at an elevation angle of 0° at begin of the mission is shown in Annex 10 (RO-DSS-RP-1014).

- The safe mode will use the HGA orientation El=0°, Az=0°.

- RF radiation on LAP&MAG experiments:

  At elevation angles between -10° and 0° in the azimuth range between -90° and -260° the lower boom may be in the RF beam of the HGA, which may have adverse effects on the LAP&MAG experiment measurements (there is no adverse effect if the experiment is off). This will be determined as part of the commissioning activities. On request of the LAP&MAG experimenters the allowed HGA pointing range may have to be constrained accordingly during their scientific operations. Reference: e-mail J.v. Casteren, 11.02.2004, 'Correction - RF Compatibility of Boom Instruments with HGA'.

3.5.6.3 Use of HGA during Delta-v and during Slews

- If the required manoeuvre attitude is such that the HGA would be at a position with elevation drive EL > 0°, the MGA-X has to be used instead of the HGA or a dog-leg strategy has to be applied (see FCP-SY0290 Dog-Leg Delta-V Manoeuvre in Deep Space).

- If the required manoeuvre attitude is such that the HGA would be in the allowed range (EL ≤ 0°), the following has to be ensured during the slew:
  - during the slew the HGA drive end-stops must be avoided
  - during the slew the HGA elevation drive must always stay below EL = 0°.

  To ensure this, the slew has to be simulated on ground to check whether maintaining HGA tracking is feasible. If this cannot be guaranteed, the HGA shall be commanded from ground to its final position before the slew (FCP-AC0450 HGAPM Rotation and Hold).
- If the required manoeuvre attitude is such that the HGA would be in the range, in which plume impingement effects would cause extra propellant losses, the HGA shall be used only for verification of correct manoeuvre attitude. It shall then be moved out of this range before start of the delta-V manoeuvre. In this case the manoeuvre itself cannot be monitored on ground.

3.5.7 Other Constraints

- Link degradation due to solar noise, see RO-DSS-TN-1132 (in Annex 6)
- Commanding the PL-RTU on using CDMU HPC requires, that both nominal and redundant PL-RTU LCLs are closed, see ro-dss-cr-1077.
- The heater switch status telemetry is only valid, if the LCL which provides the power to the HSW is closed.
- In case of HW Safe Mode[1] all previous contents in RAM is lost, like the data pool parameters for the TT&C OBCPs.
- The size of the Short MTL as well as the Back-up MTL is constrained to 117 command entries.
- The DSHM wake-up time will be accurate only to +/- 2 hours. The degradation of the clock accuracy is detected on-board assuming a threshold of 10^{-4} before a new master clock is selected. This leads to ± 2 hours wake-up time accuracy. Note, that the default threshold is 10^{-2}. Therefore ground has to set the new threshold (10^{-4}) before entry into DSHM.

  Note: As the CDMUs stay operational in DSHM (for safety reasons to protect against mainbus undervoltage effects), there could be an additional delay of up to 1 day; this may be due to a failure causing a reset of the S/C clock, after which it will be re-initialised with the Last Loaded On-board Time (LLOBT) taken from EEPROM, where the actual S/C clock is saved on a daily basis.
- The error in the execution times of MTL commands over long non-coverage periods may be up to ± 0.8 sec/month, see RO-DSS-AN-1007.

[1] Referenz: procedure CRP-SY0010

3.5.7.1 Payload Keep Alive Lines switch-off

The consequences of a Keep Alive Line switch-off are:

Lander

If both Keep Alive Lines are OFF and the Lander solar generator is illuminated at the same time, a “wake-up” sequence is initiated including heaters switch-on from solar generator power; the Power Subsystem and CDMS are switched-on as soon as the temperature in the Lander compartment is above –47°C. (Batteries do not come on until they are commanded.) This is not catastrophic but may lead in some cases to damage of the Lander Power Subsystem. It is expected however that illumination of the Lander solar generator during a worst case Safe Mode (i.e. with a fall back to SAM) will not take more than 15 minutes until the Lander is again on the shadow side.

COSIMA, GIADA

Software uploading, respectively context file reload is required after KAL switch-off.

In summary it has to be kept in mind that

- Keep Alive Line switch-off may happen during a main bus undervoltage. While the main bus undervoltage would be of limited duration (except in multiple failure cases), the Keep Alive Line might remain switched off for a long time.

- Any intentional Keep Alive Line switch-off shall only be performed upon specific, duly justified, highly infrequent request (e.g. upon absolute need from GIADA or COSIMA) from the scientific community, and after due consideration by the operations team of the consequences especially on Lander.

- For operational robustness, no Keep Alive Line switch-off shall coincide with the Lander activities, especially the deployment sequence.

3.5.7.2 MIDAS[1]

Microvibrations

Microvibrations generated by mechanical noise sources in spacecraft subsystems (reaction wheels, high gain antenna ,solar array srive mechanism) or other payload elements may disturb the measurements during scanning.

It is expected that the typical operating cycle of the reaction wheels will leave them at rotation rates below 1500 rpm during at least five hours. At these lower frequencies it is expected that disturbances for MIDAS are acceptable, and MIDAS can perform scanning operations.

At higher speeds of the reaction wheels the data obtained by scanning may be disturbed.

Other possible sources of microvibrations among the spacecraft subsystems are the high gain antenna (HGA) and the solar array drive mechanism (SADM).

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[1] Referenz: Midas UM

Possible sources of microvibrations from other payload elements are the Stirling cooler of the instrument VIRTIS and - probably to a minor extent, but still worth a check during commissioning - some shutters and filter wheels of remote sensing instruments (e.g., filter wheel of OSIRIS, shutter of VIRTIS).

The disturbances due to quasi-continuous microvibration noise (e.g., wheels) result in a "noisy" image. At some higher noise level the images become scientifically useless. With increasing noise amplitude alse the lifetime of the tips may be shortened.

The disturbances due to bursty microvibration noise (e.g., shutters) result in a local artefact in the image, most likely one or more disturbed lines in the image. At some higher repetition frequency of the noise events, and high noise level the images become scientifically useless. With very high noise amplitudes also the integrity of the used tip may be endangered.

Midas **mode dependant constraints** are shown in the table below:

Mode	**General Constraints**
Cover opening (activation by s/c powered pyros; MIDAS shall be in standby mode for monitoring)	Not on ground (except SPT of EM) One-shot
Kernel	"Alternative" power-on mode Limited functionality No modification of kernel by upload is possible For program uploads including refreshing of onboard EEPROM during cruise
Standby	Default power-on mode Safe mode; interim mode between mode transitions
Prepare exposure	By going from scanning to exposure the fine positioning of the scanner versus the target is lost
Exposure	Instrument is OFF Requires pointing into the dust flux Time to be co-ordinated with other "dusty instruments" Duration strongly dependent on dust flux (cometary activity, altitude, pointing)
Exposure in standby	Instrument is in standby mode (TM, power) Requires GIADA dust flux data triggers autonomous "terminate exposure" within some time window Pointing requirements same as "exposure"
Terminate exposure	None
Prepare scan	Not possible while approach is in locked position
Line scan	Not possible while approach, linear stage, or scanner are in locked position Requires low level of microvibrations: fast movements of High Gain Antenna should be avoided Sensitivity to microvibrations (from reaction wheels, high gain antenna, and other sources)

Mode	General Constraints
Scanning	Not possible while approach, linear stage, or scanner are in locked position Sensitivity to microvibrations (from reaction wheels, high gain antenna, and other sources) Some image processing is part of this mode. Science data are generated in small blocks throughout this mode, or as one block at the end. Duration depends strongly on settings (image size, data acquisition algorithm, etc.) Requires constant temperature of the scanning subsystem, i.e. needs TBD time of constant power consumption and constant TRP temperature before scanning
Image processing	Science data generation Requires raw image data in instrument RAM as input
Calibration	Not possible for approach, linear stage, or XY scanner are while locked position
Exercise piezos	Not possible for linear stage, or XY scanner are while locked position
Hardware self-test	Not possible for approach, linear stage, or XY scanner are while locked position
Telemetry test	Generates dummy science data
Technical	Mode for various check-out operations; constraints depend on actual operation performed.

3.5.7.3 Lander[1]

The possibility to include an Orbiter maneuver before and after Lander deployment is not excluded. In that case, minimum distance between Orbiter and Lander before Orbiter thruster firing shall be 100 m (TBC).

3.5.7.4 OSIRIS[2]

Mass Memory usage

When accessing the MMB without switching it on, the respective link fails (i.e. no more sub-unit communication can take place, e.g. NAC/MCB/PCM if link A was addressed, WAC if link B). When you switch on the MMB after this link failure, also the 2nd link can fail. Spurious numbers within the MMB status telemetry come from getting "0xffffffff" when the link is off.

[1] Referenz: Lander LID-B

[2] Referenz: Osiris UM

Front door usage

In low power mode situations (e.g. at high heliocentric distance) only one camera shall be open at any one time. During emergency switch-off, both doors shall close simultaneously if both are open. The front door shall not be used while the filter wheel is being commanded.

Filter wheel mechanism usage

The filter wheel shall not be used while the front door mechanism is being used.

Software usage

No UDP (imaging or otherwise) shall consume more than 14 MB RAM (image memory) during execution at a single instant.

No two imaging UDPs shall run simultaneously.

3.5.7.5 Rosina Covers[1]

Rosina DFMS and RTOF covers have to be closed during thruster firing and in case of high dust activity near the comet in order to keep the sensor clean.

3.5.7.6 RPC Magnetic Interference[2]

The operation of other payload, subsystems (particularly the reaction wheels) and the Lander must be taken into account, since these are a significant cause of magnetic interference.

3.5.7.7 VIRTIS Incorrect Housekeeping[1]

The reading of the H/K value of the M_Grating_Temperature parameter in the MTM_PEM_IR_HK_Report (3,25) telemetry is wrong due to a malfunction of the relevant thermistors inside the Optics Module. The value must not be considered valid.

3.5.7.8 VIRTIS Primary Boot[3]

Upon power-on VIRTIS shall perform the download of the PROM S/W to RAM, and shall initialise the ME (Primary Boot). At the end of the primary boot the ME shall be in Safe_Mode. However, no event report has been anticipated to signal the end of execution of this command. Moreover, no H/K is sent until completion of the synchronisation to the S/C SCET, by

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[1] Referenz: Rosina UM

[2] Referenz: RPC UM

[3] Referenz: Virtis UM

means of TC_Accept_Time_Update. If not synchronised within 60s the instrument shall start with a SCET of 0x8000000000.

3.5.7.9 OBDH-Bus Commanding Limit

Telecommands to Platform and Payload Users are distributed on board by the DMS via OBDH-Bus and the RTUs.

The nominal mode during mission is a sharing of the OBDH-Bus for Platform and Payload Users. When the OBDH is in shared mode, the size on the OBDH buffer is 100 elements i.e. a maximum of 50 [1] [x] couples of commands. In such a shared mode, 125 ms are dedicated every second to platform OBDH acquisitions and command sending.

When the OBDH is in unshared mode, i.e. the Payload is off and the bus is used exclusively by the Platform, the size of OBDH buffer is 300 elements i.e. a maximum of 150 ML[1] ML[x] couples of commands. In this mode, full time is allocated to platform OBDH acquisitions and command sending.

3.5.7.10 Prevention of Thruster Firing During Payload Operations

Three instruments have requested that they are deactivated before any thruster firings take place:

- ROSINA
- RPC
- ALICE

Before planned thruster firings, Delta-V manoeouvres or scheduled reaction wheel offloadings, it shall be ensured that these instruments are switched off.

Un-planned thruster firings may occur in the following contingency cases:

- autonomous reaction wheel offloading
- Safe Mode triggering

Autonomous reaction wheel offloading (which is in fact a protection against erroneous momentum management) shall be enabled only when no payload is active. In phases with payload operations it shall be disabled (as a consequence, Safe Mode would be triggered in case of wrong wheel speeds).

In case of Safe Mode triggering, the instruments ROSINA and RPC (among others) are switched off before thruster firing is started. The ALICE instrument is first commanded in a safe state before it is switched off, i.e. for some seconds during deactivation of ALICE the thrusters are already firing. This was accepted by the ALICE PI.

3.5.7.11 APM Operations Constraint Close to Sun

In Mission Phases when the S/C is close to Sun, which in this context is defined as less than 1.1 AU away from Sun, neither the APM nor its substitution heater can be operated continuously.

During these periods the following operation rules apply:

- The APM and the substitution heater shall normally be switched OFF.
- For intermediate operation (e.g for re-pointing or new tracking after slew / manoeuvre) the APM can be operated safely up to 1 hour. This is based on the temperature rise of 10°C / 3 hours maximum and applies for non-coverage periods.
- During passes (under direct monitoring) the 1 hour operation shall be taken as guideline. But the real limitation is the 70°C temperature limit for thermistor #143 APMazimuth and #144 APMelevation. Therefore it is possible to extend the operation to 2 hours if the observed settled non-operational thermistor readings (e.g. from 2 days before) are below 45°C.

In practice, the change in strategy from 'hot' to 'normal' and vice versa can be applied somewhere in the period, when the Sun distance is in the range 1.1 AU to 1.35/1.4 AU, on the outgoing or incoming path.

Since the handling of the APM and its substitution heater at AOCMS mode transitions and at a fall-back to Safe Mode is automated in the software, it is also necessary to apply a software modification and an SGM update (SIT and Deep Space Flag) at the point where the operational strategy shall be changed.

When this has to be applied and what exactly has to be done, is described in the RUM procedure FCP-SY0221, 'SGM EEPROM Maintenance - for SW Version 7', section 1.1.11, and Note 7.

3.5.7.12 Special Constraints for Delta-V Manoeuvres

Beside the attitude constraints of section 3.5.1, and HGA pointing constraints of section 3.5.6, the following constraints are applicable for Delta-V Manoeuvres.

3.5.7.12.1 Ensuring the required Magnitude of the Delta-V

The most critical aspect of the Delta-V manoeuvre is ensuring that the required magnitude is obtained. If the correction manoeuvre is too large, due to errors in the real-time on-board measurement of the Delta-V, then fuel is wasted both in terms of the initial Delta-V and the subsequent correction Delta-V. This could jeopardise the mission. Consequently, the approach adopted is to impart the Delta-V in two stages. In the first stage, the targeted Delta-V magnitude is a little less than is actually required. The Delta-V that has been achieved is then measured by the ground. This may take up to two days. Finally, a "top-up" Delta-V is applied to achieve the overall required Delta-V magnitude.

There are two ways of automatically assessing when the Delta-V manoeuvre has terminated – the thruster pulse counting method and the accelerometer method. In the technical note "Accuracy of axial Delta-V manoeuvres", RO-DSS-TN-1158, the following recommendations are made:

(1) When the magnitude of the Delta-V is less than 0.1 m/sec, neither of the two methods should be used. Instead, the required number of thruster pulses should be applied with the AOCMS in NM-WDP. This situation is covered by procedure FCP-SY0311.

(2) When the magnitude of the Delta-V is between 0.1 m/sec and 20 m/sec, the thruster pulse counting method should be used.

(3) When the magnitude of the Delta-V is above 20 m/sec, both methods may be used. Note that this assumes that the accelerometer residual bias is shown to be sufficiently

stable in flight (< 10 μg over 12 hours). If it is not, then only the thruster pulse counting method should be used.

(4) Assuming that the residual accelerometer bias is sufficiently stable to permit the accelerometer method to be used, then the maximum period of time between the start of the accelerometer bias calibration and the end of the burn in which the accelerometers are used should not exceed 12 hours.

(5) In order to achieve the required Delta-V accuracy of 1.5% (3σ), the Delta-V must be split into two parts. In the first part, the commanded Delta-V is 92% of the total required Delta-V. Ground then assesses the magnitude of the actual Delta-V achieved and, hence, the magnitude of the remaining Delta-V that is still to be performed. In the second Delta-V burn, the commanded Delta-V is equal to this remaining Delta-V.

As a corollary to the above recommendations, the accelerometer surveillances, L4 and G1, must also be considered. If the accelerometer bias is shown to be sufficiently stable in flight, then these surveillances may be left enabled even if the thruster pulse counting method is used. They then provide protection against a lateral thruster failure causing a Delta-V direction error. Of course this means that the accelerometers must be calibrated, even though the thruster pulse counting method is used.

<u>Adaptation of these Recommendations based on In-flight Experience</u>

An assessment of the achieved Delta-V manoeuvre accuracies for the first manoeuvres in-flight (refer to e-mail P. Ferri, 24.05,04 'Rosetta delta-V measurement accuracy') has shown that the accelerometer method is more accurate than the impulse counting method, at least for the range of manoeuvres performed so far. Based on extrapolation it was suggested that this is true for manoeuvres down to 0.2 m/sec.

Therefore the points (2) and (3) above may be modified such that the splitting between the accelerometer method and the impulse counting method is set at 0.2 m/sec instead of 20 m/sec.

Futhermore, there was no significant accelerometer bias dependency on attitude nor a significant excursion over days observed in-flight.

Therefore also the recommendation of point (4) above may be relaxed accordingly. However, the accelerometer performance and environmental sensitivity evolution shall be closely monitored in this respect to ensure that the required Delta-V accuracy is always achieved.

3.5.7.12.2 Forbidden Modes during Delta-V Manoeuvres

(1) During Delta-V manoeuvres the GLE (gyroless estimator) shall not be active.

Reason: during a small Delta-V with impulse counting method the counter was impaired by the GLE running in the background, leading to Safe Mode caused by the time-out. To exclude any other potential adverse effect, this constraint (1) shall be applied for any type of Delta-V manoeuvre, because there is absolutely no need to have the GLE running during a manoeuvre.

(2) APM and SADM shall not be in active pointing control during the Delta-V. For the APM it is recommended to command it to Hold Mode during the Delta-V, unless it is definitely proven in-flight that the unpowered hold torques are sufficient for safety of HGA and S/C.

3.5.8 SEU Effects

3.5.8.1 TWTA

The TWTA can be switched off by a SET. To prevent data loss in active phases the SSMM will store the scientific data in parallel.

Afterwards, these data can be downlinked.

The downlink can be re-established in following ways:

- Automatical switch-over to redundant TWTA by TT&C OBCP. This will be the case, when the TWTA monitoring is active (nominal operation).
- This automatic switch-over will take about 5 minutes. No ground operation required.
- Switch-ON of TWTA by dedicated ground command during the ongoing pass.
- Nominal start of the downlink at the beginning of the next pass.

3.5.8.2 TRSP

TRSP power supply can be interrupted. TRSP may be reset to it's initial state, which is defined in: RO-ALS-MA-0092.

Link can be re-established in the following ways :

- Acquire S/C in S-Band and send command with 7.8125 bps to start again OBCP 'Start X-Band Pass' or 'Start S-Band Pass'
- Wait for next pass, when MTL will nominally start the OBCP 'Start X-Band Pass' or 'Start S-Band Pass'.

3.5.8.3 FPGA related SEU Effects

The FPGA Task Force Report [Rosetta FPGA Task Force Report issue 4 rev 1 -f] has compiled findings on the vulnerability of FPGAs used in Rosetta against SEUs.

From the operational point of view the following items are important (cases which lead to an autonomous correction on-board are not considered):

- **CDMU HIPPO Issue 1: Erroneous change of hibernation bit**

  Note, that the following two cases are only a problem with the old "passive" DSHM concept, which is valid as a backup scenario only.

  - Case 1: HIB bit is set during the preparation of hibernation after loading of the wake-up counters

    Consequences: S/C will go into DSHM mode without final authorization by ground.

The occurance of this problem is considered rather unlikely, as this can happen only when the PROM SW is used (which makes use of the passive hibernation concept[1]) and a SEU takes place while a command is sent. Sending of commands in the phase between sending the two hibernation bits is not foreseen however.

- o <u>Case 2</u>: HIB bit is set at the end of DSHM (wake-up counter = 0); only 1 HIB bit was set before entry into DSHM; this bit is reset by a SEU

  <u>Consequences</u>: DSHM Exit Flag = "ignored"

  This results in entering safe mode when exiting from DSHM. As a consequence the STR warm-up OBCP is not started. Instead the STR is switched on at -40°C (outside qual limit for optical head).

  Note, that this is only a problem with the old "passive" DSHM concept, which is valid as a backup only.

  <u>Ground action</u>: no special action needed; even so the STR performance is out of spec the unit is not endangered. After entering Safe Mode, STR is warmed up and will come into operational temperature range.

- **CDMU HIPPO Issue 27: Reading of registers changed by SEU**
  - o <u>Case 1</u>: TM status register is corrupted.

    <u>Consequences</u>: This leads nominally to an automatic reconfiguration of the TFG, assuming one TFG is declared "safe". Only if there is no redundancy available the TFG is switched off and TM is lost. If only a SEU caused this problem, Ground can recover TM by switching the TFG on again.
  - o <u>Case 2</u>: Change of "power off status register"

    <u>Consequences</u>: Transition to hibernation mode is abandoned, as this register is evaluated by the OBCP "DSHM entry". This applies to the old "passive" hibernation concept only.
  - o <u>Case 3</u>: Change of the external status register, containing the VCA RAM status.

    <u>Consequences</u>: the affected TM packets miss one word.

    <u>Ground action</u>: not necessary, only a few TM packets are involved.

- **CDMU HIPPO Issue 28-31: Writing of registers changed by SEU**
  - o <u>Case 1</u>: Reconfiguration sequence pointer changed.

    <u>Consequences</u>: This leads to an incorrect (but valid) reconfiguration sequence in case a CDMS reconfiguration is performed.
  - o <u>Case 2</u>: TCSR status register

    <u>Consequences</u>: Loss of TM of the TC Decoder (TM from the TC decoder is still being generated, however the status (old/new) is not updated.

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[1] For the "Rosetta New Mission" the PROM software is planned to be identical to at least EEPROM2, i.e. the passive hibernation concept is not used at all!

Ground action: use redundant decoder (by addressing different virtual channel)

- o Case 3: VCA configuration register, TM timestrobe register

  Consequences: VCA config. Register: the priority of VC0 and VC1 channels is modified; TM timestrobe register: only effect on timestamp of TM packets (missing timestamp).

  Ground action: switch to redundant TFG (procedure dm-crp-0170)

- o Case 4: TM configuration register

  Consequences: This may result in having no Convolutional Coding, no Reed-Solomon coding, and no subcarrier and consequently the ground will not be capable to acquire telemetry. The carrier will be available however.

  Ground action: If a SEU is suspected Ground needs to reset the TFG register. As a hardware failure is also a possible reason, a switch to the redundant TFG is advised, using procedure dm-crp-0170.

  Note: for s/c distances > 4.5 AU coherent mode needs to be maintained in order to achieve a stable downlink signal (the bit rate for uncoherent mode at 4.5 AU is about 13 bps).

The frequency of read/write errors for the HIPPO FPGA was estimated to be of the order of 7.295E-7 events/day (worst case).

- **CDMU HIPPO Issue 35: Spurious reset of the TFG**

  - o Case 1: Transient Reset

    Consequences: Loss of information regarding the priority selection between VC0 and VC1.

    Ground action: switch to redundant TFG via procedure dm-crp-0170.

- **CDMU CROC Issue 1: Involuntary setting of SCET when waking up from hibernation**

  Consequences: Only if two or more SCETs are incorrect and the old "passive" DSHM concept (see also footnote 1 above) is used this could lead to a wrong pointing of the HGA at exit of hibernation. This could in the worst case lead to MGA Strobing Mode, however with a MGA strobing angle set wrong such that no downlink can be received on Earth.

  Ground action: setting of the SCET to the nominal value (this requires 'commanding in the blind') and command the satellite into Safe Mode.

- **CMDU CROC Issue 2: User Time Register**

  Consequences: An incorrect value is read in the user time register. The contents of this register is used for datation by the PMs and for execution of the MTL. The user time is compared to the execution time of the first MTL command to verify that the MTL commands are sent in time with a maximum delay of 20 s; in the case the incorrect value of the user time is such that this one has passed the execution time of the first MTL command with more than 20 s, the MTL is abandoned and a transition into safe mode is done.

- **CMDU CROC Issue 3: Lockout of the fetch compensate mechanism**

  Consequences: Degradation of the clock accuracy from 10^{-7} to $1.5{\cdot}10^{-4}$. This is critical mainly for the Lander delivery.

  Ground action: The Lander Separation Procedure should set the threshold for a clock reconfiguration from 10^{-2} to 10^{-5} before. In case of a SEU leading to the described clock accuracy degradation the reconfiguration threshold would be exceeded, thus leading to a switch to another clock.

- **CMDU RHINO Issue 1: Spurious setting of Alarm Register**

  Consequences: SEU leads to setting of BDA alarm bits or power-on bits in the Alarm register during hibernation. Wrt the power-on bits this could lead to the assumption of a power undervoltage by the software with the result, that the last value of the SCET is loaded from the SGM EEPROM. As this SCET value represents the time before entry in hibernation mode, the new SCET will be incorrect. Eventually this will cause the HGA not pointing to Earth at exit of hibernation.

  Note: this is only true with the 'old' passive hibernation concept, which is not baseline anymore!

- **CMDU RHINO Issue 3: Erroneous write/read in the SGM RAM**

  Consequences: This error affects the monitoring list which is hold in SGM RAM. In case of an SEU part of the list could contain wrong data, for example an action assigned to a certain temperature limit could became invalid.

  The task force report suggest for this case to duplicate critical monitorings. Regarding Parameter Monitoring, the "doubling" is already standard for many parameters in order to be able to sent recovery actions via RTU-A and RTU-B. Otherwise no critical monitorings wrt s/c safety have been identified.

  For the Event Monitoring Table a doubling of entries is of not possible: the 'add to monitoring list' command checks, if the event is already in the list. If the event is in the list and recovery is enabled, then a second entry cannot be made. If the event is in the list and recovery is disabled, the event to be added overwrites the old event.

  Hence, the only "protection" for SEU related problems in the Event Monitoring Table is a regular dump & check of the contents of this table or at least verification of the checksum.

- **CMDU RHINO Issue 7: Incorrect I/O Access**

  Consequences: A SEU can cause an incorrect value is read or written in the registers accessed through the RM I/O. For example an erroneous read/write in the TFG register can occur. In this case the priority of the virtual channels to be assembled is changed. No telemetry is lost unless a TM Buffer Overflow occurs.

  Ground Action: Switch to redundant TFG via procedure dm-crp-0170.

Summary of FPGA SEU Effects

Observation	Possible Cause	Related CDMU FPGA	Ground Action
no downlink **when waking up from hibernation (using the old "passive" hibernation mode) and** no carrier	▷ **Involuntary setting of SCET when waking up from hibernation** ▷ **Spurious setting of Alarm Register**	▷ **CDMU CROC iss. 1** ▷ **CDMU RHINO iss. 1**	**setting of the SCET to the nominal value (this requires 'commanding in the blind') and command the satellite into Safe Mode.**
No TM **(carrier is available)**	▷ **TM status register corrupted** ▷ **TM configuration register changed**	**CDMU HIPPO iss. 27…31**	**Switch to redundant TFG (using procedure dm-crp-0170)**
No timestamp of TM packet	**TM timestrobe register changed**	**CDMU HIPPO iss. 27…31**	**Switch to redundant TFG (using procedure dm-crp-0170)**
TM packet incomplete	**External status register changes**	**CDMU HIPPO iss. 27…31**	**No recovery foreseen - applies only to a few single packets**

Observation	Possible Cause	Related CDMU FPGA	Ground Action
TM status from TC decoder unclear	**TCSR status register changed**	**CDMU HIPPO iss. 27…31**	**Use redundant decoder by addressing different virtual channel)**
User Time Register value incorrect	**User time register contains incorrect value**	**CDMU CROC iss. 2**	
Unexpected s/c configuration after reconfiguration	▷ **Configuration status register changed** ▷ **Reconfiguration sequence pointer changed**	**CDMU HIPPO iss. 27…31**	
Enter DSHM w/o final authorization **(for passive hibernation only)**	**Erroneous change of hibernation bit**	**CDMU HIPPO iss. 1**	**None (passive hibernation not baseline)**
Automatic transition to DSHM abandoned	**Power off status register changed**	**CDMU HIPPO iss. 27…31**	**None (passive hibernation not baseline)**
Monitoring behaviour not as expected	**Erroneous read/write in the SGM RAM**	**CDMU RHINO iss. 3**	**Regular dump & check of event monitoring table.**
Priority of virtual channels changed	▷ **Incorrect I/O Address** ▷ **Transient reset of TFG** ▷ **VCA configuration register changed**	▷ **CDMU RHINO iss. 7** ▷ **CDMU HIPPO iss. 35** ▷ **CDMU HIPPO iss. 27**	**Switch to redundant TFG (using procedure dm-crp-0170)**
STR performance out-of spec after exit from DSHM **(only for old passive concep!)**	**Erroneous change of hibernation bit**	**CDMU HIPPO iss. 1**	**None (passive hibernation not baseline)**

3.5.9 SSMM Constraints

3.5.9.1 Commanding constraints

See §3.5.11.1.2

3.5.9.2 Transition to SSMM - Operational Mode

The TC(160,2) "Transition to Operational Mode" has a parameter called "WD Inhibit/Enable" that controls whether the Watchdog shall be inhibited or enabled. The TC can be received by the SSMM in both Init Mode and Test Mode.

Starting with Nominal Software Version 1.2 onwards this parameter has only an effect at the transition from Init Mode to Operational Mode. The parameter is ignored at transition from Test Mode to Operational Mode (see also fax RO-SES-2182/01, dated 19. Nov 2001).

3.5.9.3 Virtis[1]

Due to a bug in the IEEE1355 chip, when the link is disconnected by SSMM we have to go through a full VIRTIS reset operation. That is:

- VIRTIS is sent to Safe Mode (TC_Enter_Safe_Mode command)
- Secondary boot is performed (TC_Enter_Idle_Mode command)
- The HSL is started again (TC_Reset_And_Start_HSLink)

3.5.9.4 SSMM Initialization

During SVF testing the communication with the SSMM was not working when the PL-RTU was switched on during the SSMM initialization phase. It is therefore recommended to omit switch-on of the PL-RTU while the SSMM is initializing (this will take approx. 20 sec).

3.5.10 TT&C Related Constraints

3.5.10.1 RFDU Setting

In order to allow coherent downlink to work for e.g. ranging, RFDU SW5 must always be in Pos. 2. Otherwise one transponder is used for the RX-chain and the other transponder for TX, which prevents coherent downlinks.

3.5.10.2 Transponder X-Band Receiver Lock

According to RO-ALS-NC-8234 / RO-ALS-RW-3577, the following anomalous behaviour of the TRSPs during the acquisition process has been detected for the combination of signal power level (-117 dBm @ TRSP input) and sweep rate (500 Hz/s):

The receiver cannot lock in presence of this combination of up-link power level and frequency sweeping rate.

It is possible to overcome the acquisition problem for the UL power level of "-117 dBm @ TRSP input" by sweeping the up-link signal at 1 KHz/s, but this could reduce the acquistion probability down to 94 %.

Since a reduction of the acquistion probability was not accepted by ESOC, as disposition it was agreed, that ESOC will adjust the uplink power in order to cope with this nonconformance, see fax RO-DSS-1308/02.
All the theoretical details concerning this anomaly have been provided in the Technical Note TNO/RST/0109/ALS Issue 1.

The proposed range of UL power levels to be avoided by ESOC during the acquisition process can be ascertained to be - 113 dBm .... - 121 dBm (= -117 dBm±4dB).

Remark:

[1] Referenz: Virtis UM

It needs to be underlined, that the receiver tracking performance and the carrier demodulation capabilities are not affected by this anomaly.

3.5.10.3 Operational Pre-Caution in case of "Transponder sustained lock"

On the EQM spacecraft and during the RFCT/RF suitcase tests by ESOC, a sustained lock of the EQM transponder has been observed.

In such cases the TRSP was previously locked at its restfrequency.

After removal of the UL signal by the G/S station, the TRSP remained in lock, instead of entering the "unlock" condition in less than 2 minutes. Furthermore the TRSP was entering narrowband mode and was tracking an internal very weak signal (AGC reading in the range 5000-6500 quants).

In case, that the TRSP has been in coherent mode, the down-link spectrum was quite noisy due to the up-link noise being routed to the down-link frequency synthesis loop, hence corrupting the DL performance in this case.

Also in the presence of “sustained-lock” the TRSP was still capable to acquire a nominal up-link signal, within a triangular sweep around the rest frequency. However, sample tests identified, that the nominal expected acquisition probability was degraded / reduced.

During the test on ground, it was also noticed, that switching the receiver RF front-end back and forth unlocks the transponder (eg. Rx-S → Rx-X → Rx-S).

The sustained lock has been not observed for the flight transponders integrated on the ROSETTA S/C. It was also no longer noted on EQM TRSP following a modification of the EQM Transponder built standard to be in inline with the FM TRSP design.

In any case, as pre-caution, an OBCP has been developed which performs the RF frontend switching periodically (once per 24hours). This OBCP

PF_OBCP_4.6 :'Transponder Frontend Switching', KTTR6460

- Will not be running during launch
- Will automatically start when the S/C enters Safe Mode

Whenever a sustained lock of a flight transponder should be noticed during the mission, it is recommended to start the OBCP, in order to ensure a periodic unlock of the receivers (e.g. during non-coverage phase).

Note : When the uplink carrier is removed, it may take up to 2 minutes until the receiver unlocks. Various TRSP Mode state transitions with high values of AGC readings may be noticed during that time . This is normal behaviour and does not represent a sustained lock condition.

This mode state transition may be also observed during switch over of the TRSP reference oscillator (TCXO ←→ USO).

3.5.10.4 Downlink limitations

During the RF Compatibility Tests it was observed the ground station receiver could not lock on the transponder downlink signal at its lowest receiver loop band width (Loop BW) of 0.3Hz, when using the internal TCXO in non-coherent mode.

The ground station receiver could lock to the downlink signal at

- 3 Hz Loop BW in S-Band
- 10 Hz Loop BW in X-Band

Hence, more carrier power is needed for carrier recovery. This reduces the link performance, especially when the received power on ground is already quite low (low bit rate links via LGAs, MGAs, far distance).

In principle, there are 3 measures to increase again the DL performance, if needed:

1. Operate transponder in coherent mode.

When the DL signal is locked to the uplink signal,

- the 0.3Hz can be selected again for S-Band at all signal levels

- In X-Band the 0.3Hz can be selected for signal levels above -125dBm (at receiver input).

2. Use of USO as reference frequency for the transponders.

In this case, the 0.3 Hz loop BW can be selected again without any constraints.

3. Use of DSN70m G/S instead of New Norcia G/S

When only the un-modulated carrier shall be received on ground (Safe Mode / Survival Mode) it is possible to operate the Ground Station Receiver in 'open loop mode'. This mode is as sensitive as the receiver in closed loop at 0.3Hz loop bandwidth. Demodulation of TM data is not possible in that mode.

For all nominal operational phases, it is recommended to operate the transponder incoherent mode when it is necessary to increase the DL performance. The DL performance for non-coherent mode and coherent mode as function of the distance and DL bit rate is given in RO-DSS-TN-1182, 'Space / Ground Coherent Downlink Budgets'. This note identifies, when the coherent mode is necessary.

For non-nominal mission operations following measures are recommended :

- When the S/C enters Survival Mode: The S/C will send an un-modulated S-Band carrier in non-coherent mode via the MGA-S or LGA which will periodically strobe across the Earth. RO-DSS-TN-1192 'LGA and MGA strobing on the ROSETTA mission to Churyumov-Gerasimenko', dated 012.09.2003 issue 2.0 identifies, when the ground station receiver needs to be operated in open loop mode in order to receive the strobing signal. Detailed technical background is given in RO-DSS-TN-1195, issue 2.0, 'Establishing TM/TC when ROSETA is in MGA strobing'

- When the S/C enters Safe Mode: The S/C will send an un-modulated S-Band Carrier in non-coherent mode via the HGA. This S-Band DL carrier can be received at NNO in closed loop at any distance. The ground then has to activate the TM downlink (set to 21.33ps / MI=1.0 rad). For this data downlink, the coherent mode might be necessary, depending on the S/C distance. The DL performance for non-coherent mode and coherent mode as function of the distance is given in RO-DSS-TN-1182, 'Space / Ground Coherent Downlink Budgets'. This note identifies, when the coherent mode is necessary.

- When the AOCMS ends up in Permanent SKM: The S/C will send an un-modulated S-Band carrier in non-coherent mode via the MGA-S. The pointing of the MGA-S antenna towards the Earth will be controlled in an angle of up to 25° degree. Thus, it is might be necessary to operate the G/S receiver in open loop. RO-DSS-TN-1195, issue 2.0, 'Establishing TM/TC when ROSETA is in MGA strobing' provides all information for selecting the ground station (NNO or DSN70m) and the receiver operational mode (closed tracking loop or open loop) depending on the S/C to Earth distance.

3.5.10.5 USO

RF Output Power:

On page 17 of the USO Operations Manual (RO-TIM-MA-3001) an output power calibration is given for RF Out A and RF Out B.

The telemetry output (voltage) is very temperature dependent, so that the given conversion formula to convert the telemetry voltage into RF output power in dBm can not be used via the wide operation range of the USO.

Therefore only the TM voltage ranges shall be used as follows:

Condition	USO PFM TM voltage range for OUT A (NTTAUS50) Power Monitor 1A	USO PFM TM voltage range for OUT B (NTTAUS600) Power Monitor 2A
USO OFF	0V - 1V	0V - 1V
USO ON / MUTED	1V - 2 V	1V - 2 V
USO ON/ NOT MUTED	2V - 4.5 V	2V - 4.5 V

Oven Temperature:

The oven temperature telemetry shall be considered as a status signal, therefore no conversion to temperature in °C is given. The USO oven temperature is ok for the following TM voltage:

USO PFM TM voltage range for USO TEMP A (NTTAUS30)	USO PFM TM voltage range for USO TEMP B (NTTAUS40)
1.15 V - 3.15 V	1.15 V - 3.15 V

3.5.10.6 3-Axis Acquisition after Launch[1]

[1] Referenz: procedure FCP-SY0040

The S/C has a small rate of ~ 0.2°/sec around the Sun line. Therefore the view angles of the LGAs with respect to Earth are changing.

If the downlink signal of the currently active S-Band TX gets weak or disappears, the ground station has to resume sweeping of the uplink carrier to lock the new upcoming RX on the other LGA. The downlink may be interrupted for up to 1 min, until the other TX is activated.

3.5.10.7 NSHM Earth Pointing Guidance[1]

The bitrate and TM Mode for X-Band downlink via MGA is always the same during the entire NSHM phase, i.e. suitable for the maximum Earth distance encountered during the current phase. This has to be set up accordingly in the Data Pool Variables Table during the NSHM Entry operations.

3.5.10.8 DSHM Exit and Recovery[2]

- low bitrate of 21.3 bps in Safe Mode; by ground command this can be increased to 42.6 bps for New Norcia in coherent mode (if available: DSN 70 m can receive 341.3 bps)
- the duration until the ground is synchronised on the downlink telemetry is assumed to be about 40 min (at least 4 frames à 8 min) tbc ESOC.
- X-Band downlink performance through HGA in SHM-HP is not considered feasible due to attitude excursions up to 1°
- the procedure is based on the most constraining scenario, which is use of New Norcia station only, i.e. 5 hours contact per day initially, DSN 70 m available on short notice
- use of S-Band only at 32 bps maximum

3.5.10.9 Recovery from Survival Mode[3]

DSN will be required for the recovery procedure CRP-SY0020 (possibly apart from short periods when the spacecraft is close to earth).

3.5.10.10 Solar Conjunctions and Oppositions Phases

During the mission a number of Solar Conjunction and Opposition Phases with degraded up- and downlink performance occur (see table 1-3).

The commanding performance is influenced both during conjunction and opposition phases. As a rule of thumb, commanding via HGA-X band is possible without restriction down to an SSCE angle of 1.3° (wrt the edge of the sun disk) and approximately 4.5° for commanding via HGA-S band. MGA-X Band commanding is possible for SSCE angles > 2.5°.

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[1] Referenz: procedure FCP-SY0125

[2] Referenz: procedure FCP-SY0170

[3] Referenz: procedure CRP-SY0020

The performance also depends on the distance between S/C and Sun, see the detailed calculations described in RO-DSS-TN-1132, "Influence of Solar Noise on Link Budgets". If during the mission the SSCE angle becomes smaller than these critical angles, commanding may not be possible and critical uplinks should be avoided. For the same reason Safe Mode recovery may not be feasible until the S/C trajectory is such that a more suitable SSCE angle/distance combination is reached.

See also RO-DSS-TN-1151, 'Station Pass Management C-G 2004'.

Note, that the TC Link Monitor time-out has to be adjusted according to the expected degraded commanding performance.

Spacecraft Mode during Conjunctions/Oppositions

During conjunctions and oppositions the positions of Sun and Earth are swapped as seen from the spacecraft. This means that in normal operational mode, with the AOCMS in GSEP or GLEP, the HGA and SA pointing constraints would require a 180° slew around the Sun line, very close to the point where this Earth/Sun swap takes place. Otherwise, if the actual guidance is with the X-axis pointed to the Sun, the HGA would need to move into the (up to the comet phase) forbidden positive elevation angle range in order to follow the Earth. If the actual guidance is with the X-axis pointed to the Earth, then at the cross-over point the solar array would have to be moved downwards, into the +X/-Z quadrant, which shall be avoided as well. Making the 180° slew at the centre of the conjunction resp. opposition is in principle possible, but is not recommended.

An easy way to overcome this is to point a different axis than the X-axis to Earth or Sun in these modes. An axis, which is say 10° above the +X-axis towards +Z, appears a good choice. This 10° offset provides a considerable operational margin so that the 180° slew can be made well outside the conjunction or opposition period. Alternatively, FPAP could be used.

The following operational mode is proposed:

- AOCMS in GSEP
- Y-axis as close as possible to the ecliptic normal
- +Y-axis North or South, same as defined for the Safe Mode flags for the current phase, see FCP-SY0221
- Sun or Earth pointing of the 10° offset axis.

3.5.11 DMS Subsystem Operational Constraints

--- copy of chapter 3 of Avionics User Manual, RO-MMT-MA-02025, Vol 2, issue 4, Rev. 0, 10.12.2004 ---

3.5.12 AOCMS Subsystem Operational Constraints

--- copy of chapter 6 of Avionics User Manual, RO-MMT-MA-02025, Vol 2, issue 4, Rev. 0, 10.12.2004 ---

3.5.13 Periodic Operations and Maintenance Requirements

This is a summary of requirements for periodic operations and maintenance activities.

Operation	Frequency	Reference	Comments
Gyro drift calibration	every 6 months	AUM FCP-AC0192	and after every SW initialisation
Check gyro LIM (laser intensity monitor)	every month for the used gyro, every 6 months for the non-used gyros	AUM Vol2, section 6.1.2	
RW maintenance	every 6 months	AUM FCP-AC0071	
Observe RW current	we propose: at each contact check the RW current history since last contact	RW User Manual RO-MMK-MA-2001, issue 6	to detect potential cage instability
Refresh EEPROM contents in STRs, CAMs, CDMUs (data and code)	once during the mission before 10 years are elapsed; proposed date: shortly after 3rd Earth fly-by (good link and power conditions)	AUM Vol2, section 6.1.1	safe data retention time in EEPROM is 10 years
Update S/C velocity in STR SW	every week	AUM FCP-AC0570	STR SW needs to be updated before this works correctly (NCR)
Regular update of SA position in Earth-pointed NSHM	about every month during NSHM	AUM FCP-AC0042	
Data acquisition via ACM-B (RCS pressures PT 2, 5, 6)	before and after each manoeuvre, every month during NSHM (together with SA position update)	AUM Vol2, section 6.1.7	required for the book-keeping of propellant consumption
Accelerometer bias calibration and size effect compensation	before each Delta-V manoeuvre, when accelerometer method is used	AUM FCP-AC0190/194	see also section 3.5.7.12.1
many of the paremeters in SGM EEPROM need update during the mission	depends on parameter	RUM FCP-SY0221, issue 11	this FCP defines criteria and planned updates of numerous parameters and flags, which are not repeated here

3.5.14 Lifetime and other Limitations requiring Bookkeeping

Item	Limitation	Reference	Comments
Writing in EEPROM	not more than 10000 writes in same location		
safe data retention time in EEPROM	10 years		
number of RW zero speed crossings	not more than 2000 in flight	RW User Manual RO-MMK-MA-2001, issue 6	
number of RW revolutions	max. 16.6x10^9 revolutions during life	RW User Manual RO-MMK-MA-2001, issue 6	
duration with RW speed below 190 rpm	no explicit limit can be given, but duration shall be minimised	RW User Manual RO-MMK-MA-2001, issue 6	
ancient TCs in MTL	don't keep a TC in the MTL, after which 30.000 other TCs are added to the MTL	AUM Vol2, section 3.1.3.1	

3.6. Mission Phases and Reference Event Times

The following tables give a coarse breakdown of the ~~above~~ mission phases in major mission/operational events, indicating the event time and duration of operation, as well as the applicable System- and AOCMS-Mode. The detailed time line of the mission phases refers to the respective "Main Event Time".

Mission Phase	Phase Start (Mission Day)	Phase Duration (days)	Reference Event(s)	Ref Event Date	Ref Event Time (Mission Day)
LEOP	few hours before lift-off	3	Lift-off (on Mission Day 1)	26.02.2004	**T_0 = 1**
Commissioning, part 1	4	99	Begin of Commissioning Phase 1	29.02.2004	T_1 = 4
DSM 1				05.06.2004	T_2 = 101
Cruise #1: Earth to Earth 1	103	105	Start of Cruise Phase #1	07.06.2004	T_3 = 103
Commissioning, part 2	208	45	Begin of Commissioning Phase 2	20.09.2004	T_4 = 208
Earth Swing-by 1	253	151		04.11.2005	
			DSM 2	08.12.2004	$T_{5,1}$ = 287
			Closest Approach to Earth	03.03.2005	$T_{5,2}$ = 372
Cruise #2: Earth to Mars	404	520	Start of Cruise Phase #2	04.04.2005	T_6 = 404
Mars Swing-by	924	203		06.09.2006	
			DSM 3	05.10.2006	$T_{7,1}$ = 953
			Closest Approach to Mars	27.02.2007	$T_{7,2}$ = 1098
Cruise #3: Mars to Earth	1127	172	Start of Cruise Phase #3	28.03.2007	T_8 = 1127
Earth Swing-by 2	1299	91		16.09.2007	
			Closest Approach to Earth	05.11.2007	T_9 = 1349
Cruise #4: Earth 2 to Earth 3	1390	636	Start of Cruise Phase #4	16.12.2007	T_{10} = 1390
DSM 4				24.03.2009	T_{11} = 1854
Earth Swing-by 3	2026	91		12.09.2009	
			Closest Approach to Earth	11.11.2009	T_{12} = 2086
Cruise #5: Earth to RVM1	2117	395	Start of Cruise Phase #5	12.12.2009	T_{13} = 2117
Asteroid Fly-by (TBD)					
RVM-1 Phase	2512	181	RVM-1	10.05.2011	T_{14} = 2631
Cruise #6	2693	927	Deep Space Hibernation Phase	11.07.2011	T_{15} = 2693
RVM-2 Phase	3620	211		23.01.2014	
			RVM-2	22.05.2014	T_{16} = 3739
Global Mapping and Close Observation Phase	3831	58	Begin of Comet Mapping	22.08.2014	T_{17} = 3831

Mission Phase	Phase Start (Mission Day)	Phase Duration (days)	Reference Event(s)	Ref Event Date	Ref Event Time (Mission Day)
SSP Delivery & Relay	3889	27		19.10.2014	
			SSP Ejection	10.11.2014	T_{18} = 3911
Comet Escorting	3916	411	Lander delivery + 5d	15.11.2014	T_{19} = 3916

Table 3-14: Mission Phases and Reference Event Times

3.7. Timeline of Major Mission Phases and Events

This section gives an overview on the characteristic events and operational activities for each major mission phase. The tables represent a chronology of all mission critical events and sub-phases as S/C separation, orbital manoeuvres, solar conjunctions, system mode transitions, optical target detection, etc.. Routine ground activities as S/C health checks and data dump phases are not listed.

LEOP	start date	time	start at mission day
start/end of phase	26.02.2004		1
Lift-off. Launch by Ariane 5 from Kourou	26.02.2004	00:00	
S/C Separation		02:13:50	
Start of S/C Separation Sequence			
Start of Solar Array Deployment		02:36:50	
End of Solar Array Deployment		02:55:20	
End of S/C Separation Sequence		03:13:50	
Transition to Safe Mode		04:13:00	
Transition to Normal Mode		09:13:00	
HGA Deployment		02:25:00 after New Norcia AoS	
1st RCS Pressurisation	27.02.2004	01:00:00 after Madrid AoS	2
Slew and Axial Manoeuvre Checkout		03:00:00 after Madrid AoS	
Switch RF Link to HGA		01:00:00 after New Norcia AoS	
SGM Update Nominally on day 2, latest on day 7 (end of high downlink bitrate capability via LGA to NNO): After HGA deployment and verification of HGA link, the SGM shall be updated to provide the Safe Mode downlink via HGA, instead of LGA: - insert in SIT the call of Safe Mode OBCP with invocation parameters - Low Power flag = FALSE (= 1) - MGA Strobing flag = FALSE (= 1) - delete in SIT the call of Survival Mode OBCP - set TFG information bitrate to 18 bps (FCP-SY0221)	28.02.2004		3
Trajectory Correction Manoeuvre 1	28.02.2004	01:00:00 after Madrid AoS	3

Table 3-15: Timeline of Major Mission/Operational Events (1/18)

CP 1	start	end	duration	mission day	procedure ref
start/end of phase	29.02.2004	07.06.2004	99	4	
TCM-2					fcp-sy0300
SGM Update Restore in SGM the nominal orientation of the S/C axis to be pointed to Sun or Earth: set the mga_pointed_sc_axis back to (1;0;0) = X-axis	03.03.2004			7	fcp-sy0221
Commissioning of S-band	03.03.2004	03.03.2004	1	7	fcp-tt0011
Commissioning of X-band	04.03.2004	17.03.2004	13	8	fcp-tt0012
DSM 1	05.06.2004			101	fcp-sy0302

Table 3-16: Timeline of Major Mission/Operational Events (2/18)

Cruise 1 - Earth to Earth	start	end	duration	mission day	procedure ref
start/end of phase	07.06.2004	20.09.2004	105	103	
SGM Update At some time in June 2004 the DSHAP patch shall be uploaded. When this is done, the parameter SEP_SEQ_STEP_COUNTER shall also be changed in SGM EEPROM to the value 0x000C, to be in line with the SW default value	07.06.2004			103	fcp-sy0221
AOCS checkout 1	10.06.2004		1	106	fcp-ac0020
s/c ranging & tracking					fcp-sy0200
SGM Update When SSCE angle falls below 94°, MGA Strobing gets feasible: Set MGA Strobing flag = TRUE (= 0 in call of Safe Mode OBCP in SIT)	23.06.2004			119	fcp-sy0221
AOCS checkout 2	16.09.2004			204	fcp-ac0020

Table 3-17: Timeline of Major Mission/Operational Events (3/18)

CP 2	start	end	duration	mission day	procedure ref
start/end of phase	20.09.2004	04.11.2004	45	208	
MGA commissioning	20.09.2004	20.09.2004	1	208	fcp-tt0013
various commissioning activities					
MGA Pattern measurement	02.11.2004	02.11.2004	1	251	fcp-sy0560

Table 3-18: Timeline of Major Mission/Operational Events (4/18)

Earth Swing-by 1	start	end	duration	mission day	procedure ref
start/end of phase	04.11.2004	04.04.2005	151	253	
SGM Update After measurement of MGA pattern (FCP-SY0560): update the mga_pointed_sc_axis according measurement results	04.11.2004			253	fcp-sy0221
DSM 2	08.12.2004			287	fcp-sy0302
begin of LGA TM visibility	27.01.2005			337	
s/c ranging & tracking	03.02.2005			344	fcp-sy0200
SGM Update Change the Safe Mode flag 'is_Y_axis_north_pointing_TC' to South, when the SSCE angle falls below 25° (see FCP-SY0221). The reason is that with the Y-axis North and the X-axis Sun-pointing the Earth tracking by HGA will no longer be possible, when the SSCE angle gets below 18° (SW limit).	06.02.2005			347	fcp-sy0221
SGM Update At 14 days before Earth fly-by 1: Set MGA Strobing flag = FALSE (= 1 in call of Safe Mode OBCP in SIT) i.e. LGA Strobing will be used	16.02.2005			357	fcp-sy0221
TCMs (approach)	21.02.2005			362	
S-band downlink via HGA	25.02.2005			366	
change to S-band downlink vial LGA	01.03.2005			370	fcp-sy0200
closest approach	03.03.2005			**372**	
change to S-band downlink vial HGA	04.03.2005			373	fcp-sy0200
Attitude recovery					
X-band downlink via HGA	11.03.2005			380	
System checkout					
AOCS checkout 3	17.03.2005			386	fcp-ac0020
SGM Update At 21 days after Earth fly-by 1: Set MGA Strobing flag = TRUE (= 0 in call of Safe Mode OBCP in SIT)	24.03.2005			393	fcp-sy0221

Table 3-19: Timeline of Major Mission/Operational Events (5/18)

Cruise 2: Earth to Mars	**start**	**end**	**duration**	**mission day**	**procedure ref**
start/end of phase	04.04.2005	06.09.2006	520	404	
update heater configuration					fcp-sy0370
Transition to NSHM0	04.04.2005	04.05.2005	30	404	fcp-sy0120
Receivers switched to LGA/MGA					fcp-sy0200
drive HGA to NSHM position and switch-off					fcp-sy0200
Exit of NSHM0					
update heater configuration					fcp-sy0370
NSHM sun pointing test	09.05.2005	14.05.2005	5	439	
update heater configuration					fcp-sy0370
SGM Update SSCE is at a minimum and Sun/Earth are changing sides, therefore the Safe Mode flag 'is_Y_axis_north_pointing_TC' has to be reversed: change the flag 'is_Y_axis_north_pointing_TC' in SGM to North	19.05.2005			449	fcp-sy0221
Transition to NSHM1	23.05.2005	02.10.2005	132	453	fcp-sy0120
Receivers switched to LGA/MGA					fcp-sy0200
drive HGA to NSHM position and switch-off					fcp-sy0200
Exit from NSHM1	02.10.2005			585	
update heater configuration					fcp-sy0370
Switch-on HGA pointing mechanism, point HGA to Earth, X-band downlink initiation, receivers to HGA/LGA					
SGM Update When the Earth distance is approximately 0.8 AU, i.e. a number of days before the 'earth_min_distance' of 135 Mio km (default setting) is reached: Set the 'earth_min_distance' to 150 Mio km = 1 AU	07.08.2005			529	fcp-sy0221

Cruise 2: Earth to Mars	**start**	**end**	**duration**	**mission day**	**procedure ref**
SGM Update When the Earth distance just exceeds the 'earth_min_distance' 135 Mio km: - Set the 'earth_min_distance' back to 135 Mio km = 1 AU - Set the flag 'is_Y_axis_north_pointing_TC' in SGM to South Note, that it is important that these flags become valid at the same time. For example, if the Y-axis flag is set to South before the 'earth_min_distance' is reached, then the Safe Mode cannot point the HGA to Earth!!! The reason is that in this case the Sun-pointing attitude is still established and the Earth direction would require a positive HGA elevation angle (which is forbidden before the comet orbit phase is reached). Vice versa: if the S/C falls in Safe Mode after the 'earth_min_distance' is exceeded but the Y-axis flag is still set to North, then the Safe Mode would point the X-axis to Earth and the solar array would be driven to a negative angle (which is not critical as such, but should be avoided in view of a potential SADM blockage, which would have more severe drawbacks than at a positive angle)	19.08.2005			541	fcp-sy0221
AOCS checkout 4	04.10.2005			587	fcp-ac0020
Payload checkout 1	17.10.2005	22.10.2005	5	600	
update heater configuration					fcp-sy0370
Transition to NSHM2	07.11.2005	21.02.2006	106	621	fcp-sy0120
Exit of NSHM2	21.02.2006				
update heater configuration					fcp-sy0370
AOCS checkout 5	24.02.2006			730	fcp-ac0020
begin of Solar Conjunction 1	21.03.2006	08.05.2006	48	755	
possible communication blackout begins: SSCE drops below 1°	09.04.2006			774	
Solar Conjunction 1 SGM Update Sun and Earth are changing sides, therefore the S/C orientation for Safe Mode has to be reversed: change the flag 'is_Y_axis_north_pointing_TC' in SGM to North (FCP-SY0221). Because of the small SSCE direct commanding is not safe, therefore this action shall be performed from the MTL and Back-up MTL.	12.04.2006			777	fcp-sy0221
possible communication blackout ends: SSCE increases above 1°	18.04.2006			783	
RSI tests					

Cruise 2: Earth to Mars	start	end	duration	mission day	procedure ref
end of Solar Conjunction 1	08.05.2006			803	
Payload checkout 2	15.05.2006	20.05.2006	5	810	
AOCS checkout 6	03.06.2006			829	fcp-ac0020
update heater configuration					fcp-sy0370
transition to NSHM3	05.06.2006	06.09.2006	93	831	fcp-sy0120
Exit from NSHM3	06.09.2006			924	
update heater configuration					fcp-sy0370

Table 3-20: Timeline of Major Mission/Operational Events (6/18)

Mars swing-by	start	end	duration	mission day	procedure ref
start/end of phase	06.09.2006	28.03.2007	203	924	
DSM3	05.10.2006			953	fcp-sy0302
AOCS checkout 7	26.10.2006			974	fcp-ac0020
Payload checkout 3	27.11.2006	22.12.2006	25	1006	
Begin of Earth occultation - **loss of communication links**					
End of Earth occultation - **reacquisition of communication links**					fcp-sy0200
TCMs (approach)					fcp-sy0302
Preparation of Mars science (if applicable)					
closest approach	27.02.2007			1098	
Attitude recovery					
AOCS checkout 8	22.03.2007			1121	fcp-ac0020

Table 3-21: Timeline of Major Mission/Operational Events (7/18)

Cruise 3: Mars to Earth	start	end	duration	mission day	procedure ref
start/end of phase	28.03.2007	16.09.2007	172	1127	
s/c health checks					
update heater configuration					fcp-sy0370
Transition to NSHM4	28.03.2007			1127	fcp-sy0120
Exit from NSHM4	16.09.2007			1299	
s/c ranging & tracking					fcp-sy0200
update heater configuration					fcp-sy0370

Table 3-22: Timeline of Major Mission/Operational Events (8/18)

Earth Swing-by 2	**start**	**end**	**duration**	**mission day**	**procedure ref**
start/end of phase	16.09.2007	16.12.2007	91	1299	
AOCS checkout 9	17.09.2007			1300	fcp-ac0020
Payload checkout 4	17.09.2007	19.10.2007	32	1300	
SGM Update When the SSCE angle falls below 25°, change the direction of the mga_pointed_sc_axis such that it is 50° above the +X-axis towards +Z (direction cosines are (cos 50°, 0, sin 50°), see FCP-SY0221). This is the same set-up as after launch, in preparation for the large SSCE angles. Otherwise, blinding of the STRs by the Earth could occur. This set-up is done so early, because with the Y-axis North and the X-axis Sun-pointing the Earth tracking by HGA will no longer be possible, when the SSCE angle gets below 18° (SW limit).	08.10.2007			1321	fcp-sy0221
begin of LGA TM visibility	01.11.2007			1345	
SGM Update At 14 days before Earth fly-by 2: Set MGA Strobing flag = FALSE (= 1 in call of Safe Mode OBCP in SIT) i.e. LGA Strobing will be used (see FCP-SY0221)	01.11.2007			1345	
s/c ranging & tracking					fcp-sy0200
TCMs (approach)					
S-band downlink via HGA	12.11.2007			1356	fcp-sy0200
change to S-band downlink via LGA	14.11.2007			1358	fcp-sy0200
closest approach	15.11.2007			**1359**	
change to S-band downlink via HGA	15.11.2007			1359	fcp-sy0200
Attitude recovery					
X-band downlink via HGA	20.11.2007			1364	
SGM Update Change the mga_pointed_sc_axis back to nominal direction (see FCP-SY0221)	29.11.2007			1373	fcp-sy0221
Before the Sun distance falls below 0.91 AU the MPPT shall be switched off, according procedure CRP-SY0080.	03.12.2007			1377	crp-sy0080

Table 3-23: Timeline of Major Mission/Operational Events (9/18)

Cruise 4: Earth 2 to Earth 3	**start**	**end**	**duration**	**mission day**	**procedure ref**
start/end of phase	16.12.2007	12.09.2009	636	1390	
SGM Update At 58 days after Earth fly-by 2: Set MGA Strobing flag = TRUE (= 0 in call of Safe Mode OBCP in SIT). (see FCP-SY0221) For recovery the MGA S-Band TM downlink at 64 bps will be used, until the SSCE is below 74 deg for MGA X-Band downlink (80 days after fly-by)	12.01.2008			1417	fcp-sy0221
After the Sun distance has increased above 0.91 AU, the MPPT shall be switched on again, according procedure CRP-SY0080.	14.01.2008			1419	crp-sy0080
SSCE angle is below 74°, i.e. MGA X-Band TM downlink can be used during recovery from MGA strobing	03.02.2008			1439	
AOCS checkout 10	24.03.2008			1489	fcp-ac0020
Payload checkout 5	24.03.2008	29.03.2008	5	1489	
SGM Update Change the Safe Mode flag 'is_Y_axis_north_pointing_TC' to South, when the SSCE angle falls below 25° (see FCP-SY0221). The reason is that with the Y-axis North and the X-axis Sun-pointing the Earth tracking by HGA will no longer be possible, when the SSCE angle gets below 18° (SW limit).	01.04.2008			1497	fcp-sy0221
begin of Solar Opposition 1	19.04.2008	30.04.2008	11	1515	
possible communication blackout begins: SSCE drops below 1°	24.04.2008			1520	
Solar Opposition 1 SGM Update Sun and Earth are changing sides, therefore the S/C orientation for Safe Mode has to be reversed: change the flag 'is_Y_axis_north_pointing_TC' in SGM to North (FCP-SY0221). Because of the small SSCE direct commanding is not safe, therefore this action shall be performed from the MTL and Back-up MTL.	25.04.2008			1521	fcp-sy0221
possible communication blackout ends: SSCE increases above 1°	26.04.2008			1522	
RSI tests					
end of Solar Opposition 1	30.04.2008			1526	
update heater configuration					fcp-sy0370
Transition to NSHM5	05.05.2008			1531	fcp-sy0120

Cruise 4: Earth 2 to Earth 3	start	end	duration	mission day	procedure ref
SGM Update via MTL and Back-up MTL When the Earth distance is approximately 0.8 AU, i.e. a number of days before the 'earth_min_distance' of 135 Mio km (default setting) is reached: Set the 'earth_min_distance' to 150 Mio km = 1 AU	25.05.2008			1551	fcp-sy0221
SGM Update via MTL and Back-up MTL When the Earth distance just exceeds the 'earth_min_distance' 135 Mio km: - Set the 'earth_min_distance' back to 135 Mio km = 1 AU - Set the flag 'is_Y_axis_north_pointing_TC' in SGM to South Note, that it is important that these flags become valid at the same time. For example, if the Y-axis flag is set to South before the 'earth_min_distance' is reached, then the Safe Mode cannot point the HGA to Earth!!! The reason is that in this case the Sun-pointing attitude is still established and the Earth direction would require a positive HGA elevation angle (which is forbidden before the comet orbit phase is reached). Vice versa: if the S/C falls in Safe Mode after the 'earth_min_distance' is exceeded but the Y-axis flag is still set to North, then the Safe Mode would point the X-axis to Earth and the solar array would be driven to a negative angle (which is not critical as such, but should be avoided in view of a potential SADM blockage, which would have more severe drawbacks than at a positive angle).	04.06.2008			1561	fcp-sy0221
Exit from NSHM5	14.09.2008			1663	
update heater configuration					fcp-sy0370
s/c ranging & tracking					fcp-sy0200
AOCS checkout 11	15.09.2008			1664	fcp-ac0020
Payload checkout 6	22.09.2008	27.09.2008	5	1671	
begin of Solar Conjunction 2	15.12.2008	25.01.2009	41	1755	
Solar Conjunction 2 SGM Update Sun and Earth are changing sides, therefore the S/C orientation for Safe Mode has to be reversed: change the flag 'is_Y_axis_north_pointing_TC' in SGM to North (FCP-SY0221). Because of the small SSCE direct commanding is not safe, therefore this action shall be performed from the MTL and Back-up MTL.	04.01.2009			1775	fcp-sy0221
end of Solar Conjunction 2	25.01.2009			1796	

Cruise 4: Earth 2 to Earth 3	start	end	duration	mission day	procedure ref
Payload checkout 7	16.02.2009	28.02.2009	12	1818	
AOCS checkout 12	15.03.2009			1845	fcp-ac0020
DSM4	24.03.2009			1854	fcp-sy0302
Transition to NSHM6	06.04.2009			1867	fcp-sy0120
SGM Update via MTL and Back-up MTL When the Earth distance falls below 150 Mio km: - Set the 'earth_min_distance' to 150 Mio km = 1 AU - Set the flag 'is_Y_axis_north_pointing_TC' in SGM to South Note, that it is important that these flags become valid at the same time. (see FCP-SY0221)	27.07.2009			1979	fcp-sy0221
SGM Update via MTL and Back-up MTL When the Earth distance is fallen below 135 Mio km: Restore the default setting 'earth_min_distance' = 135 Mio km (see FCP-SY0221)	04.08.2009			1987	fcp-sy0221
Exit from NSHM5	12.09.2009			2026	

Table 3-24: Timeline of Major Mission/Operational Events (10/18)

Earth Swing-by 3	start	end	duration	mission day	procedure ref
start/end of phase	12.09.2009	12.12.2009	91	2026	
AOCS checkout 13	14.09.2009			2028	fcp-ac0020
Payload checkout 8	14.09.2009	08.10.2009	24	2028	
begin of Solar Opposition 2	15.10.2009	26.10.2009	11	2059	
possible communication blackout begins: SSCE drops below 1°	19.10.2009			2063	
Solar Opposition 2 SGM Update Sun and Earth are changing sides, therefore the S/C orientation for Safe Mode has to be reversed: change the flag 'is_Y_axis_north_pointing_TC' in SGM to North (FCP-SY0221). Because of the small SSCE direct commanding is not safe, therefore this action shall be performed from the MTL and Back-up MTL.	21.10.2009			2065	fcp-sy0221
possible communication blackout ends: SSCE increases above 1°	22.10.2009			2066	
RSI tests					
end of Solar Opposition 2	26.10.2009			2070	
begin of LGA TM visibility	26.10.2009			2070	

Earth Swing-by 3	start	end	duration	mission day	procedure ref
SGM Update At 14 days before Earth fly-by 3: Set MGA Strobing flag = FALSE (= 1 in call of Safe Mode OBCP in SIT) i.e. LGA Strobing will be used (see FCP-SY0221)	27.10.2009			2071	fcp-sy0221
S-band downlink via HGA.	06.11.2009			2081	
Change to S-band downlink via LGA.	10.11.2009			2085	fcp-sy0200
TCMs (approach)					
closest approach	11.11.2009			**2086**	
change to S-band downlink vial HGA	12.11.2009			2087	fcp-sy0200
Attitude recovery					
X-band downlink via HGA	16.11.2009			2091	

Table 3-25: Timeline of Major Mission/Operational Events (11/18)

Cruise 5: Earth 3 to RVM1	start	end	duration	mission day	procedure ref
start/end of phase	12.12.2009	11.01.2011	395	2117	
SGM Update At 39 days after Earth fly-by 2: Set MGA Strobing flag = TRUE (= 0 in call of Safe Mode OBCP in SIT). (see FCP-SY0221)	20.12.2009			2125	fcp-sy0221
SGM Update Change the Safe Mode flag 'is_Y_axis_north_pointing_TC' to South, when the SSCE angle falls below 25° (see FCP-SY0221). The reason is that with the Y-axis North and the X-axis Sun-pointing the Earth tracking by HGA will no longer be possible, when the SSCE angle gets below 18° (SW limit).	27.01.2010			2163	fcp-sy0221
SGM Update Sun and Earth are changing sides, therefore the S/C orientation for Safe Mode has to be reversed: change the flag 'is_Y_axis_north_pointing_TC' in SGM to North (FCP-SY0221).	20.02.2010			2187	fcp-sy0221
SGM Update When the Earth distance is approximately 0.8 AU, i.e. a number of days before the 'earth_min_distance' of 135 Mio km (default setting) is reached: Set the 'earth_min_distance' to 150 Mio km = 1 AU (see FCP-SY0221)	14.03.2010			2209	fcp-sy0221
AOCS checkout 14	15.03.2010	15.03.2010	1	2210	fcp-ac0020
Payload checkout 9	15.03.2010	20.03.2010	5	2210	

Cruise 5: Earth 3 to RVM1	start	end	duration	mission day	procedure ref
SGM Update When the Earth distance just exceeds the 'earth_min_distance' 135 Mio km: - Set the 'earth_min_distance' back to 135 Mio km = 1 AU - Set the flag 'is_Y_axis_north_pointing_TC' in SGM to South Note, that it is important that these flags become valid at the same time. (see FCP-SY0221)	22.03.2010			2217	fcp-sy0221
update heater configuration					fcp-sy0370
transition to NSHM7	05.04.2010			2231	fcp-sy0120
exit from NSHM7	15.08.2010			2363	fcp-sy0120
update heater configuration					fcp-sy0370
AOCS checkout 15	30.08.2010	30.08.2010	1	2378	fcp-ac0020
Payload checkout 10	30.08.2010	04.09.2010	5	2378	
SGM Update Above 3.19 AU Sun distance the S/C does not get enough power from one panel of the solar array, when in Survival Mode (MGA Strobing). This means that the AOCMS flag 'is_ES_alwd_despite_sade_fail' (Means: Is Earth Strobing allowed despite failure of one SADM?) may have to be set to FALSE, if large attitude excursions are planned. It is required to verify by power calculation, that the blockage of one solar array panel at transition to MGA Strobing mode from any of the commanded attitudes can be survived by the S/C. In FCP-SY0221 Table 1.1.13-3 the critical offset angle as function of Sun distance is defined, above which this flag has to be set to FALSE. This Table shall be updated by new calculations, once the really available solar array power has been determined (which can be done at about 4.1 AU Sun distance, according FCP-TS0270).	14.09.2010			2393	fcp-sy0221
begin of Solar Conjunction 3	24.09.2010	13.11.2010	50	2403	
possible communication blackout begins: SSCE drops below 1°	14.10.2010			2423	

Cruise 5: Earth 3 to RVM1	start	end	duration	mission day	procedure ref
Solar Conjunction 3 SGM Update Sun and Earth are changing sides, therefore the S/C orientation for Safe Mode has to be reversed: change the flag 'is_Y_axis_north_pointing_TC' in SGM to North (FCP-SY0221). Because of the small SSCE direct commanding is not safe, therefore this action shall be performed from the MTL and Back-up MTL.	18.10.2010			2427	fcp-sy0221
possible communication blackout ends: SSCE increases above 1°	23.10.2010				
end of Solar Conjunction 3	13.11.2010				

Table 3-26: Timeline of Major Mission/Operational Events (12/18)

RVM-1 Phase	start	end	duration	mission day	procedure ref
start/end of phase	11.01.2011	11.07.2011	181	2512	
At about 4.1 AU it can be tested, how much power is available from the solar array (FCP-TS0270). For the following deep space phases operational constraints will have to be observed depending on the available solar array power (which is, for the same Sun distance, different for the phases before and after DSHM, due to radiation effects). The operational constraints for normal operations are explained and defined in section 3.5 of Vol. 1. The Safe and Survival Mode related constraints are handled by flags stored in SGM EEPROM. The timeline includes these required SGM updates, based on predicted performance data. After the really available solar array power has been determined, the dates shall be adjusted, if necessary.	27.02.2011				fcp-ts0270
AOCS checkout 16	28.02.2011	28.02.2011	1	2560	fcp-ac0020
SGM Update Above 4.15 AU: Put constraints on SSMM usage in Safe/Survival Mode: use 1 MM only (16.9 W) and update GSUT in SGM accordingly (FCP-SY0221)	09.03.2011				fcp-sy0221
Above 4.17 AU: Put constraints also on RWs usage in Safe/Survival Mode, RWs shall not consume more than 54W together: set lower reference speed, patch autonomous offloading threshold to lower value, e.g. 20 Nms (to be defined)	13.03.2011			2573	

RVM-1 Phase	start	end	duration	mission day	procedure ref
Payload checkout 11	21.03.2011	26.03.2011	5	2581	
SGM Update Above 4.28 AU: Set the flag 'is_deep_space' to TRUE in SGM for AOCMS (for intermittent operation of mechanisms in Safe Mode) (see FCP-SY0221); like-wise for normal operations: operate the mechanisms only when needed and not simultaneously	08.04.2011			2599	fcp-sy0221
Perform 2nd RCS Pressurisation (FCP-SY0150) SGM Update Update blow-down factor (bdf) in SGM to 1 (FCP-SY0221)	12.04.2011			2603	fcp-sy0150, fcp-sy0221
begin of Solar Opposition 3	13.04.2011	22.05.2011	39	2604	
possible communication blackout begins: SSCE drops below 1°	28.04.2011			2619	
Solar Opposition 3 SGM Update Sun and Earth are changing sides, therefore the S/C orientation for Safe Mode has to be reversed: change the flag 'is_Y_axis_north_pointing_TC' in SGM to North (FCP-SY0221). Despite the small SSCE direct commanding should be safe because of the large Sun distance, but nevertheless this action shall be performed from the MTL and Back-up MTL.	02.05.2011			2623	fcp-sy0221
possible communication blackout ends: SSCE increases above 1°	05.05.2011			2626	
RSI tests					
Execute RVM1a Due to the HGA pointing constraints this manoeuvre has to be splitted in two parts (FCP-SY0290 Dog-leg Delta-V Manoeuvre in Deep Space).	10.05.2011			2631	fcp-sy0290
Execute RVM1b (FCP-SY0290 Dog-leg Delta-V Manoeuvre in Deep Space).	20.05.2011			2641	fcp-sy0290
start tracking	20.05.2011			2641	
end of Solar Opposition 3	22.05.2011			2643	
Perform 2nd RCS Isolation (FCP-SY0152)	22.05.2011			2643	fcp-sy0152
SGM Update Above 4.46 AU: Set Low Power flag to TRUE in the SGM SIT for Safe Mode (SSMM to St-by, 5h per 12h downlink with tank heaters off) For Recovery from Survival Mode: Set 'Continuous Link' flag to FALSE (MGA X-Band downlink for 10h with tank heaters off) (see FCP-SY0221)	26.05.2011			2647	fcp-sy0221

RVM-1 Phase	start	end	duration	mission day	procedure ref
SGM Update Before DSH Entry the flag 'is_the_use_of_wheels_alwd' shall be set to FALSE in SGM for the Exit operations (see FCP-SY0221).	13.06.2011			2665	fcp-sy0221
tracking ends	15.06.2011			2667	
Start DSH Entry Operations, 20 days before latest possible entry (includes patch of SKM overrate thresholds, to avoid triggering of overrate surveillance in case of fallback to SKM during spin-up)	15.06.2011			2667	fcp-sy0160
DSH Entry is nominally achieved after 6 days (there are 14 days operational margin to latest possible entry at 4.6 AU)	21.06.2011			2673	
Latest DSH Entry	05.07.2011			2687	

Table 3-27: Timeline of Major Mission/Operational Events (13/18)

Cruise 6: Deep Space Hibernation	start	end	duration	mission day	procedure ref
start/end of phase	11.07.2011	23.01.2014	927	2693	
Solar Conjunction 4	15.10.2011	18.12.2011	64	2789	
Solar Opposition 4	29.04.2012	17.06.2012	49	2986	
Solar Conjunction 5	29.10.2012	06.01.2013	69	3169	
Solar Opposition 5	19.05.2013	04.07.2013	46	3371	
Solar Conjunction 6	23.11.2013	22.01.2014	60	3559	
DSHM Exit Initial Setting of flags is as follows (from setting before DSHM): - is_deep_space = TRUE - Low Power = TRUE (invocation parameter in Safe Mode OBCP) - is_the_use_of_wheels_alwd = FALSE - is_ES_alwd_despite_sade_fail = TRUE (see FCP-SY0221) For Recovery from Safe Mode: - switch to 1 gyro and switch-off PL heaters 8,13,18 before enabling the use of wheels For Recovery from Survival Mode: - set Continuous Link flag = FALSE for tank heaters off during 10h downlink - switch-off SADM when switching on STR	22.01.2014			3619	fcp-sy0170

Table 3-28: Timeline of Major Mission/Operational Events (14/18)

RVM-2 Phase	start	end	duration	mission day	procedure ref
begin/end of phase	23.01.2014	22.08.2014	211	3620	
update heater configuration					fcp-sy0370
Below 4.32 AU: Setting of flags is still as follows: - is_deep_space = TRUE - Low Power = TRUE (invocation parameter in Safe Mode OBCP) - is_the_use_of_wheels_alwd = FALSE (see FCP-SY0221) For Recovery from Safe Mode: - 2 gyros can stay on, but switch-off PL heaters 8,13,18 before enabling the use of wheels For Recovery from Survival Mode: - set Continuous Link flag = FALSE for tank heaters off during 10h downlink - switch-off SADM when switching on STR	11.03.2014			3667	fcp-sy0221
Below 4.26 AU: Setting of flags is still as follows: - is_deep_space = TRUE - Low Power = TRUE (invocation parameter in Safe Mode OBCP) - is_the_use_of_wheels_alwd = FALSE (see FCP-SY0221) For Recovery from Safe Mode: - 2 gyros can stay on, but switch-off PL heaters 8,13,18 before enabling the use of wheels For Recovery from Survival Mode: - set Continuous Link flag = FALSE for tank heaters off during 10h downlink - SADM need no longer be switched off when switching on STR	25.03.2014			3681	fcp-sy0221
SGM Update Below 4.21 AU: Setting of flags is now as follows: - is_deep_space = TRUE - Low Power = TRUE (invocation parameter in Safe Mode OBCP) - is_the_use_of_wheels_alwd = TRUE (see FCP-SY0221) For Recovery from Safe Mode: - no constraint except intermittent downlink (Low Power flag = TRUE) For Recovery from Survival Mode: - set Continuous Link flag = FALSE for tank heaters off during 10h downlink	06.04.2014			3693	fcp-sy0221

RVM-2 Phase	start	end	duration	mission day	procedure ref
SGM Update Below 4.04 AU: Setting of flags is now as follows: - is_deep_space = TRUE - Low Power = FALSE (invocation parameter in Safe Mode OBCP) - is_the_use_of_wheels_alwd = TRUE (see FCP-SY0221) For Recovery from Safe Mode: - no constraints, S-Band downlink is continuous For Recovery from Survival Mode: - no constraints: set Continuous Link flag = TRUE for continuous X-Band downlink	14.05.2014			3731	fcp-sy0221
RVM-2 burn	22.05.2014			3739	fcp-sy0280
SGM Update Below 3.86 AU: Setting of flags is now as follows: - is_deep_space = FALSE - Low Power = FALSE (invocation parameter in Safe Mode OBCP) - is_the_use_of_wheels_alwd = TRUE (see FCP-SY0221) For Recovery from Safe and Survival Mode: no constraints For Normal Operations: constraints on SSMM and RWs usage have still to be maintained: SSMM 1 MM only (16.9 W), RWs 54W	18.06.2014			3766	fcp-sy0221
begin of Solar Opposition 6	25.06.2014			3773	
RSI tests					
Below 3.74 AU: no constraints anymore (but RWs should stay below say 80 W initially)	12.07.2014			3790	
SGM Update At some convenient time during comet approach, when the major maneouvres are over, the mass properties of the S/C shall be reassessed (FCP-AC0575). Then the sc_inertia_matrix in SGM shall be updated accordingly (FCP-SY0221).	16.07.2014			3794	fcp-sy0221
end of Solar Opposition 6	23.07.2014			3801	

Table 3-29: Timeline of Major Mission/Operational Events (15/18)

Global Mapping and Close Observation Phase	start	end	duration	mission day	procedure ref
start/end of phase	22.08.2014	19.10.2014	58	3831	
Comet Orbit Insertion	22.08.2014			3831	
SGM Update In the following phases, where the S/C is close to the comet, the star acquisition in SAM or SKM (after a failure triggering fall-back to Safe Mode) may be hampered by the presence of comet dust in the STR FoV. In SAM and SKM a time-out of normally 1 hour will be active; if star acquisition is not achieved within this time-out, the S/C will enter Survival Mode. To avoid this transition to Survival Mode due to a transient disturbance by comet dust, the time-out shall be adjusted according to the actual environment and orbit conditions. This time-out 'max_stap_dur' shall be kept updated in SGM as required for the actual conditions (FCP-SY0221).	23.08.2014			3832	fcp-sy0221
update heater configuration					fcp-sy0370
delta-v maneouvre calibration					fcp-sy0270
comet mapping					
close observation	28.09.2014			3868	

Table 3-30: Timeline of Major Mission/Operational Events (16/18)

SSP Delivery and Relay Phase	start	end	duration	mission day	procedure ref
start/end of phase	19.10.2014	15.11.2014	27	3889	
update heater configuration					fcp-sy0370
Lander activation and test					
touch-up delta-v for SSP separation					fcp-sy0330
Orbiter re-orientation to Lander separation attitude					fcp-sy0180
Adjust solar array and HGA; if HGA Earth pointing is not possible in the given attitude, stop downlink and continue recording on SSMM					fcp-sy0180
Separation of SSP					
Orbiter manoeuvre to relay orbit					
Orbiter re-orientation for Lander data relay					
Solar array to Sun and HGA to Earth - resume downlink	10.11.2014			3911	
Begin of Relay Phase: acquisition and reception of Lander data link; downlink of data to Earth					

SSP Delivery and Relay Phase	start	end	duration	mission day	procedure ref
SGM Update Update SIT in SGM: remove the LCL 5A and 5B ON commands and add the LCL 17A ON command (PL PDU LCLs) (see FCP-SY0221)	11.11.2014			3912	fcp-sy0221
Below 2.96 AU Sun distance the AOCMS flag 'is_ES_alwd_despite_sade_fail' can be 'TRUE' permanently. Reminder: Above this distance (after DSHM) it was required to verify by power calculation, that the blockage of one solar array panel at transition to MGA Strobing mode from any of the commanded attitudes can be survived by the S/C. (see FCP-SY0221 Table 1.1.13-3)	13.11.2014			3914	fcp-sy0221

Table 3-31: Timeline of Major Mission/Operational Events (17/18)

Comet Escorting Phase	start	end	duration	mission day	Procedure ref
start/end of phase	15.11.2014	31.12.2015	411	3916	
update heater configuration					fcp-sy0370

Table 3-32: Timeline of Major Mission/Operational Events (18/18)

4. AVIONICS DEFINITION

For the Avionics Subsystem a dedicated Users Manual is available: RO-MMT-MA-2025.

5. PLATFORM DEFINITION

The ROSETTA platform is designed to fulfill the need to accommodate the payload (including fixed, deployable and ejectable experiment packages), high gain antenna, solar arrays and propellant mass in a particular geometrical relationship (mass properties and spacecraft viewing geometry) and with the specified modularity (Bus Support Module and Payload Support Module incorporating Lander Interface Panel). The thermal environment also drives the configuration such that high dissipation units must be mounted on the side walls with thermal louvres providing trimming for changing external conditions during the mission.

The design of the platform's electrical architecture is driven by the need to meet specific power requirements at aphelion (the solar array sizing case) and to incorporate maximum power point tracking. Additional factors such as the uncertainty in the performance of the Low Intensity Low Temperature solar cell technology have also influenced the design.

The telecommunications design is driven by the need to be compatible with ESA's 15m and 32m ground stations and the 34m and 70m DSN stations. This has produced requirements for dual S/X band and variable rate capability, together with an articulated High Gain Antenna to maximise data transfer during the payload operations, and a fixed Medium Gain Antenna to act as backup for the HGA in case of failure.

5.1. Platform Description

5.1.1. Platform Reference Axes

The Platform Reference Axes have their origin at the centre of the launcher interface. From there, the Z axis extends vertically upwards through the top panel on which the majority of the payload is mounted, the X axis extends forward such that it is normal to and extending past the face on which the HGA is mounted, and the Y axis completes the right-handed axis set. The sense of the axes is shown in Figure 5-1.

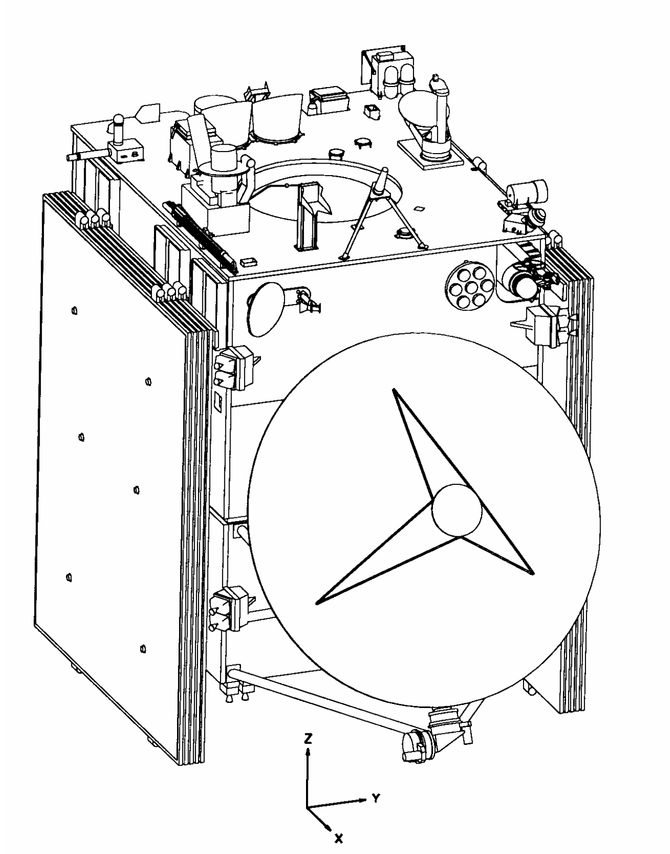


Figure 5-1: Direction of Platform Reference Axes

SADM Reference Axes

The array zero position is as defined in Figure 5-2 and Figure 5-3. At zero (reference) position the array wing is aligned such that the array surface is in the spacecraft Y-Z plane, with the face (cells) aligned such that the array normal is parallel to the +X axis of the spacecraft.

Array rotation is limited to plus and minus 180 degrees to the reference position.

The direction of positive rotation for both array wings is such that viewed from the array side of the SADM the motion is clockwise.

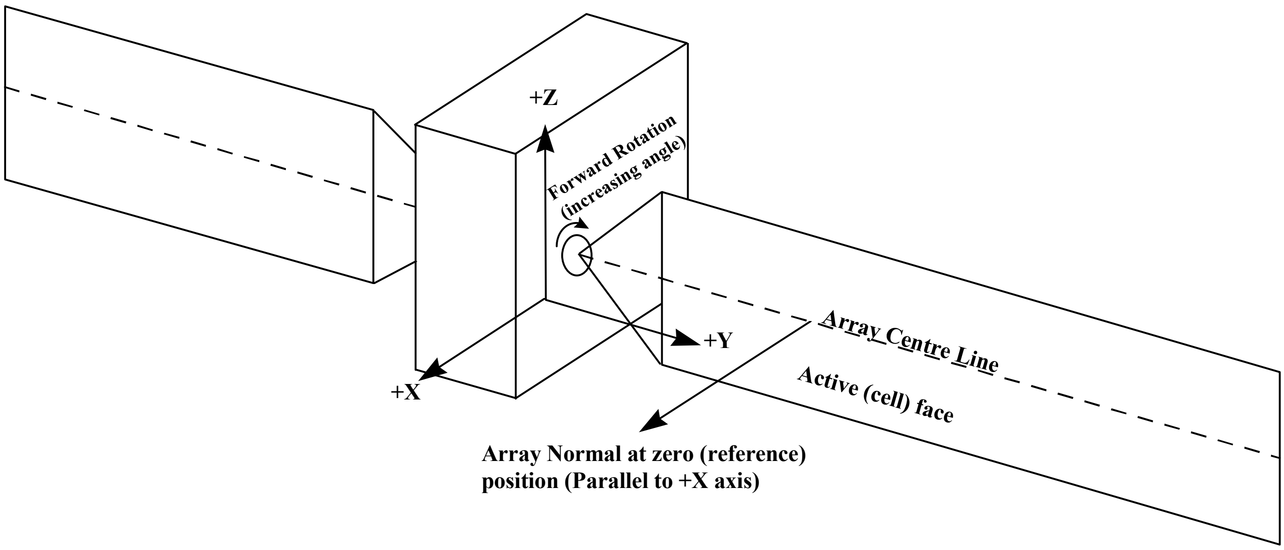


Figure 5-2: +Y Solar Array Drive Reference Axis

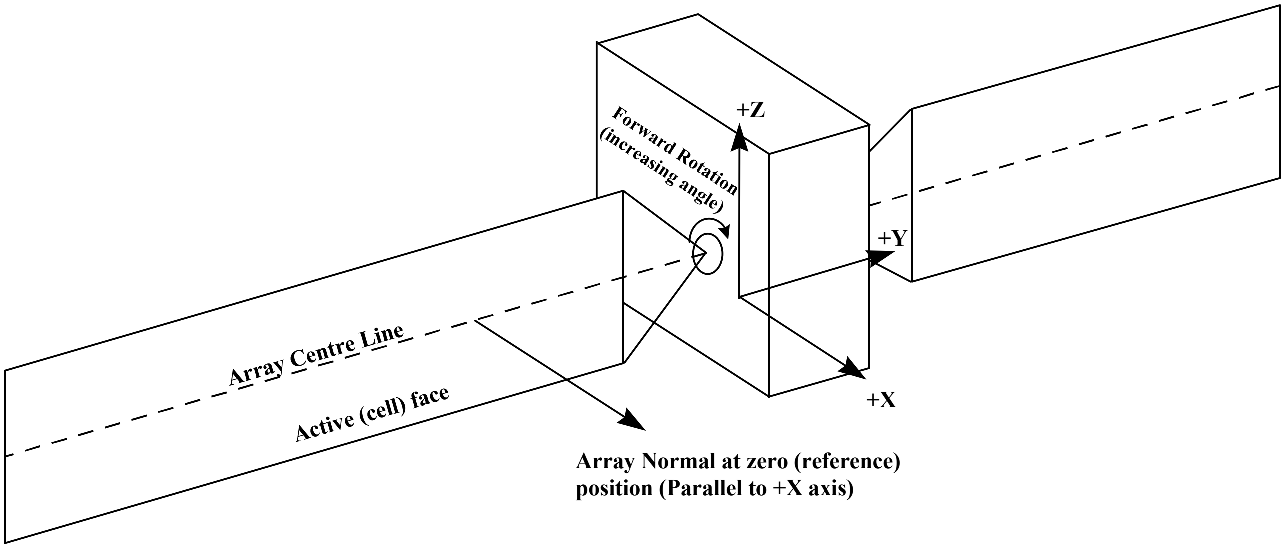


Figure 5-3: -Y Solar Array Drive Reference Axis

High Gain Antenna Reference Axes

The HGA zero position is as illustrated in

Figure 5-4

Figure 5-5 and

Figure 5-6

HGA elevation rotation is limited to +30° / -165° from the reference position (except during deployment when elevations between –210° and –165° are allowable).

HGA azimuth rotation is limited to +80° / -260° from the reference position.

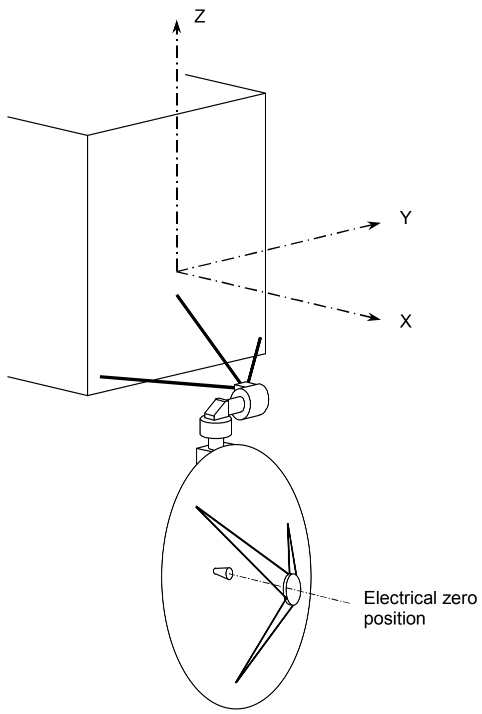


Figure 5-4: APM Electrical Zero

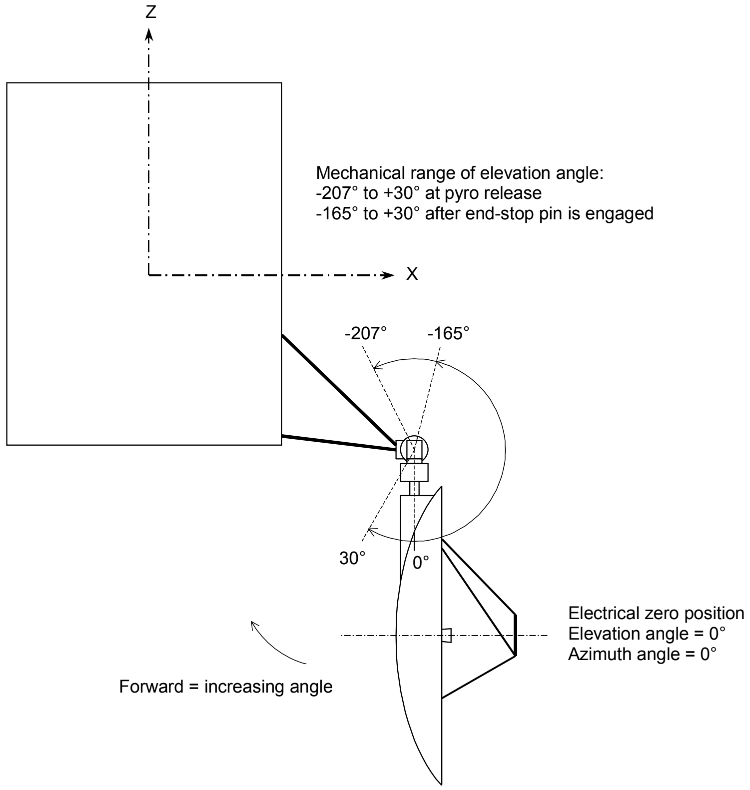


Figure 5-5: Elevation Zero

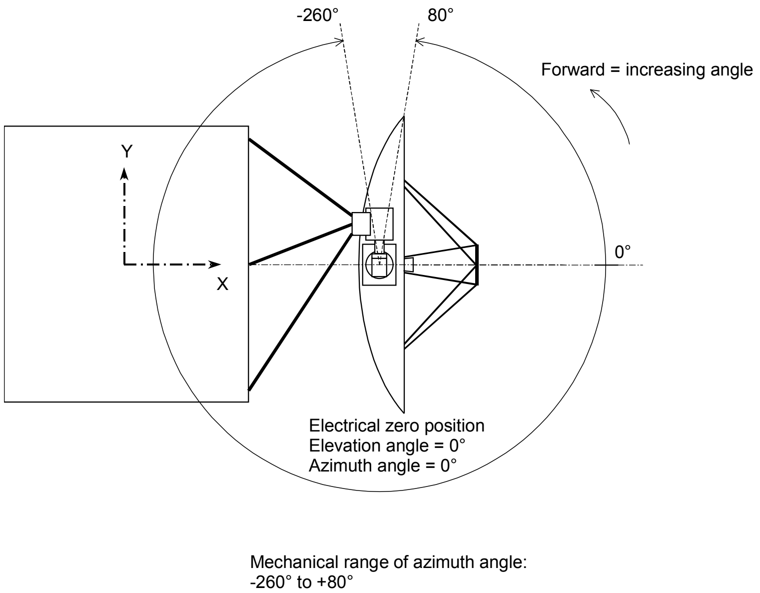


Figure 5-6: Azimuth Zero

5.1.2. External Interfaces

N/A

5.1.3. Internal Interfaces

Internal interfaces of the platform are described in the relevant subsystem sections of §5.

5.2. Spacecraft Configuration

Views of the external configuration of the PFM spacecraft and the layout of each panel are shown in the following figures. Links to larger scale configuration drawings in Annex 9 have been included. In case a figure contains a hyperlink, the figure title is underlined and colored in blue.

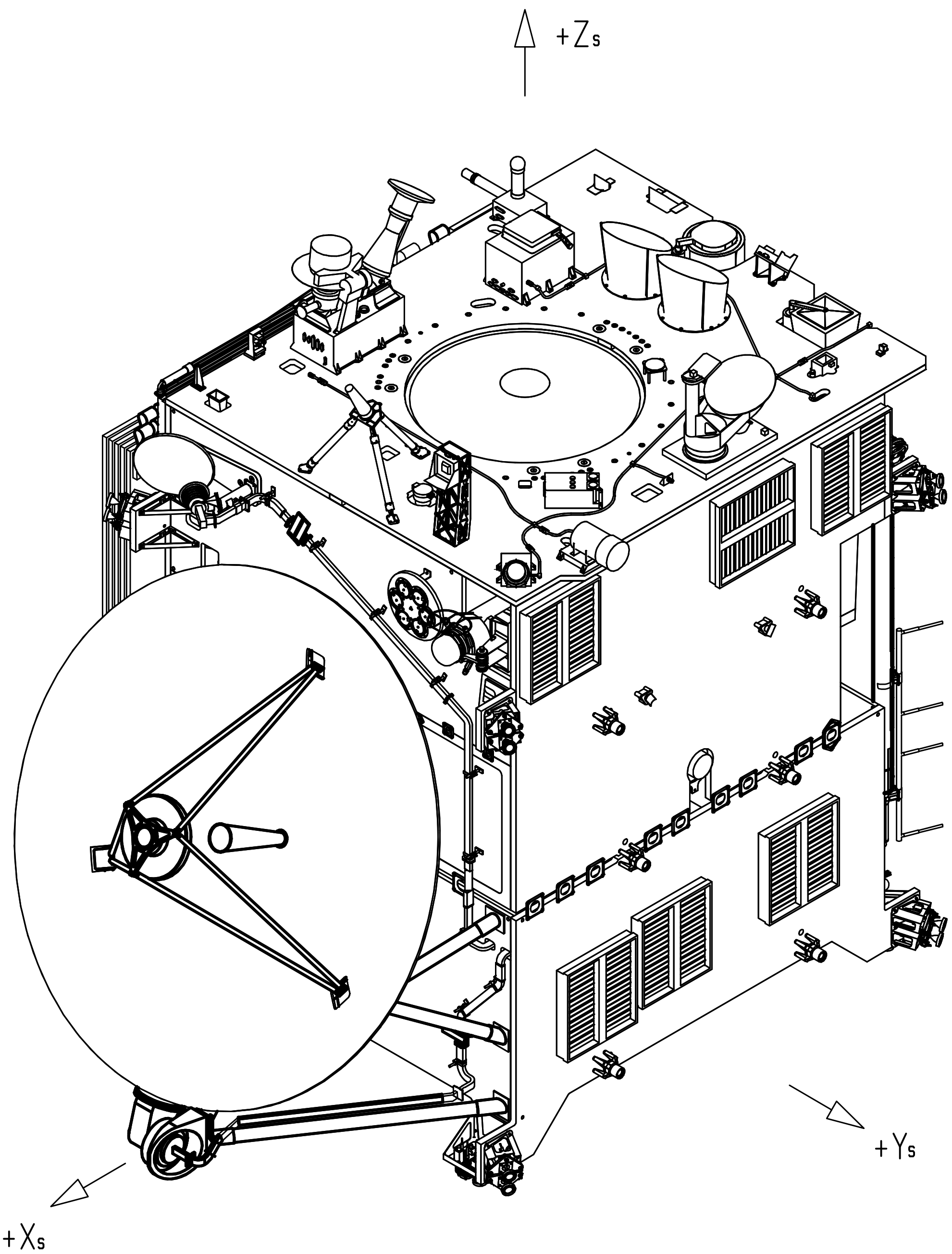


Figure 5-7: Isometric View of spacecraft (Launch Configuration +X face)

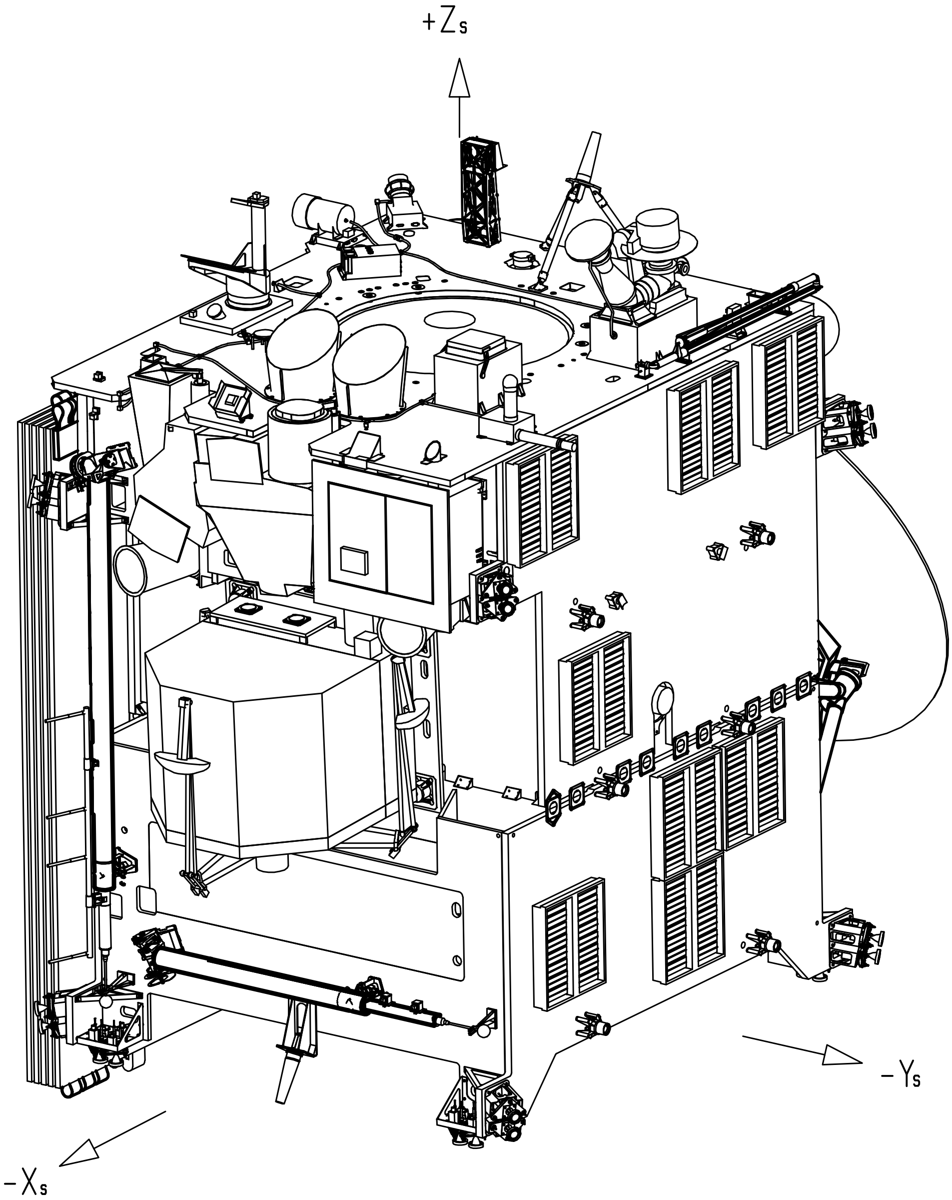


Figure 5-8: Isometric View of spacecraft (Launch Configuration -X face)

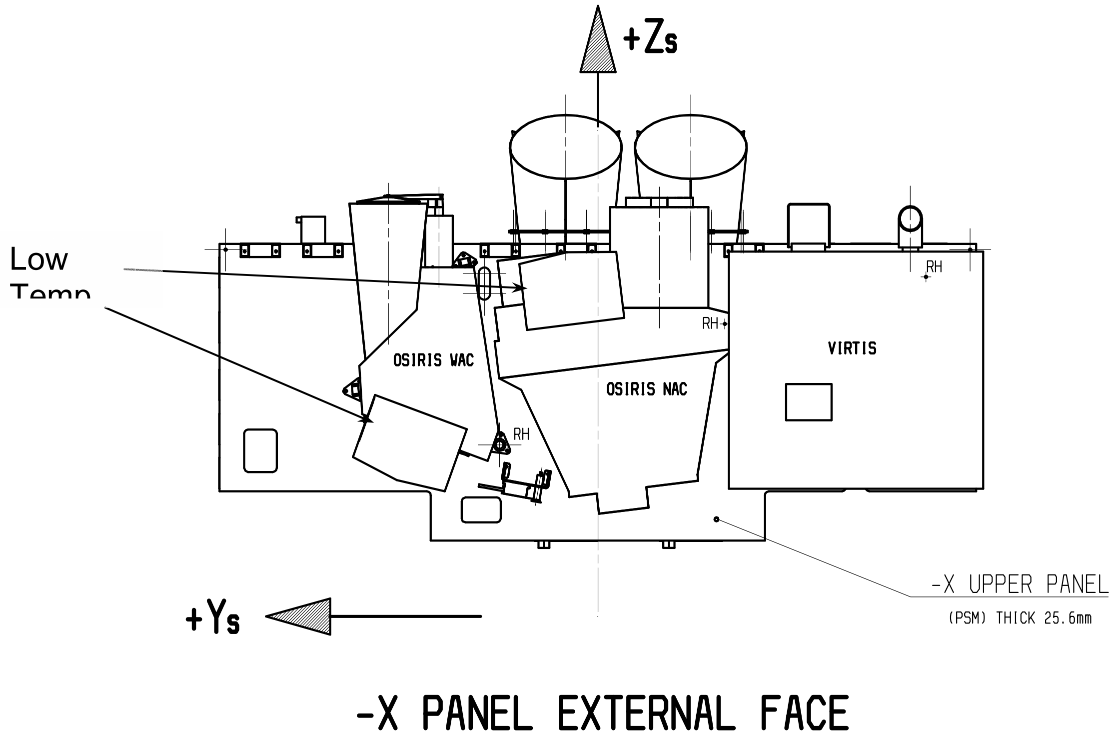


Figure 5-9: -X Panel External Face

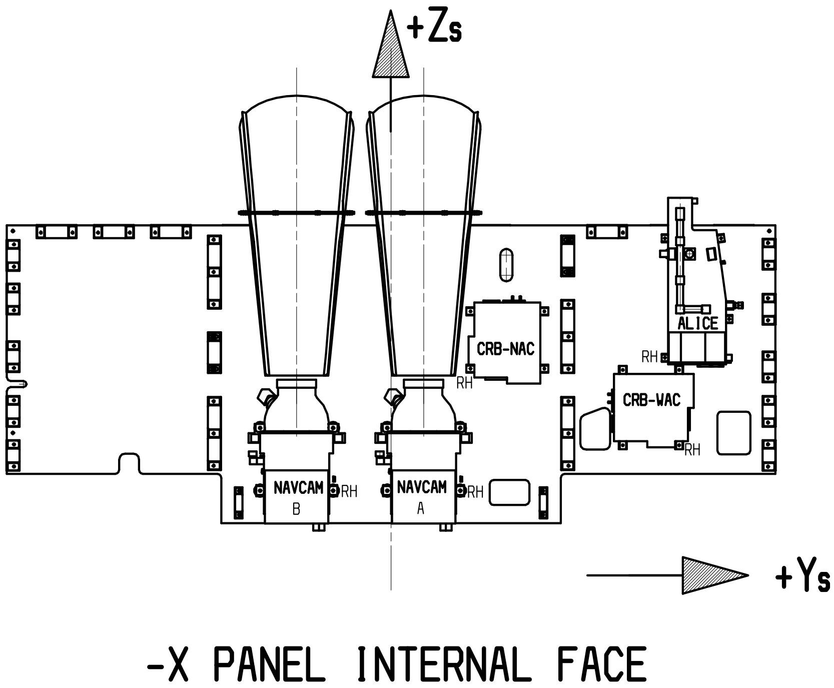


Figure 5-10: -X Panel Internal Face

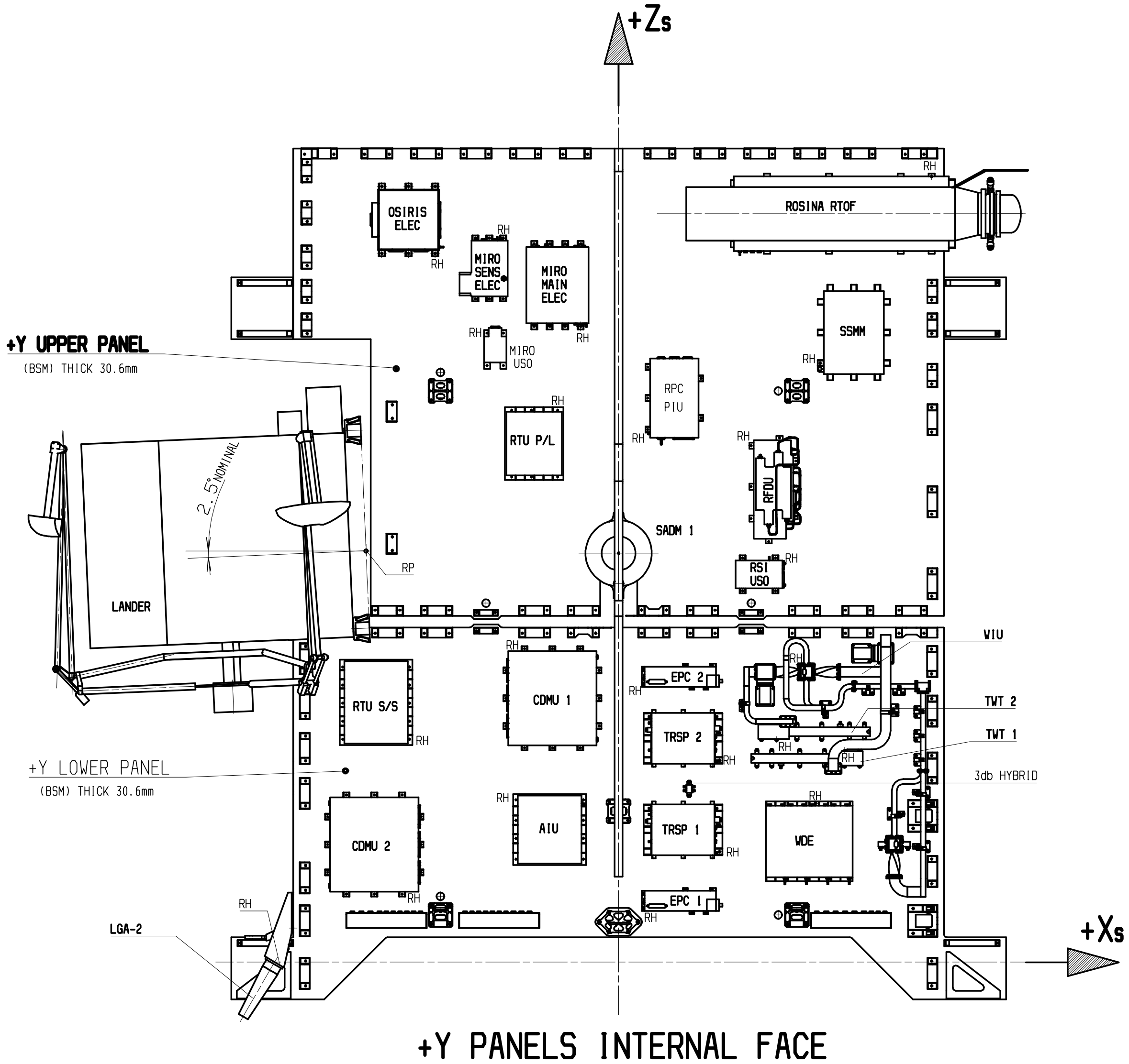


Figure 5-11: View on +Y panel

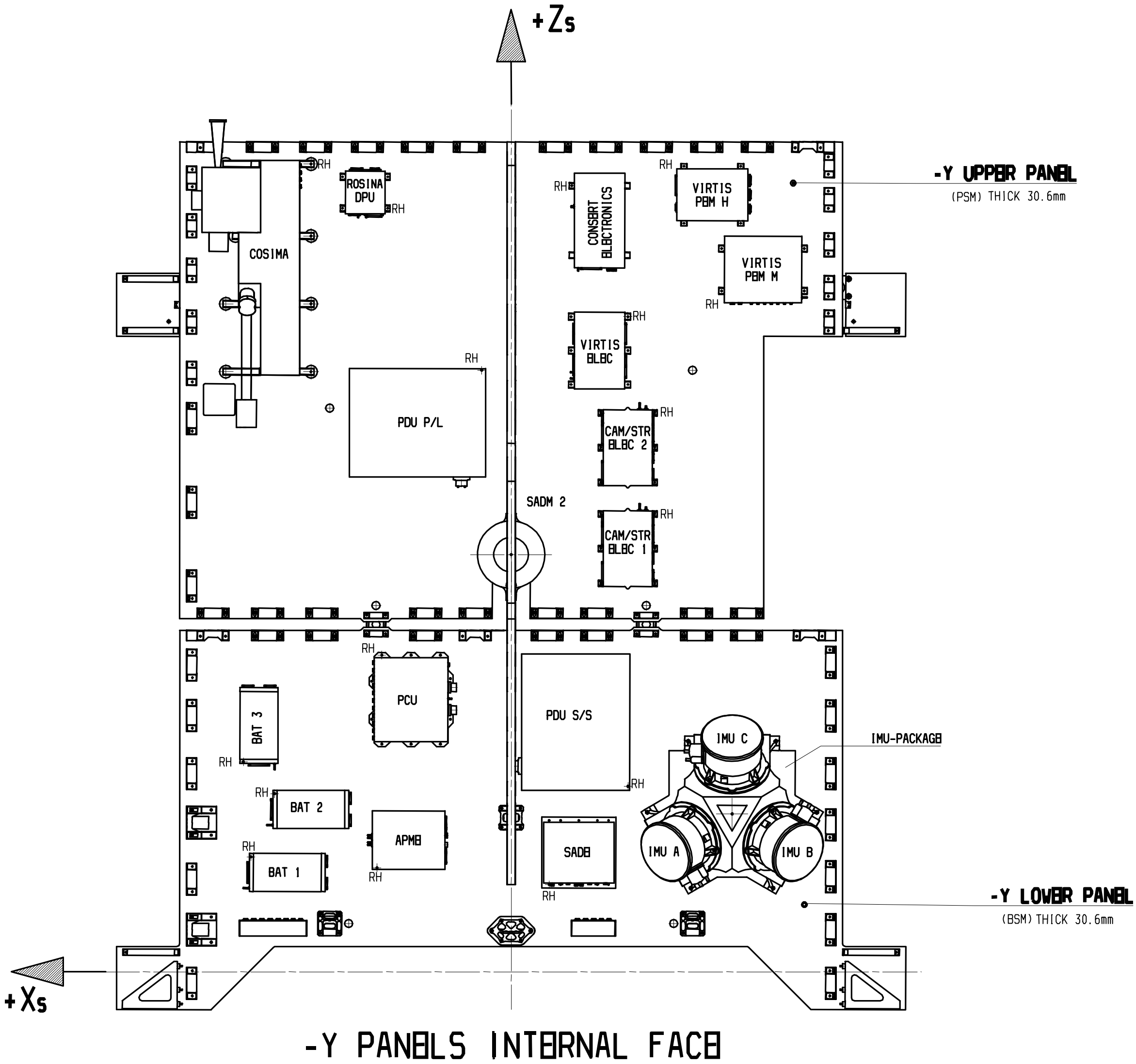


Figure 5-12: View on -Y panel

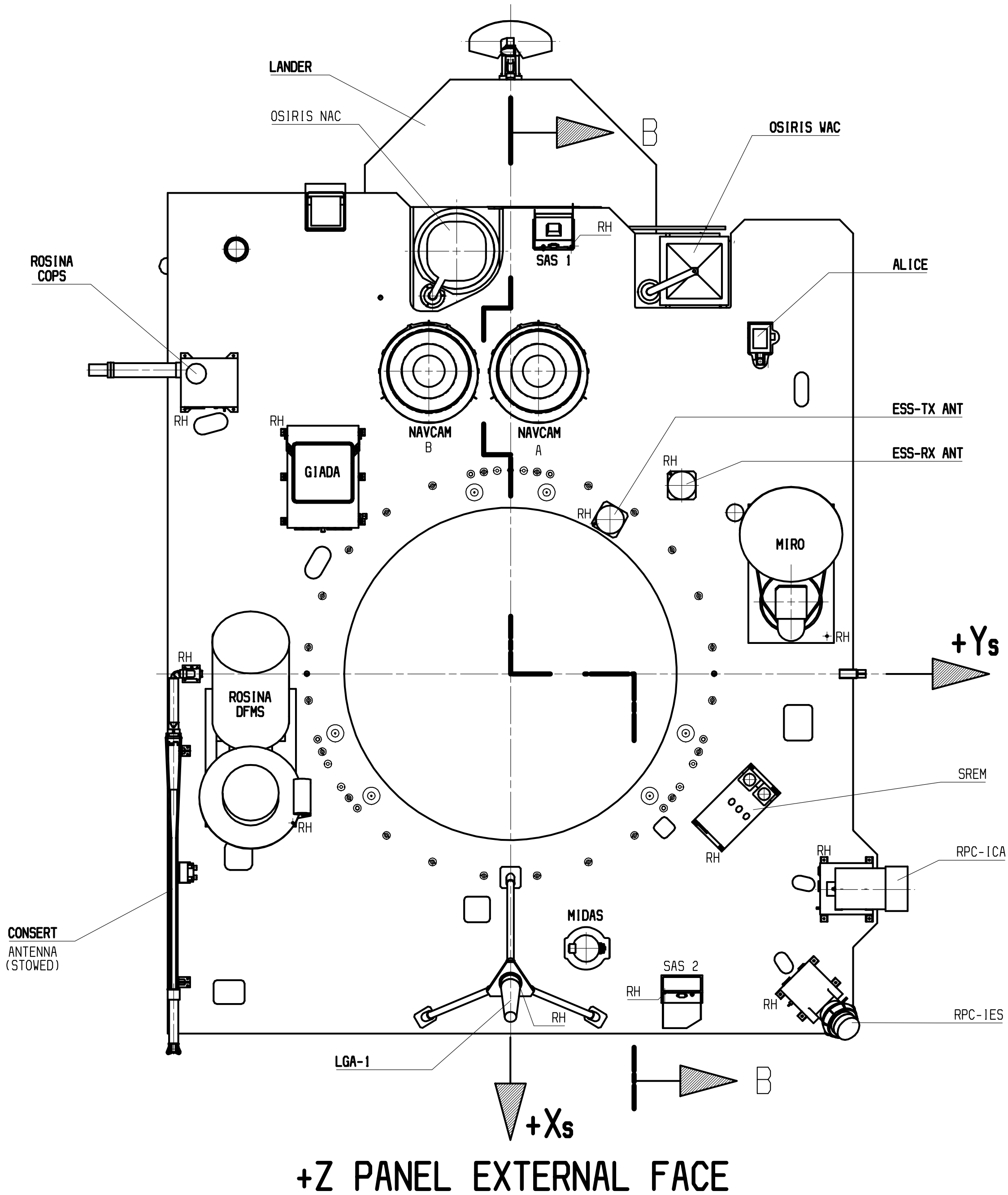


Figure 5-13: View on upper platform, top face

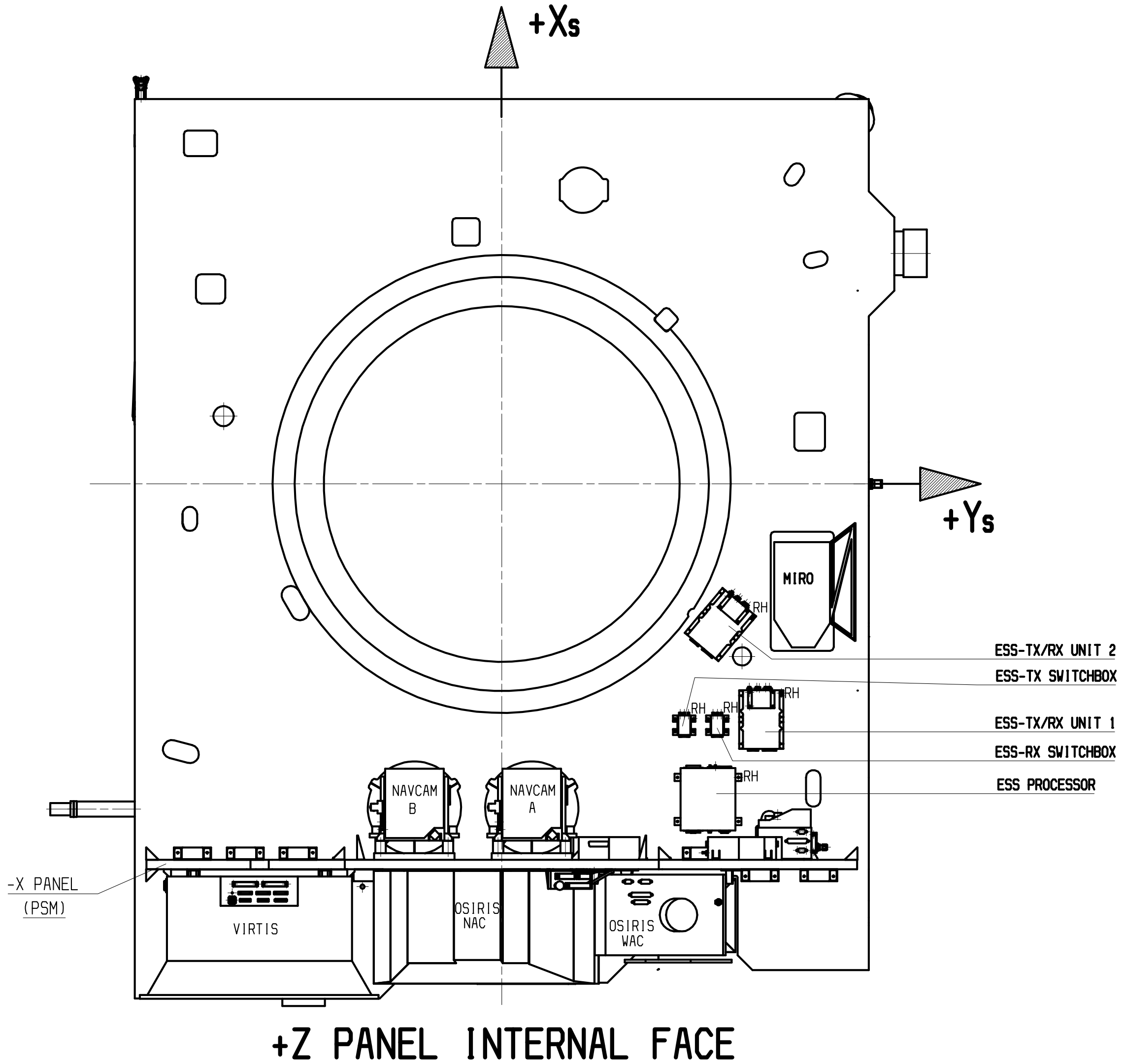


Figure 5-14: View on upper platform, lower face

5.3. Electrical Subsystem

5.3.1. Overall Electrical Architecture and Design

The Platform Electrical Subsystems comprise the following

Power

- 1 off Power Control Unit (PCU)
- 1 off Payload Power Distribution Unit (PL-PDU)
- 1 off BSM Power Distribution Unit (SS-PDU)
- 3 off 16Ahr Li ion Batteries
- The Solar Array Photo Voltaic Assembly is also included for completeness

TTC RF

- 2 off Dual Band Transponders (X/S)
- 2 off X band Travelling Wave Tube Amplifiers (TWTA)
- 1 off Ultra Stable Oscillator (RSI use only) (USO)
- 1 off Medium Gain Antenna (X) (MGA X)
- 1 off Medium Gain Antenna (S) (MGA S)
- 2 off Low gain Antenna (S) (LGA)
- 1 off Waveguide Switching Unit (WIU)
- 1 off Radio Frequency Distribution Unit (RFDU)
- Waveguide
- Coax cables

DC Harness

- 1 off BSM Power/Signal harness
- 1 off PL Power/Signal harness

- 1 off Pyro harness
- BSM/PL interface connector brackets
- Skin connector brackets
- Internal harness demounting brackets

Intra Experiment harness is not included, but is provided by ESA.

Miscellaneous electrical equipment, APME/SADE/Pressure Transducers are covered in the HGAMA, SADM and Propulsion areas respectively.

5.3.2. Power Subsystem

5.3.2.1. Subsystem Description

The following block diagram (Figure 5-15) shows the elements of the Rosetta Power System :

The Power Subsystem (PSS) conditions, regulates and distributes all the electrical power required by the spacecraft throughout all phases of the mission. Distribution involves the switching and protection of power lines to all users, including the Avionics units and the Payload instruments, and includes equipment power, thermal power and keep-alive-lines. The PSS also switches, protects and distributes power for the pyrotechnics and thermal knives of the various release mechanisms on the spacecraft.

The main power source for Rosetta is provided by the Solar Array Subsystem from solar cells mounted on 2 identical solar array wings, which are deployed from the +Y and -Y faces of the spacecraft and can be rotated to track the sun. The PSS design has a solar array comprising all silicon (Si) cells which are specially designed to work in Low Intensity, Low Temperature (LILT) conditions. The solar cells on the outer panel of each wing are outward facing when in the launch (stowed) configuration in order to provide power input to the PSS for loads and battery recharge following separation from the launcher and prior to full array deployment. When initially deployed, these cells point towards +Z so as to be sun facing during the initial 45° bias.

Batteries provide power during the launch, coast and post-separation phases until the solar arrays are fully deployed and sun pointing, and thereafter will support the main power bus as necessary to supply peak loads. Batteries are also the main power source for the pyrotechnics, although pyrotechnic power is also available from the main bus as a back-up in case there is no battery power.

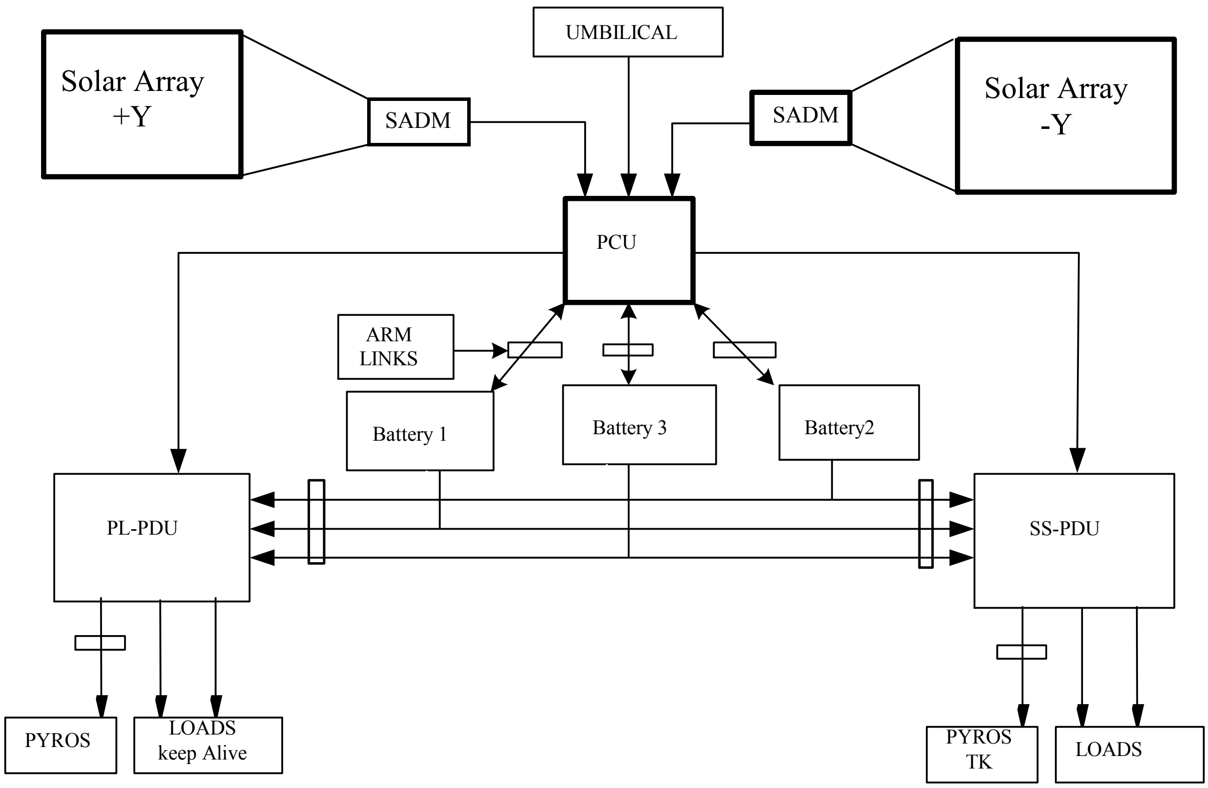


Figure 5-15: Power subsystem schematic

5.3.2.2. Subsystem Configuration

Figure 5-16 shows the basic hierarchy of the power subsystem. The power generators (the batteries and the solar array) supply power to the Power Control Unit. The PCU provides regulated power to the two Power Distribution Units (PDU) which then supply power to the equipments needing it.

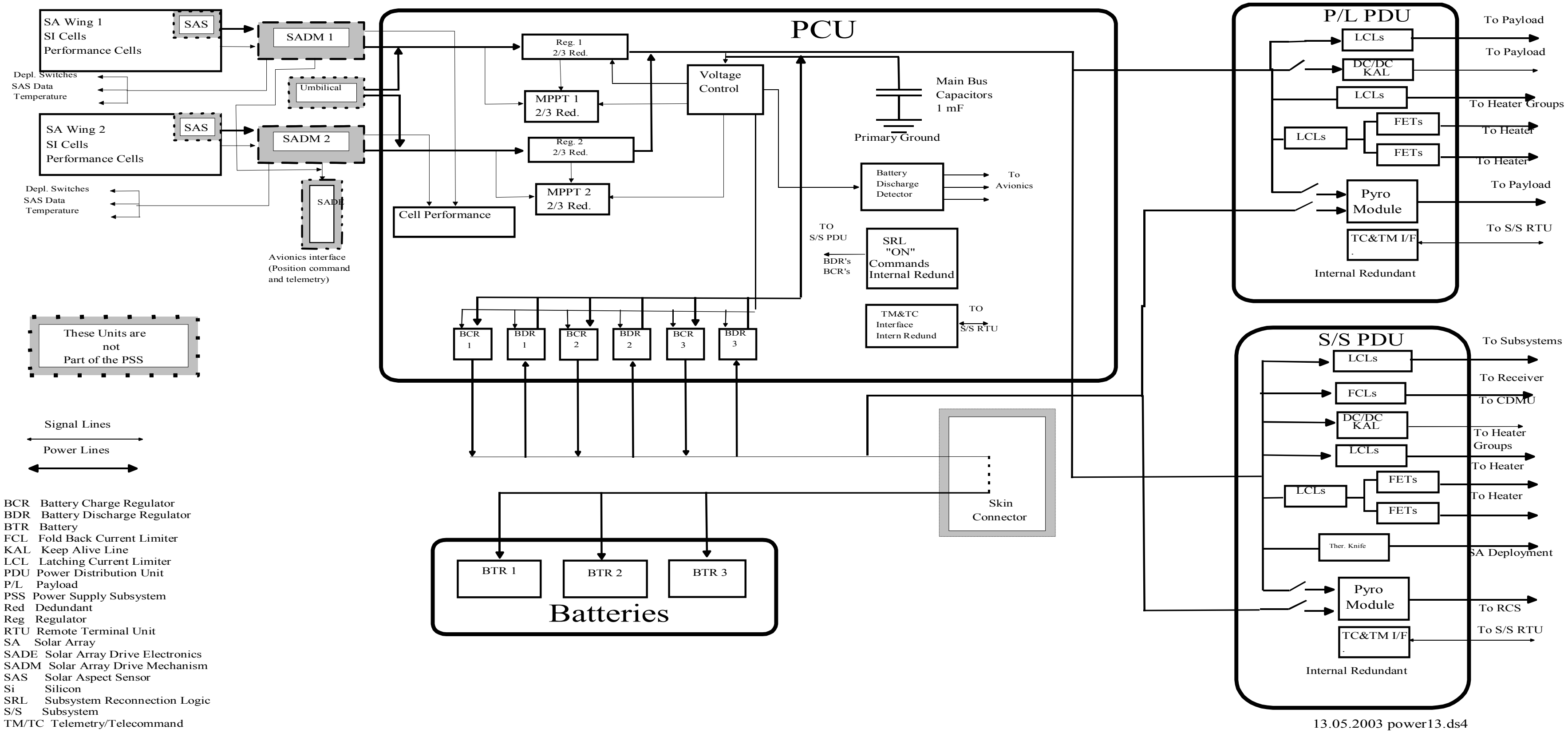


Figure 5-16: Power Supply block diagram

5.3.2.3. Subsystem Functions

The main functions of the PSS units are summarised below :

Power Conditioning Unit (PCU)

- Produces a fully regulated 28V (+/-1%) power bus from solar array and battery inputs.
- Main bus voltage control including triple redundant error amplifiers
- Separate redundant Array Power Regulators (APR) for each array wing.
- Separate Maximum Power Point Trackers (MPPT) for each array wing.
- Separate Battery Discharge Regulators (BDR) for each battery[1].
- Separate Battery Charge Regulators (BCR) for each battery[1].
- Array performance monitors for each wing.
- Redundant TM/TC interfaces.
- Produces automatic functions to support power bus management.
- Produces automatic functions to support DMS autonomous operations

Payload Power Distribution Unit (PL-PDU)

- Dedicated to Payload power distribution.
- Fully redundant unit.
- Main bus power outlets are all switched and protected by Latching Current Limiters (LCL).
- LCL's have current measurement and input under-voltage protection.
- 7 LCL power rating classes (A to G) covering 8.4W to 128.8W (nominal load capability).
- Provision of Keep Alive Lines (KAL's).

[1] each BCR and BDR set for a battery are combined in a single common circuit

- Pyrotechnic power protection and distribution, including firing current measurement and data storage.
- Redundant TM/TC interfaces,.
- Distributes power to the Thermal Control Subsystem hardware and software controlled heaters.
- Individual on/off switching for each software controlled heater circuit.

Subsystems Power Distribution Unit (SS-PDU)

- Dedicated to Platform and Avionics power distribution.
- Fully redundant unit.
- Foldback Current Limiters (FCL) for non-switchable loads (Receivers and CDMUs).
- All other main bus power outlets are switched and protected by Latching Current Limiters (LCL).
- FCL's and LCL's have current measurement and LCLs share input under-voltage protection.
- LCL classes and power ratings as for PL-PDU.
- Pyrotechnic power protection and distribution, including firing current measurement and data storage.
- Thermal Knives (TK's) power distribution (for Solar Array panels release).
- Redundant TM/TC interfaces,
- Distributes power to the Thermal Control Subsystem hardware and software controlled heaters.
- Individual on/off switching for each software controlled heater circuit.

Batteries

- 3 batteries each comprising series/parallel connected Lithium-ion (Li-ion) cells.
- Power and monitoring connections (to PCU/DMS).

- Power connections to the PDU's for the pyrotechnics.
- Cells arrangement and wiring to minimise magnetic moments.
- 1 thermistor per battery for temperature monitoring (to PCU for conditioning).

Solar Array

- Based on Fokker ARA , used extensively for telecom spacecraft.
- Comprises 2 wings, each of 5 panels.
- Outer panels illuminated in LEOP for Battery charging and Bus support.
- Retained for launch by 6 Kevlar cable hold-down mechanisms.
- Redundant harnesses feed power into spacecraft.
- Specially developed solar cells for deep space use.
- Deployment telemetry .
- Monitor strings on each wing for short circuit current I_{sc} and open-circuit voltage V_{oc}.
- Sun Sensors mounted on wings provide data to Avionics[1].

Each unit is now described in more detail.

5.3.2.3.1. Power Conditioning Unit (PCU)

5.3.2.3.1.1. General Description

The PCU regulates the power required by the spacecraft into one reliable, regulated main power bus supply line. The PCU provides this power line to a payload PDU and a subsystem PDU for protected distribution to all spacecraft units required electrical power.

[1] Sun sensors are not part of the power subsystem

The PCU accepts power inputs from the solar array panels and batteries and converts them into a regulated 28V +/-1% power bus. Solar array regulation is based on voltage conversion using a current controlled super buck regulator with a Maximum Power Point Tracker (MPPT) to maximise array power transfer during the Low solar Intensity and Low Temperature (LILT) conditions which occur at the large spacecraft to sun distances involved for this mission (the maximum spacecraft to sun distance is 5.25AU), at comet rendezvous and in the LEOP phase to maximise charge power..

Main bus voltage regulation is based on a conventional 3 domain control system comprising array, battery charge and battery discharge regulation bands. Triple integrating error amplifiers with majority voting logic provide a common reliable control voltage for the array power regulators (APR's), the BCR's and the BDR's, with the voltage ranges applicable to each control domain defined by resistive networks. When required, the MPPT's work in conjunction with the APR's to maintain the solar array operating point at around its maximum power voltage.

Separate APR's and MPPT's are provided for each array wing to cover dissimilar sun aspect angle, array temperature or any other factor that may result in dissimilar array inputs from the wings (due to differing illumination and temperature). Each array wing supplies power to 3 array regulator modules, operated in a 2 from 3 hot redundancy, and a triple hot redundant MPPT with majority voting.

Each MPPT is automatically and separately activated to control the respective array wing at its maximum power point when the Main Error Amplifier(MEA) demands a power level from this array in excess of its maximum available power.

The PCU provides a commandable facility to clamp the solar array input voltage to one of eight fixed minimum levels, to avoid the MPPT collapsing the array voltage below the Bus if the maximum power point lay below Bus voltage. This facility can operate with or without the MPPT enabled and is applied to each APR module individually. The commandable levels are as follows:-

Vsa set (MPPT disabled) = 29.9, 34.8, 39.7, 44.5, 49.5, 54.4, 59.2, 64.1

Vsa set (MPPT enabled) = 32.5, 37.4, 42.3, 47.1, 52.1, 57.1, 61.8, 66.7

With the MPPT disabled, these levels are shifted down a little to allow the APR to operate close to saturation in cases where the array has very little headroom.

If the programmed voltage level is set above the array Voc, the APR would attempt to regulate at the desired input voltage level and output current would fall to zero. The default case for Vsa setting at start-up or after a bus under-voltage is 32.5 V and should only be increased if a faster MPPT start-up response needed or in the event of a failure where a fixed operating point is preferable. Because the Vsa setting is applied to individual APR modules, the disabling of the MPPT can only be obtained by commanding at least 2 modules per wing. In this condition the setting levels are reduced by 2.6 V, which for CTS operations would allow the APR's to work down to approximately 30 V (limited by output current).
The procedure for commanding the MPPT is in Volume 2 (Procedure-ID FCP-PW0250).

Battery power is provided by 3 Li-ion batteries and is regulated in charge and discharge by the BCR's and BDR's respectively. Each battery is provided with a dedicated BCR / BDR module in the PCU.

The BCR's are current controlled step-down regulators with 2 charge rates of normally 0.95A and 3.0A selectable by command. Batteries are charged at constant current until 1 of 8 command selectable battery voltage limits is reached (see table 5-1a) and then switched to a taper charge to maintain the selected voltage. The higher of the 2 charge rates is the default setting at start-up. The BDR's are boost regulators with conductance control to ensure high bandwidth and good matching of the currents fed to the Bus and low bandwidth input loops to ensure matching of battery currents. All BCR's and BDR's can be separately enabled and disabled by telecommand. Input and output protection for the BCR and BDR is common because of the way in which the 2 circuits are combined as a module assigned to each battery.

EOC Level	EOC V	BATT SOC %
0	24.70	89
1	24.58	85
2	24.24	75
3	23.95	65
4	23.68	55
5	23.53	50
6	25.70	~108
7	25.20	100

Table 5-1a: EOC level versus battery state of charge

A redundant TM/TC interface connects with the platform RTU. Cross-strapping of the TM/TC interfaces allows full functionality with the redundant RTU.

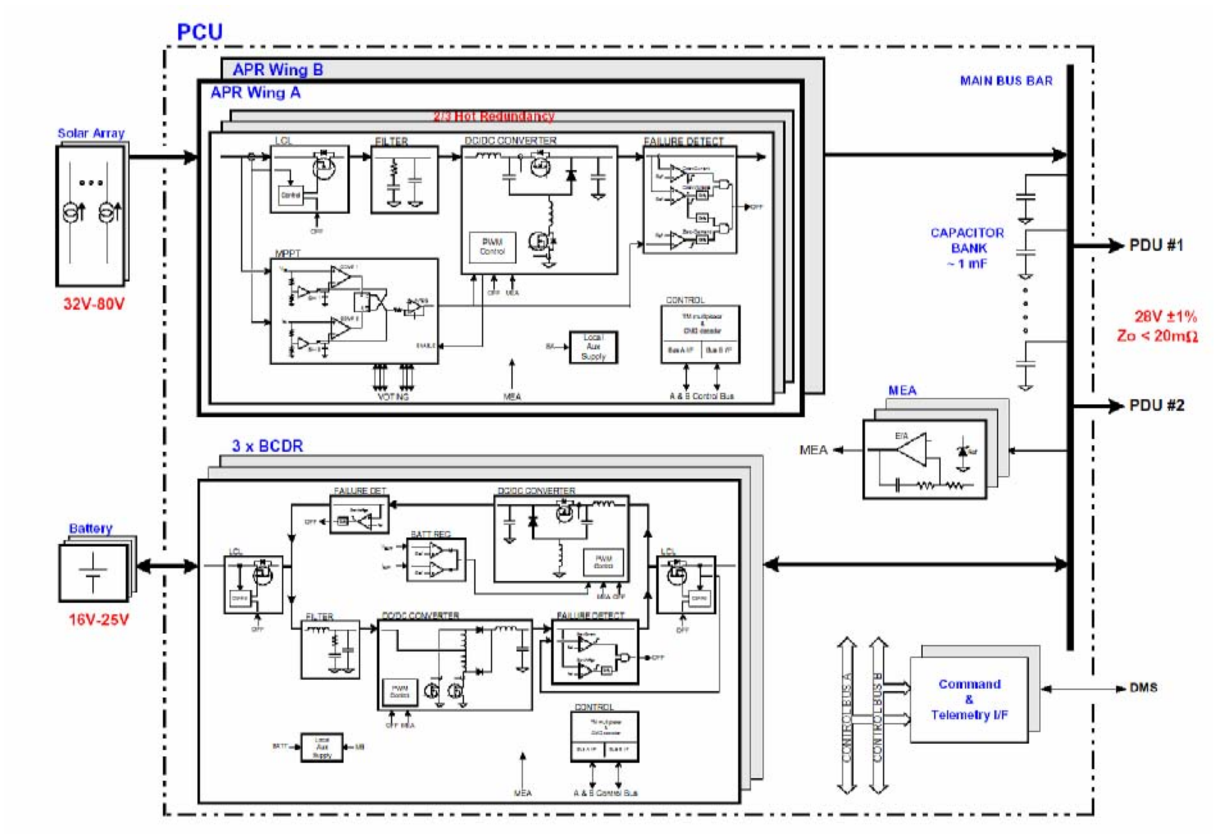


Figure 5-16a: PCU Functional Block Diagram

Two specific automatic system protection functions are provided by the PCU. They are a Battery Discharge Alarm signal, which provides 4 independent single bit high level signals to the DMS in the event of battery discharge for more than 6 minutes ± 1 minute, and a Reconnection logic, which sends a signal to the SS-PDU, following a main bus under-voltage. The Reconnection logic signals initiate the automatic switch-on of the RTU LCL’s in the SS-PDU. Note that PCU restart of the LCL’s is not guaranteed in a full start from zero case, due to the initialisation time of the PDU. In this case it is necessary for the RTU priority 1 commands to reset the LCL’s. Each of the automatic functions, (4 BDA signals and redundant Reconnection signals), can be enabled or disabled by telecommand.

The PCU also incorporates internal protection for control of potentially high dissipation failures.
The Array Performance Monitors measure the open-circuit voltage (Voc) and short-circuit current (Isc) using 2 dedicated array strings of 5 cells for Voc and 8 cells for Isc on each array wing. These are provided as telemetry only.

5.3.2.3.1.2. PCU configuration

The PCU comprises six Array Power Regulator Modules, three Battery Charge/Discharge Modules, two Command and Monitoring Modules, and one backplane Module.

All interfaces from the solar array, batteries and RTU are located on the individual module front panels. The APR, BCDR and CM modules all plug into the backplane module.

5.3.2.3.1.2.1. Array Power regulator Module

Three APR modules form a complete APR function for the +Y array wing, and similarly three modules, Bx, form a complete APR function for the -Y wing. Each APR module provides one Array Power regulator and three modules together form the 3 for 2 redundant function.

The APR module consists of one Array Power Converter (APC), comprising an input protection LCL and DC/DC converter; one MPPT circuit; and a set of protection logic. Each APR has a power capability of 250 Watts. Three modules together form one complete Array Power regulation function. Together the three modules provide a power transfer capability of 750 watts from one array wing.

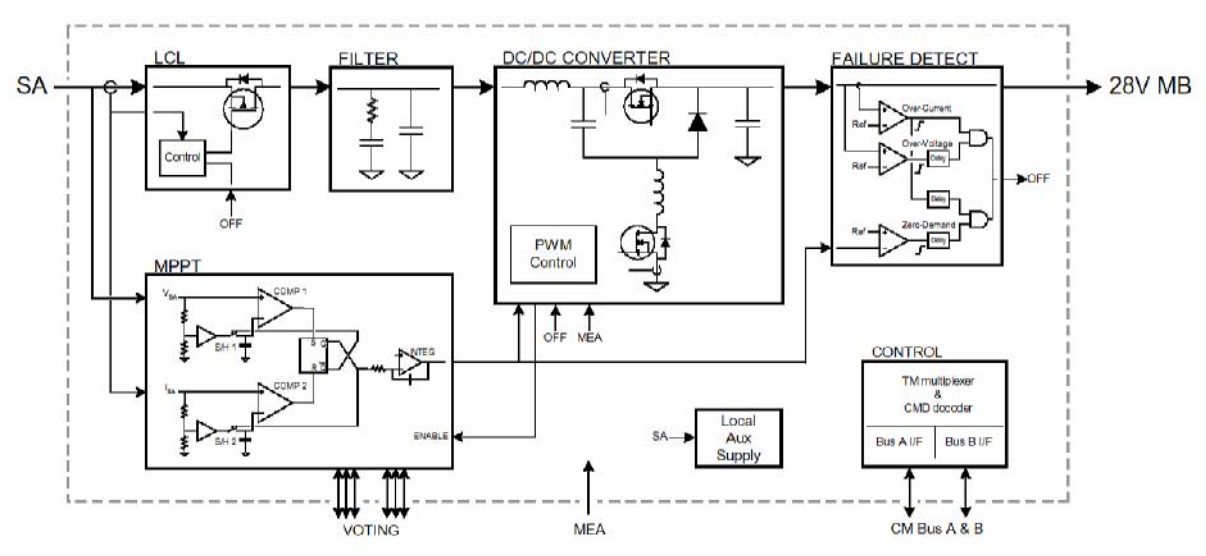


Figure 5-17: APR Module Block diagram

5.3.2.3.1.2.1.1. APC DC/DC converter

The converter is based on a current mode 2-inductor-coupled step-down topology, often referred to as a 'Super buck', having the advantage of both low input and output current ripple. In APR mode the converter operates as a (MEA) voltage controlled output current regulator while in the MPPT mode it operates as an MPPT voltage controlled input current regulator.

The output current is limited to approximately 9A. The converter is operating at constant switching frequency of 262 kHz and regulates by Pulse Width Modulation (PWM). The duty cycle is approximately 0.9 @ 32V input and 0.4 @ 70V input.

5.3.2.3.1.2.1.2. APC Protection LCL

The main purpose of the LCL is to prevent a failure in the converter from creating a main bus overvoltage, especially important during periods of excessive solar power.

The LCL operates as a fast responding linear current limiter with a maximum limitation period of about 2 ms until trip-off. The solid state switch design is based on 2 paralleled P-channel MOSFETS to obtain a low ON resistance, a precise low value sense resistor, a current feedback latching control circuit and a trip-off timer.

A switched off LCL remains in its off state until re-triggered via the ML command interface. In addition the LCL is set to its on state after recovering from a main bus under-voltage.

5.3.2.3.1.2.1.3. APR Maximum Power Point Tracker circuit

The tracker is based on a simple reliable circuit design using standard components such as CMOS / HCMOS and operational amplifiers.

By nature the Sample/Hold circuit is very sensitive to Op-Amp/comparator bias and leakage current, hence it has been designed to function at high temperatures (above +85°C) and to withstand in excess of 20 kRad total dose.

To prevent loading and to secure a stable signal the sensed Solar Array voltage and current is buffered by an Op-Amp. These signals are applied to two identical S/H tracker circuits one of which is shown figure 5-18.

Just before the tracker is to change tracking direction, the S/H control signal is high - that is the switch is closed. A voltage equivalent to 97% of the V_{SA}/I_{SA} level is present at the S/H capacitors. As the search starts the switch is opened, sampling the voltage at the capacitors. The voltage at V_{SA}/I_{SA} slopes downward and the output of the comparator is activated when the V_{SA}/I_{SA} voltage has decreased 3%. The maximum power point is thus found according to theory when the SA voltage and current are modulated in this manner.

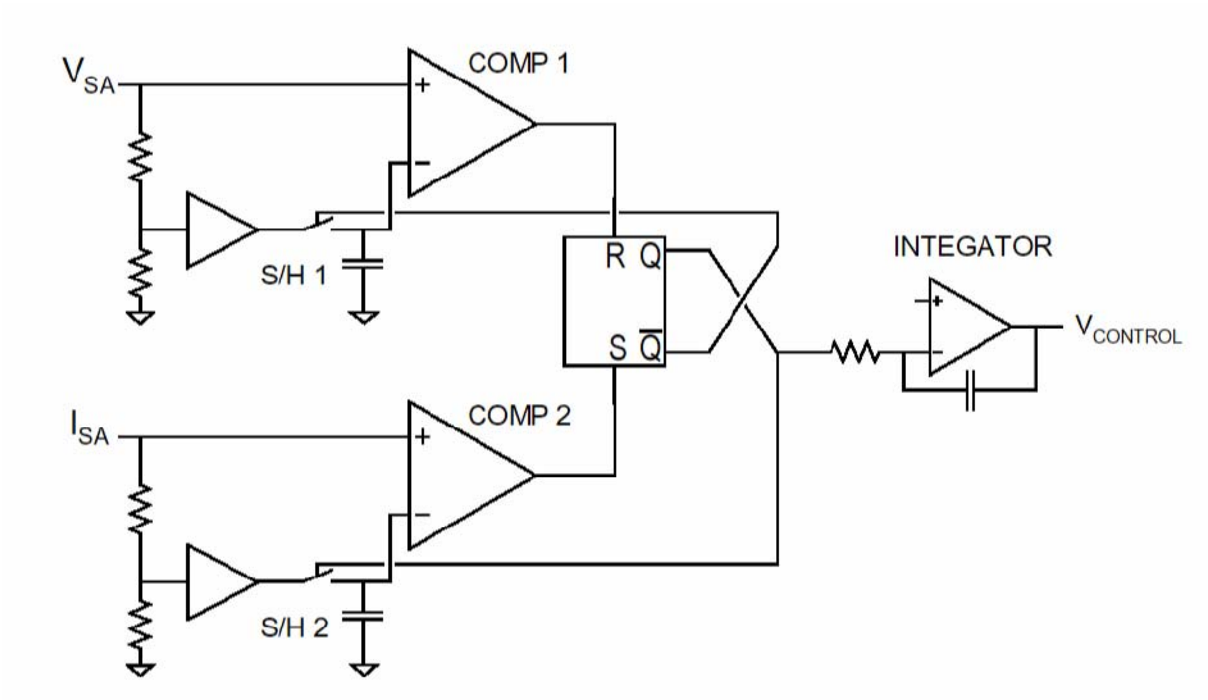


Figure 5-18: MPP Tracking Circuit

In case the MPPT loses tracking for any reason, e.g. a single event upset, each MPPT function contains a "Default Clock" circuit which will force the MPPT into its next cycle. The criteria for the Default Clock circuit to force a change in the search direction is controlled by a timer which if no MPP has been detected for about 2 seconds, will change the direction manually. The timer length is set to allow for the MPPT control circuit to sweep the entire dynamic range of the APR converter (from full to zero modulation).

For each individual MPPT circuit a "Tracker Enable" signal, derived indirectly from the MEA control voltage, ensures that all the MPPTs are initiated simultaneously and searching in the same direction. When the SA provides surplus power, all MPPTs are kept disabled. The digital part is disabled logical wise, while the analogue MPPT control loop simply is 'taken over' by the MEA loop.

Each PCU side has 3 MPPTs. To enable or disable a MPPT by command, first an 'arm command' has to be issued for each MPPT. The change in setting will be accepted if two or three settings are completed.

5.3.2.3.1.2.1.4. Failure detection / Protection

Over-voltage

The over-voltage failure detection circuit monitors if the main bus is out of an upper voltage limit threshold while the converter is still providing power to the bus. In such case the power converter is switched off. Disabling of the power converter is performed by turning off the input protection LCL and by disabling of the PWM controller.

The main bus over-voltage threshold is set to 30V and the associated delay, which prevents spurious triggering, is selected to 100 µs. The circuit still responds sufficiently fast to avoid main bus transients above 33V (caused by converter failure). The delay also ensures that there is enough time for the error amplifier to regulate down the current from the converters. which are still functional. The main bus over-current threshold (to detect current is being provided to the bus) is selected as the minimum main bus current of approximately 1.4A, i.e. 40 watt.

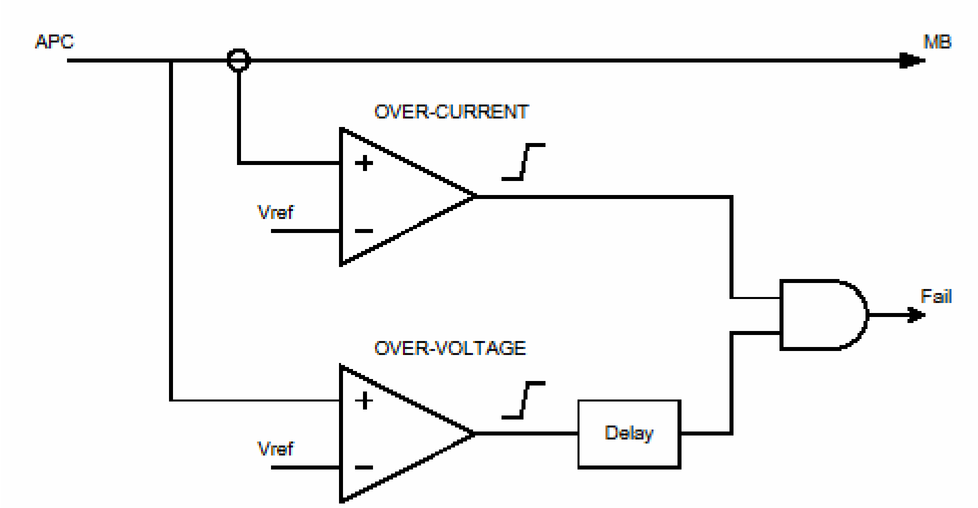


Figure 5-19: Over-voltage failure detection circuit

Solar array to main bus clamp

The 'Solar array to main bus clamp' failure detection circuit is only relevant when the solar array power is limited, e-g. the LILT case. The circuit monitors if the common voted MPPT control signal is below a voltage limit (requiring zero input current), while the converter still draws current from the SA. In such case the power converter in question is switched off. Disabling of the power converter is performed by turning off the input protection LCL and by disabling of the PWM controller.

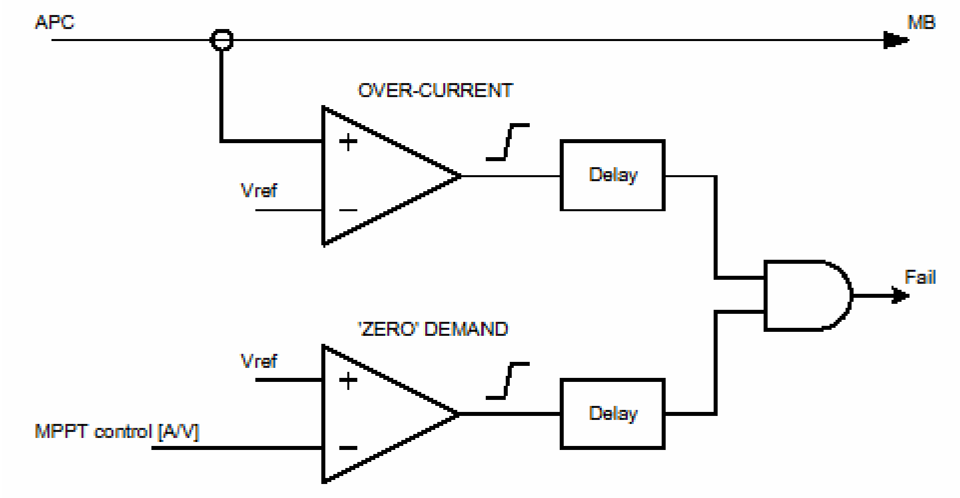


Figure 5-20: SA to main bus clamp failure detection circuit

If this failure occurs the MPPT function can not be maintained for the associated APR section. since modulation of the SA current and voltage is no longer possible due to main bus clamp. After a while the MPPT 'default trigger' function will change direction of the SA current ramp via the common voted control signal. As none of the three converters are able to follow the control signal, due to the one failed converter, this would, as long the failure persists, continue forever. However, while the control signal requires zero input current, the converter which still draws current from the SA is the failed one and can be disabled as described above.

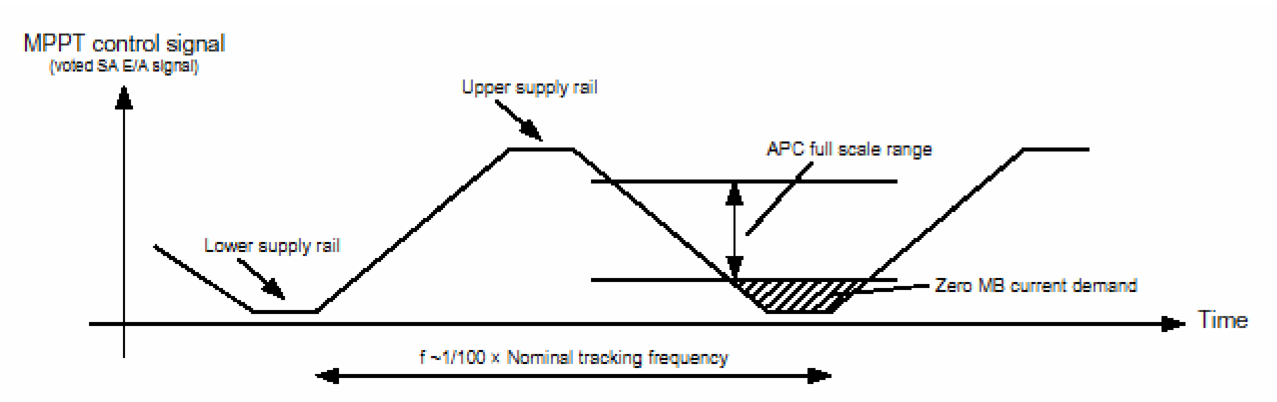


Figure 5-21: MPPT control signal seeking to re-gain tracker operation

To maintain free of single point failures in the PCU design the main bus voltage is protected in the APC by a protection switch in the ground path. In case of a failure the current in this switch will reverse compared to normal current flow and the switch will open if increasing above a certain reverse current threshold. The baseline threshold is 5 Amps.

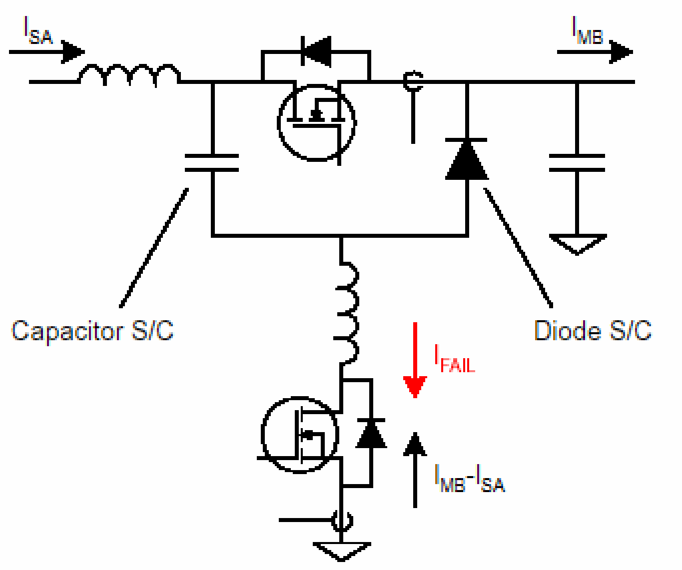


Figure 5-22: APC Overload protection

The circuit is designed such that it remains latched in the off condition as long as the reverse current flow is maintained. Should the diode or capacitor short circuit be temporary and the reverse current decreases below a few milliamps, the ground FET is automatically switched on again. Also during initial power on the FET is automatically biased to its on state. Therefore there is no need for resetting or commanding of this protection mechanism.

5.3.2.3.1.2.1.5. APR Auxiliary power supply

The local Auxiliary supply provides all necessary power for the APR module to operate. The input is supplied directly from the SA ensuring that the module is able to start-up and operates on SA power alone. During eclipse the auxiliary supply will remain powered from the main bus due to the APC switch mosfet body diode.

All failure protection circuits are supplied separately from main bus by a simple zener regulated supply.

5.3.2.3.1.2.2. Battery Charge/Discharge Module

Each BCDR provides all functions for the charge /discharge management of one battery and comprises two power converters, one for battery charge (BCR) and one for battery discharge (BDR). The two converters are associated with one battery only.

Two LCL functions are applied to provide protection against possible regulator failures that can occur during operation as a result of component failures.

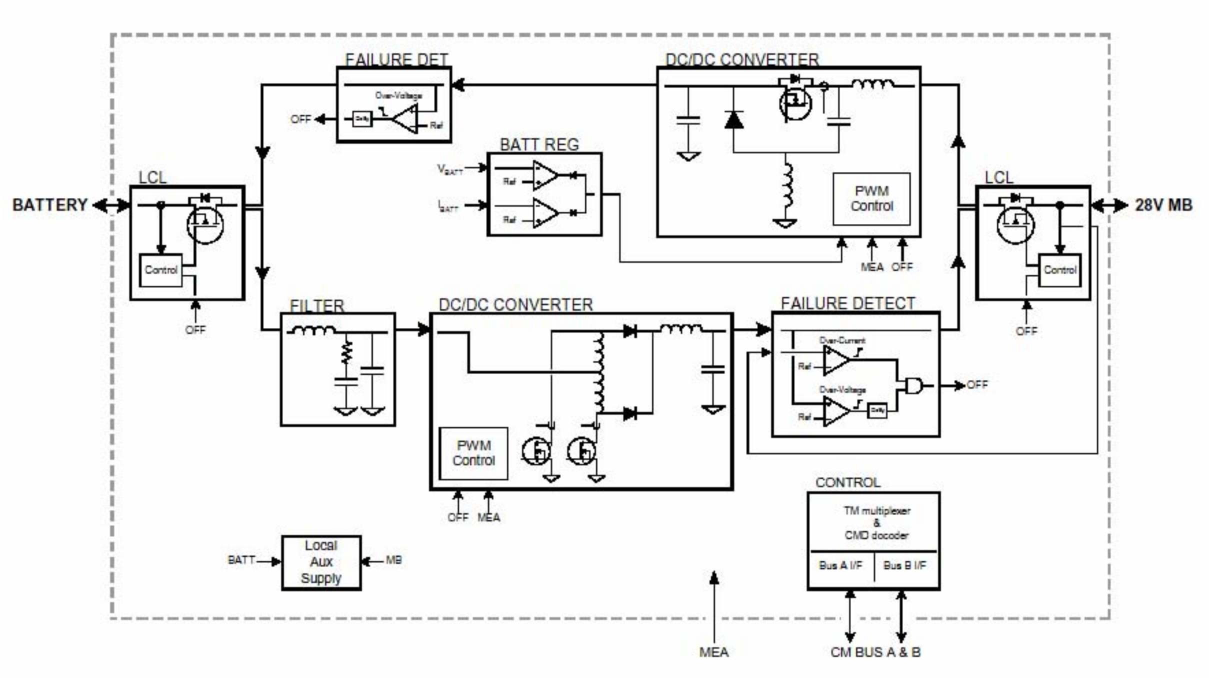


Figure 5-23: BCDR Module block schematic

Two LCL functions are applied to obtain the necessary protection against possible regulator failures that can occur during operation due to possible component failures. The battery attached LCL primarily protects against BDR failures. In normal operation it also connects the BCR output to the battery through its ON resistance. In case the LCL is tripped off by a BDR failure, the BCR still have access to charge the battery through the mosfet body diode. The same protection principle applies for the Main Bus LCL. Of course, if either of these converters fails, though the other can still function, the overall battery function is lost due to the inability to either charge or discharge.

5.3.2.3.1.2.2.1. Battery Discharge Regulator

DC/DC Converter Design

The converter is based on a current mode auto-transformer push-pull topology, having the advantage of low output current ripple. The auto-transformer solution takes advantage of the relative small difference between the battery voltage level and the main bus voltage level - the converted power only needs to reflect this difference.

The converter operates as a (MEA) voltage controlled output current regulator and a current transformer sensing the MOSFET switch current will accomplish the current feedback. Sensing the switch current also provides balanced operation of the transformer magnetizing current. The output current is limited to approximately 9 ampere and is obtained by the converter topology inherent pulse-by-pulse current limiting function.

The converter is operating at constant switching frequency of 131 kHz (ripple frequency = 262 kHz) and regulates by Pulse Width Modulation (PWM). The duty cycle is approximately 0.9 @ 17V input and 0.2 @ 24V input.

To disable a BDR an 'arm command' must be issued first.

Battery discharge current sharing

In order to minimize unequal discharge current between the batteries each BDR is, at DC, controlled as an input current regulator. Since main bus regulation loop still requires the BDRs to be output current controlled this has been maintained at frequencies above 20 Hz.

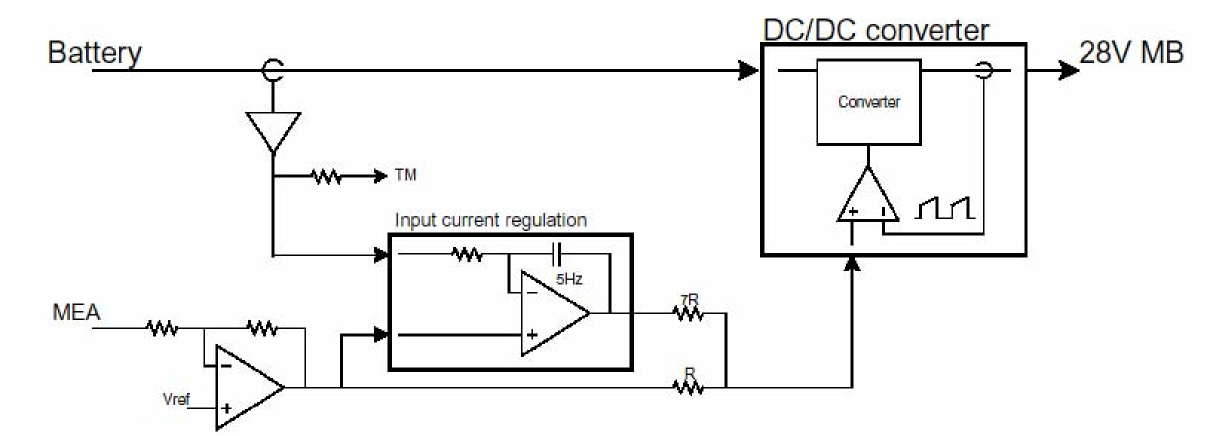


Figure 5-24: BDR Input current sharing

The battery current sense is obtained by a precision sense resistor and amplifier which also provides discharge current telemetry. In order to separate telemetry and regulation circuits w.r.t. failure propagation, the signal from the current sense amplifier is buffered.

Protection LCL Design

The main purpose of the LCL is to provide failure tolerance against converter failure resulting in overloading or short circuit of the battery.

A switched off LCL remains in its off state until re-triggered via the ML command interface. In addition the LCL is set to its on state after recovering from a main bus under-voltage.

Failure Detection / Protection

The over-voltage failure detection circuit monitors if the main bus is above an upper voltage limit while the converter still provides power to the bus. In such case the power converter is switched off. Disabling of the power converter is performed by turning off the input protection LCL and by disabling of the PWM controller.

In the case that a pre-defined battery under-voltage threshold is reached, the BDR for the battery in question will terminate discharging. Minimum battery voltage is approximately 15V.

To prevent a main bus overload in case of a converter failure the main bus is protected from the BDR output by the BCR input LCL.

5.3.2.3.1.2.2.2. Battery Charge Regulator

DC/DC Converter

The BCR DC/DC converter is based on a current mode 2-inductor-coupled step-down topology, often referred to as a 'super buck' , having the advantage of both low input and output current ripple. Compared to the conventional buck converter this simplifies the input filter design and reduces conducted emission.

The converter operates as a (MEA) voltage controlled output current regulator and the current feedback is accomplished by a current transformer sensing in the converter output branch. The output current capability is approximately 9 ampere and is obtained by the converter topology inherent pulse-by-pulse current limiting function. This limit current is scaled down for Rosetta to 3 Amps. The converter is operating at constant switching frequency of 262 kHz and regulates by Pulse Width Modulation (PWM). The duty cycle is approximately 0.6 @ I7V output and 0.9 @ 25V output.

Battery Charge functions

The BCR is able to charge on a fully discharged battery - the charge current will be limited to either 0.95 or 3 ampere dependent on the hardware selected charge level. In the case where the MEA control voltage operates in the BCR operational domain the charge current will be regulated between zero and maximum charge level.

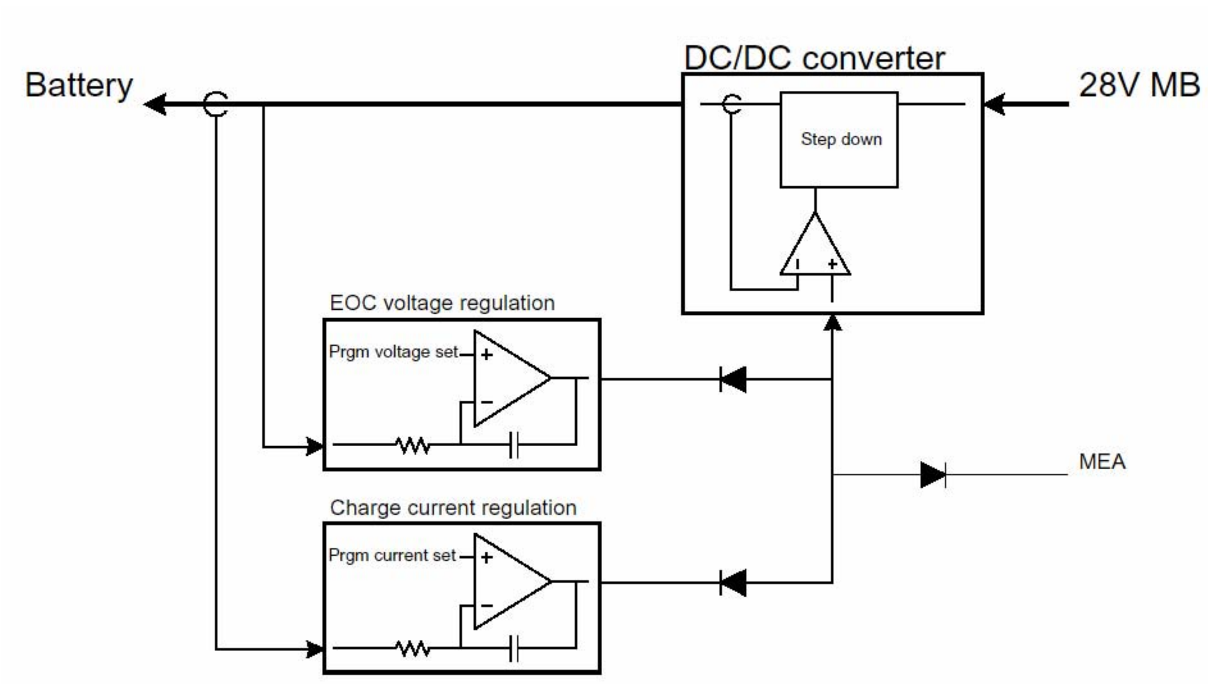


Figure 5-25: BCR Functional schematic

The BCR charges the battery until a battery voltage limit is reached (taper charge). Thereafter the BCR will maintain this battery voltage level, by a low bandwidth local voltage loop, regulating down the BCR output current to the required level. The battery EOC voltage limit can be set by delayed memory load command to 8 different levels. Selection of charge level lower than the inherent 9 Amp is obtained by a low bandwidth local current loop, regulating down the BCR current to the required level. A precise sense resistor and amplifier accomplish Battery charge current sensing. The battery charge current limit can be set by DML to 2 different levels.

Each BCR provides the conditioning of one thermistor monitoring the battery temperature. The conditioning is obtained by linearization of the thermistor resistor value in the range of -20°C to +35°C around a centre temperature of +7.5°C. The conditioned battery temperature measurement is available from the PCU telemetry interface.

Failure Detection / Protection

Should the voltage loop fail to limit charging of the battery, a protection function will turn off the BCR when an upper voltage limit is exceeded. This ensures a two-failure tolerance with respect to termination of battery charge.

Disabling the converter is performed by turning off the protection LCL and by disabling of the PWM controller.

To prevent a battery overload in case of a main bus short circuit (via the LCL and the switching mosfet body diodes), the BCR output is protected from the main bus by the BDR input LCL.

BCDR auxiliary power supply

The local Aux supply provides all necessary power for the module to operate. The input is supplied directly either from the battery or the main bus, ensuring that the module is able to start-up and operate on battery power alone. When the main bus voltage is above the battery voltage the input is taken from the main bus. This is obtained by simple diode or'ing.

All failure protection circuits for both BCR and BDR functions are supplied separately from main bus by a simple zener regulated supply.

5.3.2.3.1.2.3. Command and Monitoring Module

The Command and Monitoring (CM) module handles commands sent to the PCU and provides telemetry and status signals to the DMS.

Each CM module is able to perform the following tasks:

- Set or reset of selected PCU functions, when prompted by dedicated commands sent from the DMS via the Delayed Memory Load command (DML) interface.
- Read and store TM from all modules in a predefined format, when prompted by a dedicated command sent from the DMS via the DML interface.

- Send the stored TM via the Serial 16 Bit Digital Telemetry interfaces when prompted by the DMS.
- Generate 2 independent discrete Batteries Discharge Alarm (BDA) signals, when the MEA control signal is in the BDR region.
- Generate one discrete Main Bus Reconnect (MBR) signal, when power initially is applied or has been restored after a main bus under-voltage.

Each CM module has in addition a thermistor located close to the heat sink (PCU bottom). The thermistor is conditioned by the DMS.

The CM module auxiliary power supply generates the necessary voltages for the module itself and the directly related interface circuits on the other modules.

The CM module operation can be summarized as shown in the figure below.

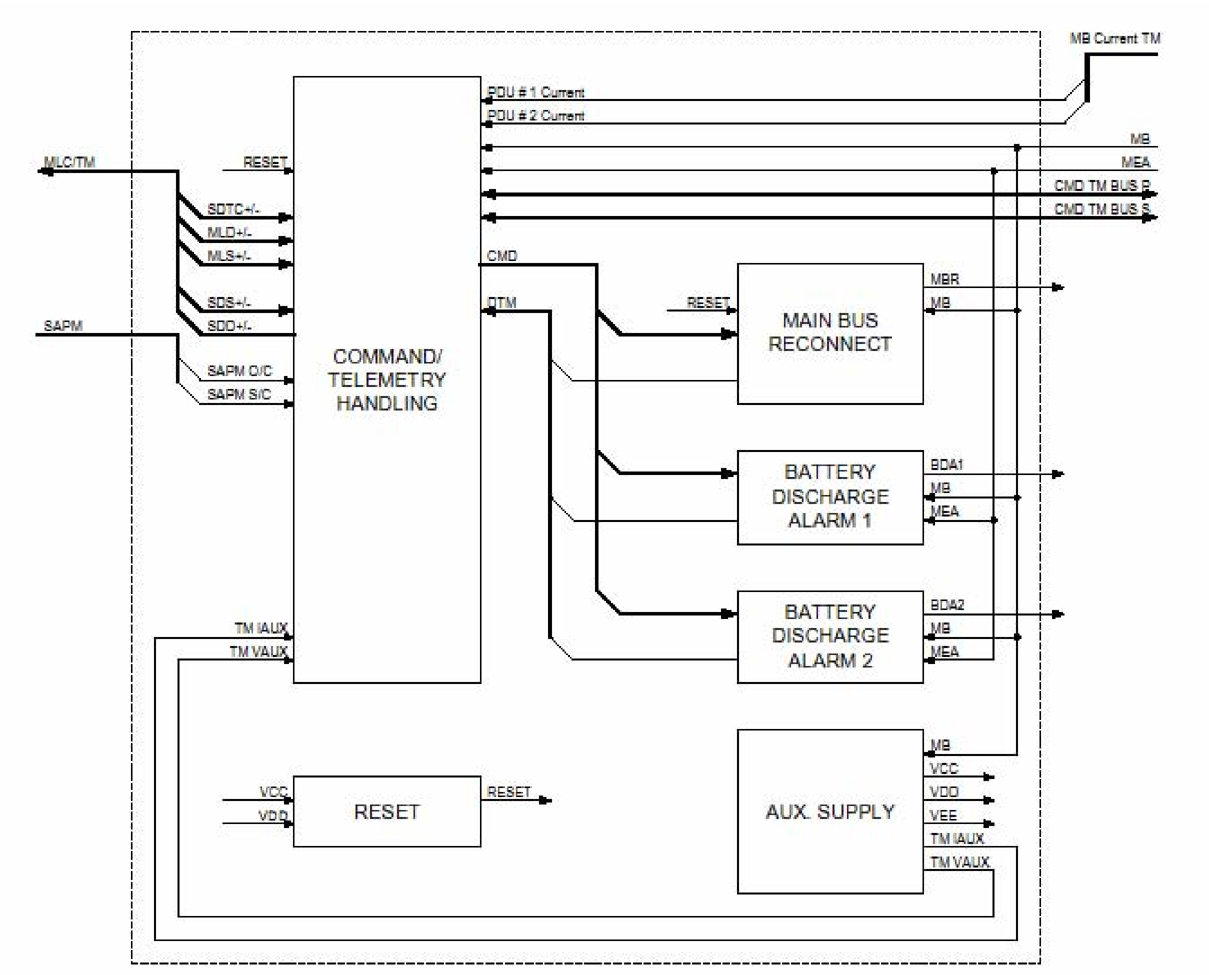


Figure 5-26: CM Module block schematic

5.3.2.3.1.2.3.1. Delayed Memory Load Processing Function

The basic function of the DML is to command a single function (or switch) within the PCU ON or OFF. In the DML budget each of the PCU command-able functions has its own dedicated DML to perform the action.

Aside from direct switch command actions, there is also provision for loading of registers and prompting of a telemetry reading.

A command consists of a PCU address, one arm bit, one parity bit (odd parity) and if required data for writing to a register.

5.3.2.3.1.2.3.2. Command and Monitoring Bus Interface

All commanding and monitoring of the power modules is performed via the CM bus located on the backplane module. The CM module performs the following functions:

1. Commanding of selected functions in the PCU (single bit write-function)
2. Pre-setting of registers (multiple bit write-function)
3. Sampling of telemetry data (analog or digital read-function)

5.3.2.3.1.2.3.3. FIFO RAM

The CM module reads and formats the unit telemetry word by word autonomously on request. The formatted TM words are stored in a pre-defined order in FIFO RAM. From the FIFO RAM the TM words are transmitted to the DMS on request, word by word according to the Serial Telemetry Sampling line.

A TM word can either contain one A/D converted analog measurement and one parity bit (odd parity) or up to 15 discrete status values and one parity bit (odd parity).

5.3.2.3.1.2.3.4. Instruction PROM

The process of assembling each TM word is governed by sequential instructions stored in a 2K x 8 bit PROM. Each instruction consists of 16 bit stored in two succeeding PROM addresses.

The instruction word contains the following information:

- 8 bit address to select the location of the desired telemetry value
- 4 bit pointer to select the desired placement of discrete status bits in the current TM word.
- Analog / discrete bit to select either analog or discrete TM reading
- Next word to indicate TM word completion.
- TM read Stop bit to terminate the TM reading process.

5.3.2.3.1.2.3.5. CM Auxiliary power supply

The local Auxiliary supply provides all necessary power for the module to operate. The auxiliary converter is based on the common PCU APR design with the following exceptions:

- The converter is supplied from the regulated main bus.
- The converter provides three regulated output voltages, +5V and ± 12 volt.
- It does not include the over voltage protection function as the nominal duty cycle is of a value that ensures that full duty cycle does not cause the 5V output to rise above 5.7V. The two other outputs can not exceed +I5V and -15V respectively.

Battery discharge alarm detection circuits are supplied separately from the main bus.

The auxiliary power supply voltage of CM module A and B is readable by CM module A as well as from the CM module B. The auxiliary power supply current is only readable from the active CM module.

5.3.2.3.1.2.3.6. Auxiliary Power Supply Under-voltage Detector

The Auxiliary Power Supply Under-voltage Detector supplies the reset signal for DML processing. The detector compares the +5V output to a reference derived from a temperature-compensated zener reference diode.

5.3.2.3.1.2.3.7. Crystal Oscillator

The Crystal Oscillator supplies a clock frequency for DML processing function.

5.3.2.3.1.2.3.8. DML Interface

The DML interface signals are Memory Load Command Data (MLD), Serial Data Transfer Clock (STC) and Memory Load Command Sampling (MLS). Each of these signals is received via dedicated differential receivers based on standard Rad Hard comparators.

5.3.2.3.1.2.3.9. TM Interface

The TM interface signals are Serial 16 bit Digital telemetry Data (SDD), Serial 16 bit digital Telemetry Clock (STC) (same as Serial Data Transfer Clock) and Serial 16 bit Digital telemetry Sampling (SDS). The signals are received/transmitted via dedicated differential receivers/drivers based on standard Rad Hard comparators and logic drivers. When TM is requested the stored TM data words will be moved one by one from the FIFO RAM to a 16 bit parallel to serial converter.

5.3.2.3.1.2.3.10. A/D Converter

The A/D conversion function converts the present analog bus line voltage into a 12 bit digital value.

5.3.2.3.1.2.3.11. Signal Conditioning and Analog multiplexer

This function provides interfaces to a number of discrete analog signal lines providing analog telemetry values from CM module itself as well as from the backplane module. The signal conditioning circuits performs the necessary analog signal conditioning for local generated analog telemetry values while the multiplexer according to the address bus function connects the selected analog line into the analog bus line. Conditioning is performed for a number of lines, e.g. for the SA performance monitoring of S/C current and O/C voltage.

All telemetry are readable from both CM module A and B, except for

- auxiliary supply current for the opposite CM module
- discrete HK for the opposite CM module (TC echoes, TM counter).

5.3.2.3.1.2.3.12. Main Bus Under-voltage Detector

The main bus under-voltage detector will identify an under-voltage if the main bus voltage has been below 26.1 ± 0.1 Volt for more than 100 µs.

When the main bus voltage has been recovered (above 26.6 ± 0. I Volt) for a period of 6 ± 2 ms it generates a reconnection signal pulse. The generation of the reconnection signal can be disabled/enabled by command. This function is default enabled after PCU power-up.

5.3.2.3.1.2.3.13. Battery Discharge Alarm

A battery discharge alarm is implemented to warn the DMS against discharge of the batteries. When the detection threshold is exceeded for more than 6 minutes two independent BDA signals are sent from each CM module to the DMS. The detector compares the MEA control signal to a reference derived from a temperature-compensated zener reference diode.

This function is default enabled after PCU power-up. but can be disabled by sending two serial commands. First command must be BDA disable arm command and the succeeding must a BDA disable command. One BDA enable command can enable the function again.

5.3.2.3.1.2.3.14. Thermistor

The thermistor is located close to the bottom heat sink to give a representative temperature of the PCU. The thermistor is conditioned by the DMS.

5.3.2.3.1.2.4. Backplane Module

The backplane distributes the necessary module interaction, command and monitoring buses and it provides the low impedance power bus bar for the main bus.

In addition, the module also contains the electronics needed for the main bus regulation.

The main bus power is routed from each power module to the backplane main bus bar. Connectors for the two main bus outputs - the PL PDU and the S/S PDU are located on the unit rear side. The backplane provides individual redundant current sensors for each of these two main bus outputs.

The backplane distributes the following internal control signals:

- MEA control line, routed as two separate PCB tracks to maintain SPFF distribution.
- Analogue and digital voting signals between APR modules operating in parallel
- Dual (Prime and Redundant) CM buses providing the Command and Telemetry interface to all modules.

5.3.2.3.1.2.4.1. Main Bus Regulation Circuit

The Main Bus Regulation circuit located on the backplane module provides three voted error amplifier functions, which provides one common, reliable regulation line for all power modules. Internal circuit separation ensures no possible failure propagation between the redundant functions.

The 3 analogue control lines from the Error Amplifiers are voted in an analogue voting circuit selecting the line, which provides a signal in between the two others. For the diode or'ing function, transistors are chosen to obtain a lower impedance on the Single Point Failure Free MEA control signal. This is to ensure immunity against external as well as internal coupled "noise" and overcome possible stray capacitance.

Two parallel lines along the backplane module distribute the MEA signal to all power regulation modules.

The main error amplifier and the active domain power regulator form the regulation loop. The three regulators, the APRs, the BCRs and the BDRs are all designed as current mode regulators providing a first order transfer function.

In the MPPT mode, the APR function contains its own independent regulation loop, independent of the MEA control.

5.3.2.3.1.2.4.2. Main Bus voltage and Current Telemetry

To provide telemetry of the main bus current, for the P/L PDU and the S/S PDU respectively parallel redundant sense resistors are connected in series with each main bus output.

The current sense resistors and the signal conditioning circuits for output current are located on the backplane module and the present analog values are readable from both CM modules.

5.3.2.3.1.2.4.3. Command and Monitoring Buses

To provide access to command and monitor the various functions on the power modules the backplane distributes two identical CM buses, each containing the following:

- An 8-bit address bus to select up to 256 functions.
- A 4 -bit data bus for bi-directional digital data transfer.
- A single analog bus line to transfer a selected analog signal from power module to CM module.
- Read and write control lines to manage the data flow.

5.3.2.3.1.3. PCU functional description

5.3.2.3.1.3.1. Overview

The PCU converts the solar array and battery power inputs into a regulated main bus voltage at 28 V ± 1%. The main bus regulation is performed by a conventional three-domain control system, based on one common reliable Main Error Amplifier (MEA) signal.

When the available array power exceeds the total power demand (including the battery recharge power) from the PCU, the Array Power regulator (APR) will perform the main bus regulation based on the MEA control signal. The regulator function is a buck type switched regulator which leaves surplus energy on the array by increasing its input impedance.

A MPPT function will automatically take over the regulation control of the APR when the MEA signal enters the BCR or BDR control domains. The MPPT monitors the array voltage and current and controls the APR to provide that specific input impedance which will derive the maximum electrical power available on the array. The MPPT function finds the maximum power point by oscillating the APR input impedance slightly around the impedance providing the maximum power.

Each APR function comprises 3 individual APRs configured as 2 out of 3 hot redundant regulators. The active regulators share equally the requested power transfer to the main bus. Each of the solar array wings has its own individual APR function to allow individual tracking of the maximum power point.

Each battery has its own dedicated BCDR function in the PCU. The BDR is a conventional current controlled step-up regulator with internal output over-current protection. The BCRs are step-down current controlled regulators with two nominal charge rates selected by command.

The batteries are charged at constant regulated current until a selected voltage limit is reached. The BCR will then maintain the battery at its voltage level. The termination voltage level is selectable by commands. The BCDR can be enabled/disabled by command. Each BDR requires 2 serial OFF commands to avoid erroneous switch off.

5.3.2.3.1.3.2. Unit Start Up Sequence

In case of loss of main bus power, the PCU is designed to be able to start up again on the presence of either solar array power or if sufficient battery power is available. Each one of the six APR modules will independently initiate its start up sequence when SA power rises. The start up circuit will continuously try to switch on the module protection LCL until the main bus voltage has increased above the defined under voltage level.

As it has to be considered marginal or random which one of the regulators actually have succeeded to generated the required main bus power, a final LCL ON command is issued when the main bus passes the under-voltage level to ensure that all modules are initiated to active status.

Each BCDR function will start up also independently if sufficient battery power is available, then feeding power to the 28 volt bus until full regulation is obtained. Otherwise it will start up when main bus voltage rises.

5.3.2.3.1.3.3. MEA Power Regulation Characteristics

The MEA function will manage the PCU power transfer according to the three-domain regulation scheme shown in the following figure:

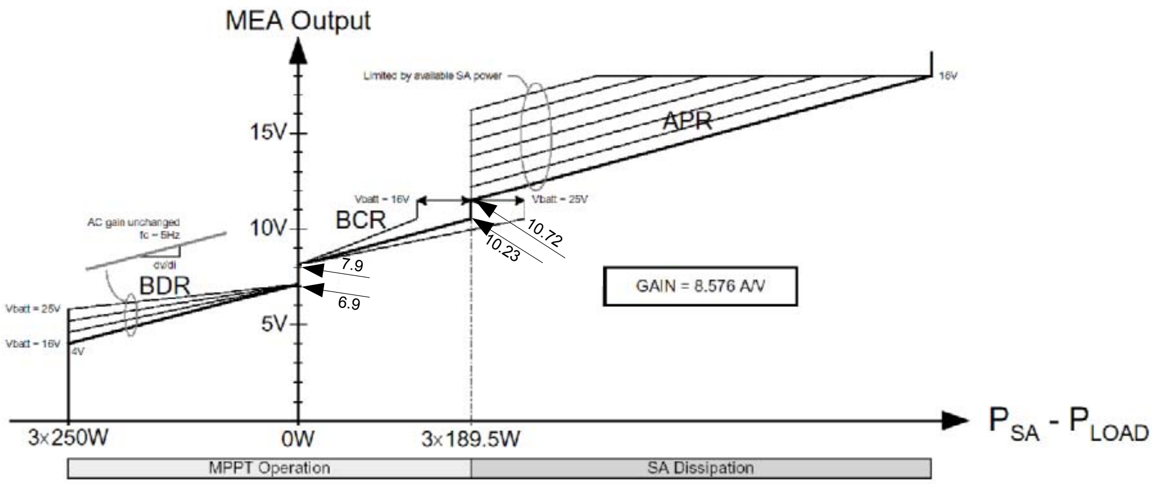


Figure 5-27: MEA Power Regulation

Each power domain provides a bus current transfer of 5.3 ampere / volt.

APR domain:

In the APR domain the power flow is managed by regulation of the two APR sections, each one with three APR modules operating in parallel. Only exception is in the case that one APR section has to operate in MPPT mode due to lower available power for that section.

APR domain is active for an MEA voltage of 23 volt down to 10.72 volt.

The MEA voltage level at which the transition into the next domain will occur depends on the SA available power as indicated in the regulation figure by the parallel dashed regulation lines in the APR domain.

BCR domain :

In the BCR domain the power flow is managed by regulation of the power drawn from the main bus for the battery charging. The MEA regulation will stay within this domain only if the battery requires charging to reach its EOC voltage threshold.

BCR domain is active for MEA voltage of 10.2 volt down to 7.9 volt.

The MEA voltage level that is reached after transition from the upper domain depends on the selection of maximum battery charge current.

BDR domain:

In the BDR domain the power flow is managed by parallel regulation of the three BDRs if all the batteries have sufficient energy storage.

The BDR domain is active for MEA voltage of 6.9 volt down to 1 volt.

The DC current supplied to the main bus according to present MEA voltage depends on the actual battery voltage level due to the implemented equal battery current sharing design. This is shown in the regulation figure by the dashed lines in the BDR domain.

5.3.2.3.1.3.4. Maximum Power Point Function

For Rosetta, the operational distance from the sun varies from about 1 AU up to more than 5 AU with array temperatures ranging from 50°C down to -130°C.

This large difference in operation temperature changes the point of maximum electrical power from about 32 volts up to 70 volts. To enable the PCU to derive the available power, especially in the low temperature condition which provides the highest operation voltage, a MPPT function is implemented instead of the traditional Sequential Switching Shunt regulators.

The MPPT function consists of a tracking circuit, which controls the Array Power Converter, a switched PWM regulator, converting the solar array power into the 28V main bus. The tracking function will determine the load impedance providing the maximum power, thus directing the APC to provide this impedance.

The MPPT design is based on the rule that the peak power point is achieved when the dynamic impedance is equal to the static impedance.

$$\frac{V}{I} = -\frac{dV}{dI} \Rightarrow \frac{dI}{I} = -\frac{dV}{V}$$

To achieve this the array is operated with a permanent oscillation about the maximum power point.

Figure 5-28 and Figure 5-29 depict the mode of operation and the principle circuit diagram of the tracker.

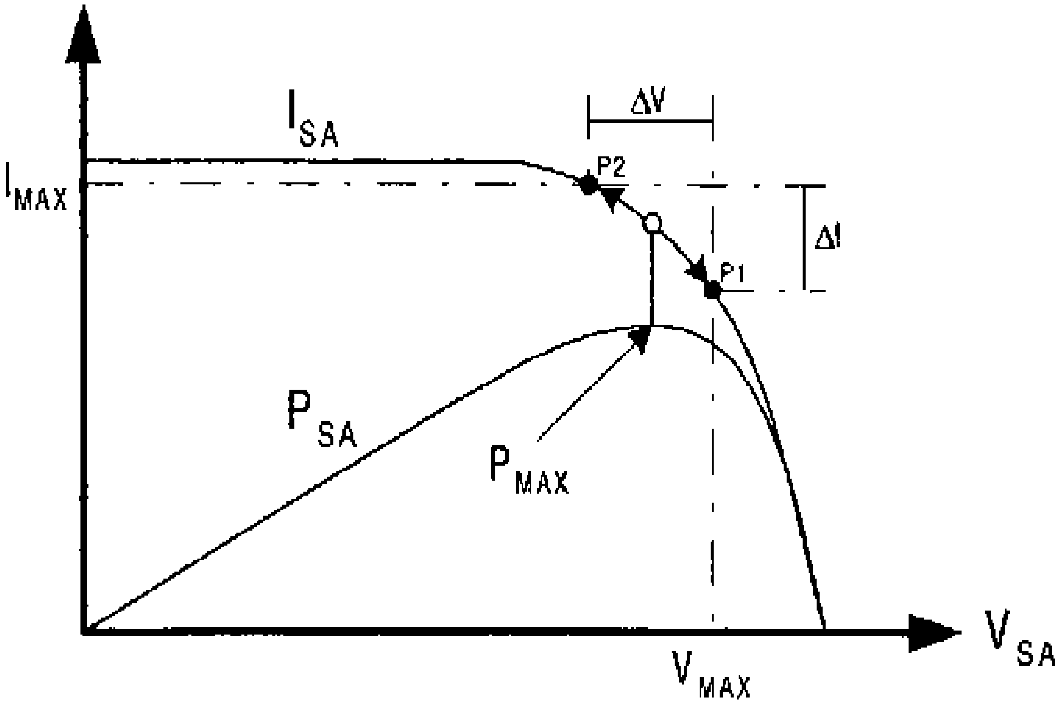


Figure 5-28: Maximum Power Point Tracker Operation Mode

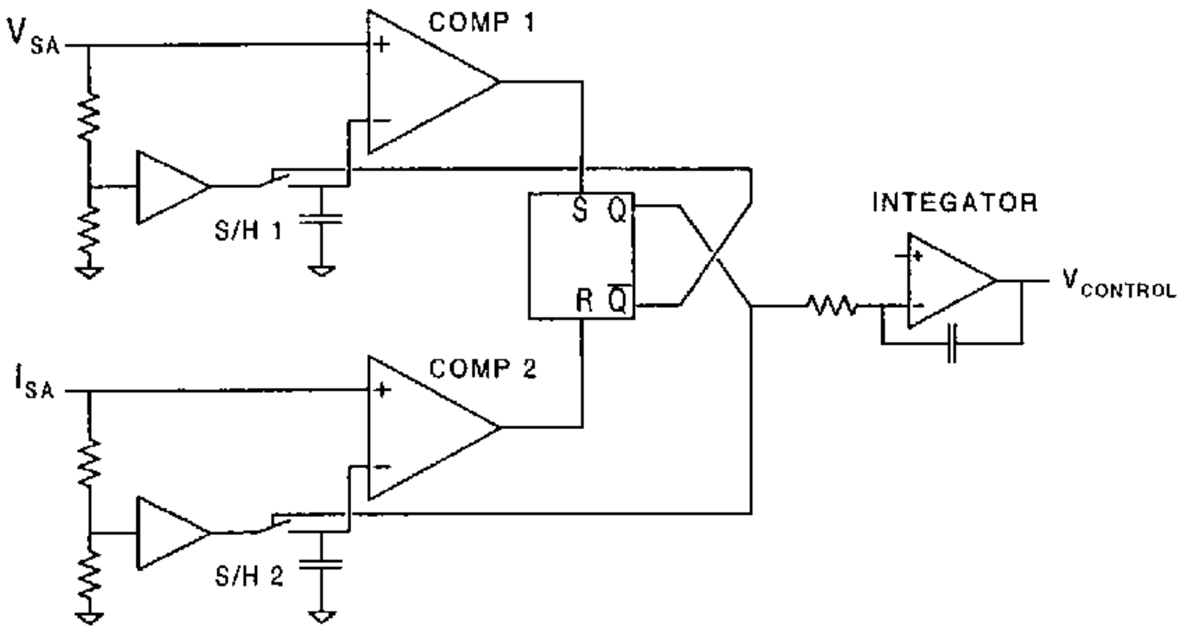


Figure 5-29: Basic circuit for Maximum Power Point Tracker

At point P1 of Figure 5-28 the sample/hold circuit 1 stores the array voltage signal Vmax - ΔV (which corresponds to point P2 on the I/V curve). The control voltage $V_{control}$ of the integrator ramps up to increase the loading of the array. Thus, the array voltage decreases until the actual array voltage is equal to the stored voltage Vmax - ΔV (point P2 on the curve).

When this point is reached, the comparator sets the flip-flop in the opposite position. The sample/hold circuit 2 stores the current signal Imax - ΔI (corresponding to point P1). The control voltage $V_{control}$ of the integrator now ramps down to decrease the loading of the array and the array current decreases until the actual array current is equal to the stored voltage Imax - ΔI (and we are now back at point P1 on the I/V curve).

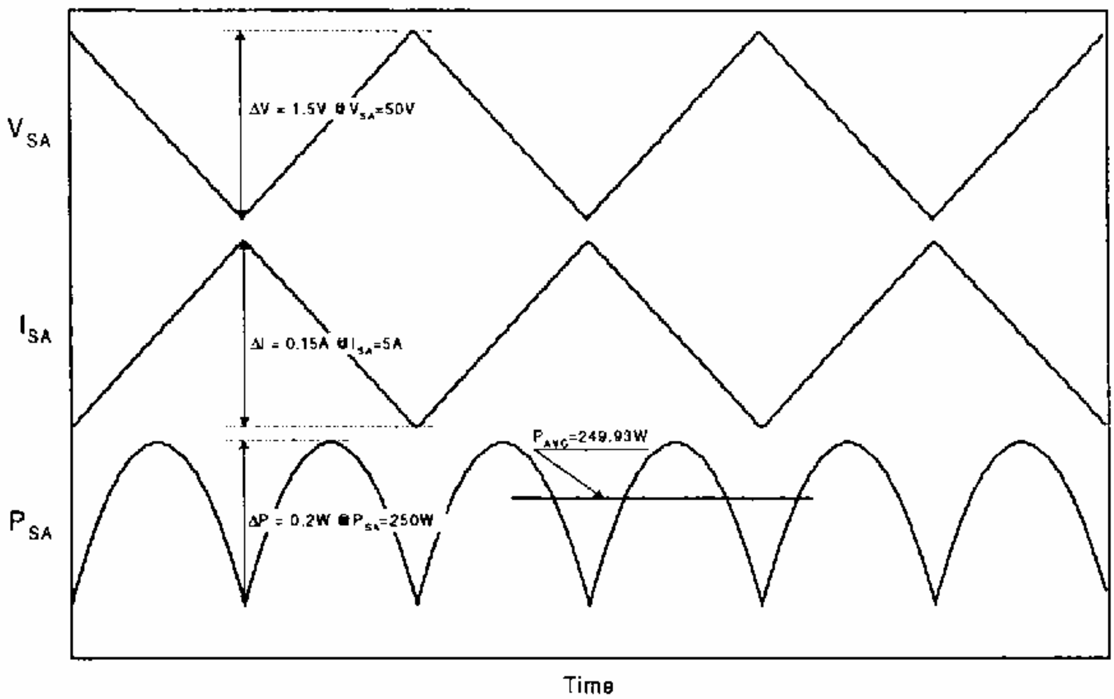


Figure 5-30: Array voltage and current waveform

The ratio of ΔV to Vmax (and ΔI to Imax) is about 3%.

MPPT redundancy concept

Each of the 3 regulators has, in principle, their own MPPT circuit. As the 3 regulators are loading one common solar array section, they have to perform the same "load modulation" to enable the tracker mechanisms to detect when loading of the array has reached the point stored at the end of of the previous tracking cycle.

This is obtained by voting the results of all the 3 MPPTs, individually voted in each MPPT circuit. In this way the control signal for the regulators can be considered as one common reliable control signal. The control signal directs, in the MPPT mode, the input current level of the regulators.

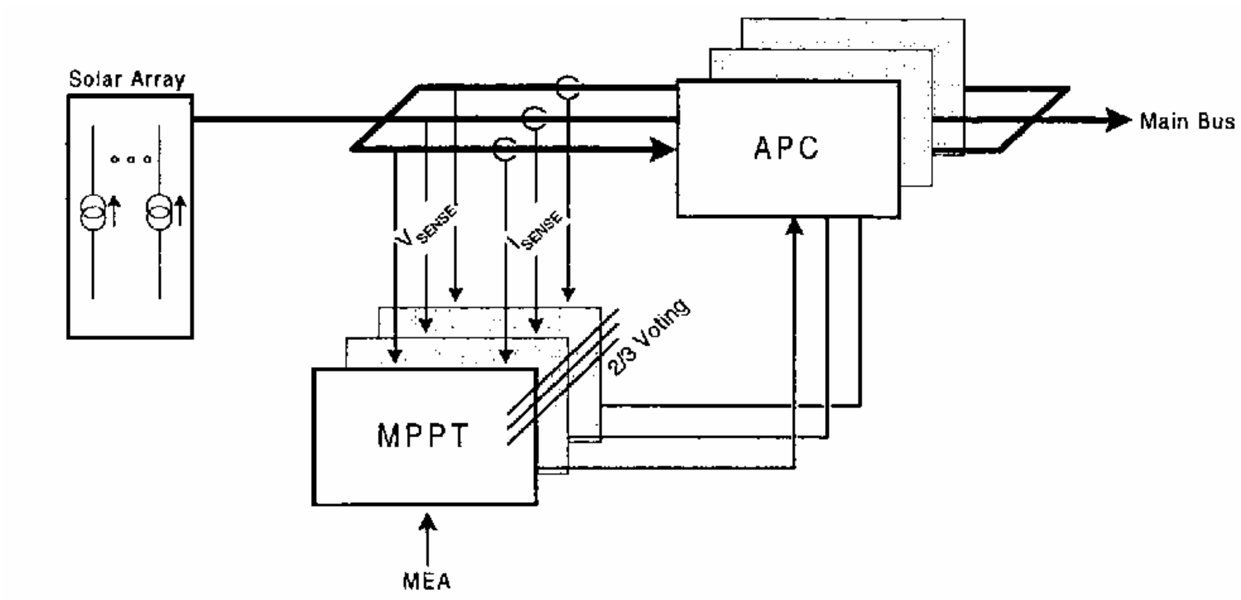


Figure 5-31: MPPT redundancy concept

Regulator 2/3 concept

In the nominal configuration, the 3 regulators are operating in parallel, each providing 1/3 of the required power level to the 28V main bus. Power sharing of the regulators is obtained by operating the regulators in current mode condition. In case one regulator is lost, the remaining two will automatically provide the requested power transfer to the main bus.

Baseline power transfer capability from one array section is 500 watt, leaving each regulator with a transfer of up to 250 watt in case of one lost regulator. Due to dynamic regulation performance and loop stability aspects the regulators are operated as output current regulators when in the APR mode, while they are operated as input current regulators in the MPPT Mode.

Voted MPPT Concept

To obtain the necessary uniform load modulation of the 2/3 regulators each of the 3 individual trackers performs a voting of both its own and the two others results and uses the agreed result for the further control. Figure 5-32 shows the 3 Power Point Tracker chains and the voting interconnection.

Each MPPT chain has its own array voltage and current tracking circuit. The output of this function is, on digital signal basis, shared with the two other chains. A digital majority voting circuit in each MPPT chain now decides when 2 of the 3 MPPTS have detected the awaited array threshold value. This occurrence initiates, due to the majority voting, simultaneously state change of all 3 MPPTS, storing the next array value for next tracking period and directs the integrator function to the opposite "load changing direction".

The 3 analog control lines from the integrator function are voted in an analog voting circuit based on the same principle as utilized in the MEA function to select the line, which provides a signal in between the two others. The selected analog line value is now used for the average operation point (DC level) as well as the load modulation (AC) of the associated array power regulators.

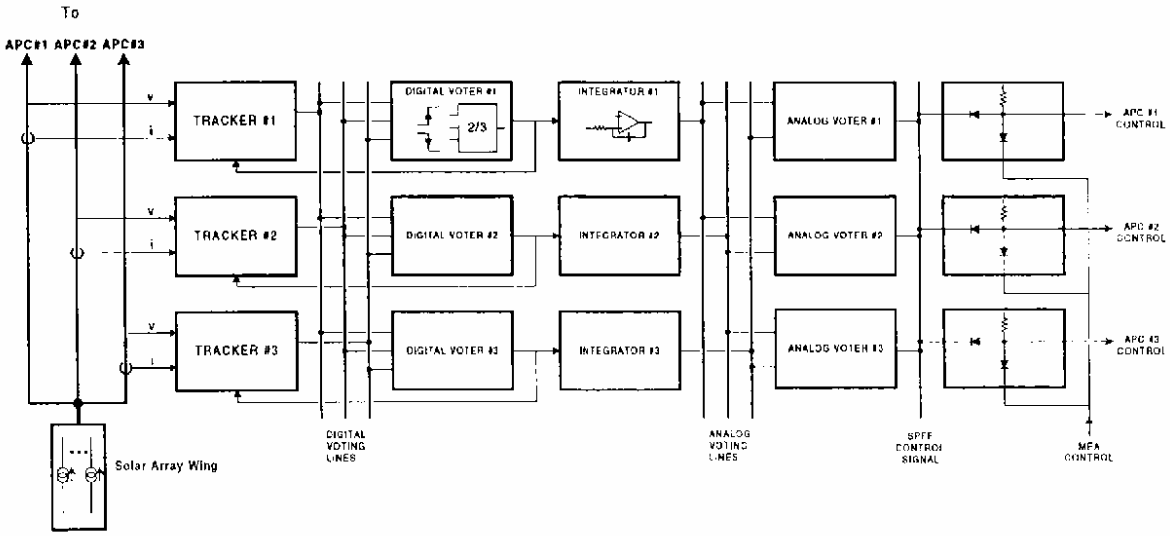


Figure 5-32: MPPT synchronisation & Voting

The MPPT function is initiated by a Tracker Enable signal. This signal is derived indirectly from the MEA control line, setting the Tracker Enable active when the control mode shifts from the APR mode into the BCR mode. Each MPPT function contains a "default clock circuit" which will force the MPPT into its next cycle in case the process stops for any reason (e.g. due to a single event upset). The tracking frequency is free running, at approximately 100 Hz.

5.3.2.3.1.3.5. MPPT Mode Enable / Disable

With two independent MPPT functions, special care is taken to maintain a stable mode when approaching and entering the MPPT mode. This is important as the available power from the two array sections always differs due either to different solar array intensity or to the APR section ability to derive it.

In a situation with either increasing bus loading or decreasing solar array power the APR section with lowest available power will, due to the MEA control signal, be regulated above its maximum power point. The actual section then immediately clamp to the main bus resulting in a reduction of its power transfer to the main bus, worst case to half of the previous delivered power. Due to the reduced power flow to the main bus the MEA signal will request the other section to compensate for this and depending of the available power this section can enter the MPPT mode also. If so, then both sections will now "climb to the top of the hill" leading to excessive power. From this it is obvious that at least the decision to exit MPPT mode must be on an individual basis for the two sections and the entering decision could be as well. Otherwise it might end up in an unstable mode.

The decision to exit the MPPT function is detected independently in each APR section, derived from the fact if the section is able to deliver its MEA requested power level. This allows the MEA signal to regulate the provided power in the APR region without disabling the MPPT operation of the one APR section, which is required to obtain sufficient power.

In the APR module the two different regulation loops, the MEA controlled one and the MPPT controlled one, meets in a type of diode or'ing such that the one which will pull the duty cycle to the lowest value, will be the active control signal. In that way, the MEA line always actively sets an upper limit for the APR current to be provided to the bus. In other words, the MPPT function can never provide more power to the main bus than that requested by the MEA control line.

The decision to enter and exit the MPPT operation is derived from that or'ing, more specific from the fact if the MEA line is the active control line or not. A simple circuit detects if the MEA line control is outside of its active regulation range and enables / disables the MPPT operation accordingly.

5.3.2.3.1.4. Interfaces

5.3.2.3.1.4.1. PCU interface with Solar Array

Individual array strings are combined at panel level and transferred to the PCU via 2 redundant power harnesses to separate power input connectors on the PCU. Each power harness contains 4 twisted pairs of wires from each of the 4 inner panels and 8 twisted pairs from the outer panel. The panel wiring is combined to form wing level wiring at the Solar array drive Mechanism and then further combined at the PCU, at the input to the APR’s.

The increased wiring for the outer panel panel is due to this panel having to be capable of carrying 712W or 15A during LEOP. Note that this reflects the peak array capability and not the spacecraft load..

The maximum array power transferred from each array wing is 750W. The APR modules are each rated at 250W (2 out of 3 redundancy = 500W).

Power input connections on the umbilical allow connection of the Solar Array Power Simulator (SAPS) for ground testing and pre-launch activities. Inside the PCU the SAPS connections are connected in parallel with the solar array power input connections.

Array Voltage

A minimum voltage drop of approximately 3V from the PCU input to the main bus regulation point, is acceptable for array regulation performance. Therefore, with a 28V main bus, the minimum operating array voltage at the PCU input must not be less than 31V in APR mode (or more precisely 30.3V @ 5A; 30.8V @ 9A). In MPPT mode, this voltage is about 1V higher. The maximum voltage drop from the SADM / SA interface to the PCU is calculated as 0.55V, with a measured maximum harness length of 3.9m and a maximum current of 23.1A / wing. A minimum array yoke voltage of approximately 31.3V is required.

The minimum array voltage occurs when the array is hot and degraded which occurs at the Mars flyby. However, under the hottest conditions there will be a large excess of array power, so the actual operating voltage will be higher than the maximum power point voltage defined by these conditions.

The maximum input voltage from the array will be the maximum open-circuit voltage of the array, which will occur when the array is cold, ie at LILT conditions. Realistically at the LILT condition, the array operating point will be towards maximum power point voltage which will lower this voltage towards 70V. However, this reduction may not be large as the cell fill factor is very high under this condition, therefore the specified PCU maximum input voltage is 78.5V.

Array Current

Maximum power able to be transferred from the solar array is 1,500W. Assuming a PCU minimum input voltage of 31.5V for this case, results in a maximum array current of < 24A per wing.

5.3.2.3.1.4.2. Array Performance Monitor

Separate inputs are provided from two special cell strings on each array wing. One of these strings (5 cells) is used for open-circuit voltage (Voc) measurement and the other string (8 cells) for short-circuit current (Isc) measurement.

Voc Measurement

At cell level the Voc range over the mission is from 355mV to 825mV for Si cells. The measurement range is 0 - 5V for the 5 cell string.

The maximum current drawn by the voltage sense circuit must not significantly affect the accuracy of the Voc measurement. A maximum current of 0.5mA was chosen as this is less than 3% of the minimum Isc at the LILT condition (5.25AU), which results in the requirement for a minimum input impedance of 10kΩ (5V/0.5mA).

Isc Measurement

The estimated Isc measurement range is 0 - 1.5A for a Si cell, with a minimum specified value to be accurately measured of 20mA (LILT, 5.25AU condition). To achieve the required accuracy 2 ranges will be used, 0-100mA and 0-1.5A.

5.3.2.3.1.4.3. PCU Interface with Battery

Each battery is connected to a dedicated BDR and BCR module in the PCU. There are no battery connect/disconnect relays in the PCU or separate interfaces for battery EGSE (battery charge/discharge/monitoring units). Battery power to the PCU is routed via externally accessible battery safety skin connectors which are part of the Harness Subsystem. Connection of the battery EGSE will also be made at these connectors for monitoring and charge /discharge operations during AIV.

The PCU also conditions battery temperature sensors and provides battery voltage telemetry.

5.3.2.3.1.4.4. PCU Interface with RTU

The PCU receives commands from and supplies telemetry to the SS-RTU

5.3.2.3.1.4.5. PCU Interface with PDUs

The PCU provides main bus power outlets to the PL-PDU and SS-PDU only, as follows :

PCU Outlet	Maximum Predicted Power (incl. margin)	Maximum Current at Predicted Power	Rated Outlet Capability	Maximum Current at Rated Power
PL-PDU	375W	13.53A	600W	21.65A
SS-PDU	565W	20.38A	900W	32.47A

The rated power capability of each outlet is twice the predicted total power to be delivered (excluding margins). Total power capability of the PCU is 1500W. The PCU provides individual measurement of main bus currents taken by the SS-PDU and PL-PDU. Each current sensor is sized for the maximum rated current.

5.3.2.3.2. Power Distribution Units (PL-PDU, SS-PDU)

5.3.2.3.2.1. General Description

All main bus power supplied to the spacecraft is protected and distributed by two Power Distribution Units. These units include Foldback Current Limiters (FCL) for essential non-switched loads (Receivers and CDMUs) and Latching Current Limiters (LCL) for all other loads, including all the payload units. Secondary power Keep Alive Lines (KAL) are also provided to specific payload users.

Battery power is protected and conditioned to provide pyrotechnic power to the platform and payload users. The pyrotechnics are also supported by a main bus power back-up capability via a capacitor bank shared between the 2 PDUs.

The PL-PDU is dedicated to the supplying of power to the payloads and provides LCL, KAL and pyrotechnic outputs. The SS-PDU is dedicated to the supplying of power to the Platform and Avionics units and also provides FCL, LCL, and pyrotechnic outputs. Additionally, the SS-PDU provides Thermal Knife(TK) outlets for releasing the solar arrays.

Both the SS-PDU and PL-PDU units supply power to the Thermal Control Subsystem heaters. Thermostat controlled (hardware) heaters are protected in groups of 4 outlets by LCL's. Thermistor controlled (software) heaters are individually switched using solid state Heater Switches(HS) in groups of 4 supplied via a common protecting LCL . All the software (S/W) heater outlets share their LCLs with hardware (H/W) heater outlets (for combined S/W-H/W heater circuits), thus each combined H/W-S/W heater LCL provides power directly to 4 H/W outlets and via heater switches to 4 S/W outlets.

Each distribution unit is fully redundant, each half having its own auxiliary power supply and TM/TC interface, with cross-strapping to allow full functionality with the redundant platform RTU.

The SS-PDU and PL-PDU are now discussed in more detail.

5.3.2.3.2.1.1. SS-PDU overview

The main functions of the SS-PDU are to:

- Distribute the regulated main bus power on the spacecraft.
- Protect the distributed main bus by ON/OFF switchable latching current limiters (LCLs) and permanent ON current limiters (FCLs). Note that the PL-PDU does not have FCLs.
- Provide power to three types of heaters on the spacecraft
- Condition, protect and provide pyrotechnic power to the specific subsystem users. Pyrotechnic power is derived from the batteries and supported by main-bus backup.
- Protect and provide thermal knife power outlets in the SS-PDU.
- Provide telecommand and telemetry Interfaces necessary for operation and evaluation of performance

The simplified SS-PDU block diagram is shown below.

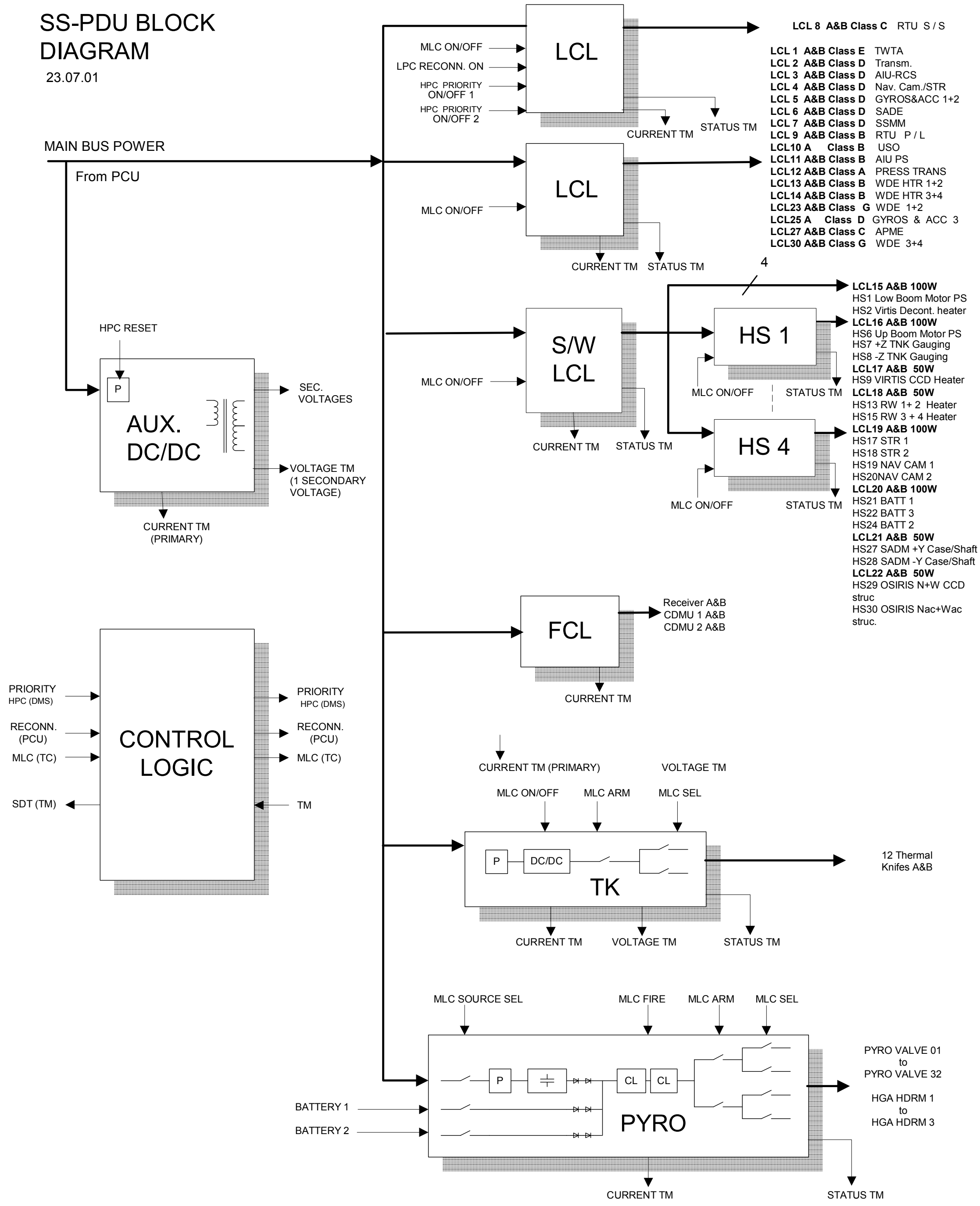


Figure 5-33: SS-PDU Block Diagram

Redundancy

The SS-PDU Unit is internally redundant and divided into two sections SS-PDU-A and SS-PDU-B. The nominal and redundant sides are identical. Each redundant half of the Unit contains:

- 30 LCLs
- 32 HSs
- 3 FCLS
- 35 pyro firing circuits with two battery interfaces as main energy source
- Backup energy source connected to the main bus for pyro firing
- 12 thermal knife (TK) outlets
- TM/TC Interface to RTU
- Auxiliary power supply (TM/TC function only – FCL's, LCL's each have a dedicated aux supply)

There is only one single main bus connector so both A and B sides of the SS-PDU are always powered. Hence the auxiliary power supplies and telemetry and telecommand interfaces are operated in hot redundancy

There is no automatic switch over from one current limiter (LCL/FCL) to the other (i.e. main to redundant)

Cross coupling

The cross coupling of the TM/TC between the nominal and redundant sides allows commanding and monitoring of the redundant chains by the main and redundant interfaces.

5.3.2.3.2.1.2. PL-PDU overview

The main functions of the PL-PDU are as follows:

- Distribute the regulated main bus power on the spacecraft to the payload users .
- Protect the distributed main bus by ON/OFF switchable latching current limiters (LCLs)
- Condition, protect and provide pyrotechnic power to the specific subsystem users powered by batteries and supported by main-bus backup.

- Provide telecommand and telemetry Interfaces necessary for operation and evaluation of performance
- Provide Keep Alive Power to the instruments
- Distribute power to Thermal Control Subsystem hardware and software controlled heaters

The PL-PDU Unit is internally redundant and divided into two sections PL-PDU-A and PL-PDU-B. The nominal and redundant sides are identical. Each redundant half of the unit contains:

- 54 LCLs
- 16 HSs
- 9 KALs
- 22 pyro firing circuits with two battery interfaces as main energy source
- Backup energy source connected to the main-bus for pyro firing
- TM/TC Interface to RTU
- Auxiliary power supply

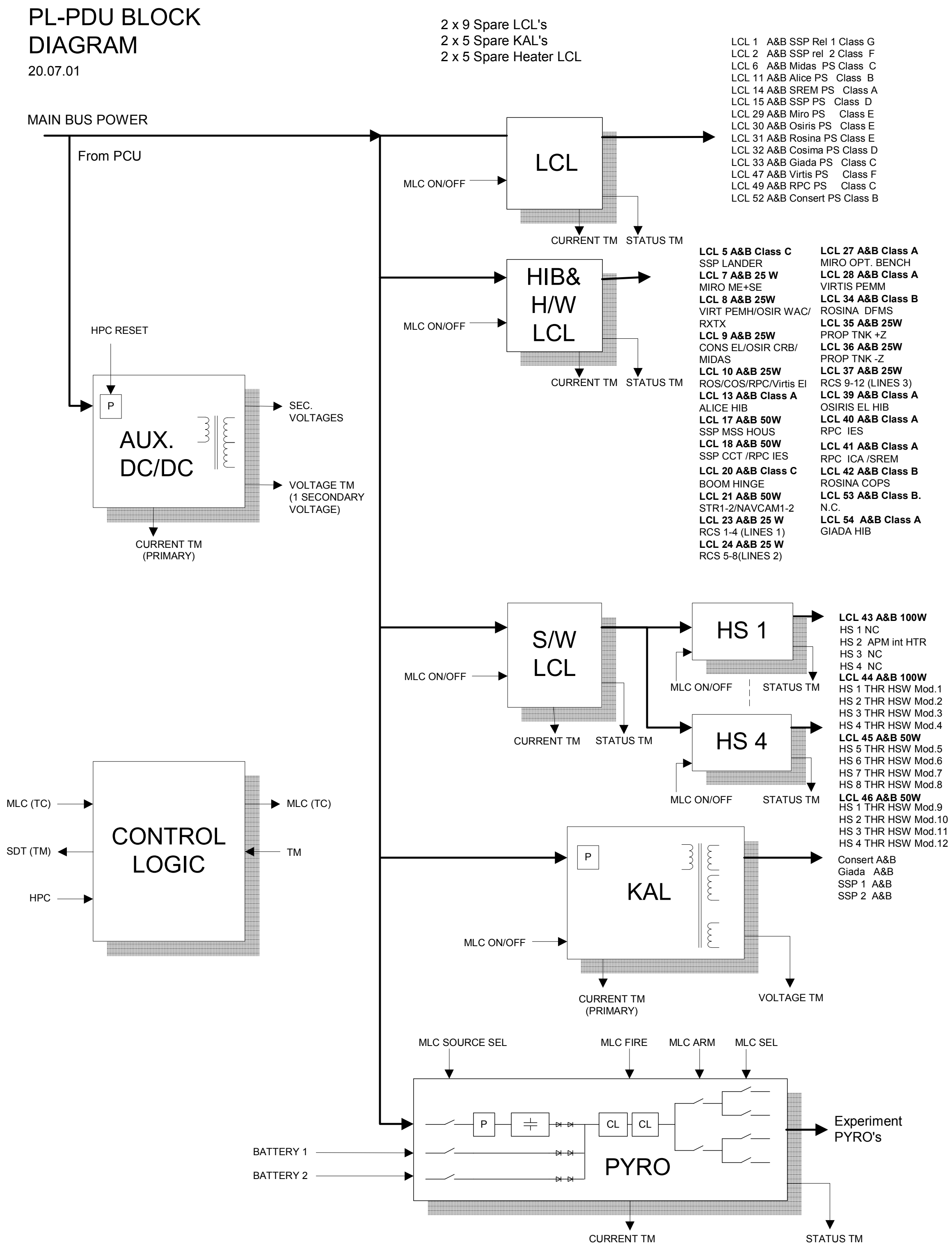


Figure 5-34: PL-PDU Block Diagram

There is only one single main bus connector so both A and B sides of the PL-PDU are always powered. Therefore the auxiliary power supplies and telemetry and telecommand interfaces can be operated in hot redundancy. It is also possible to operate the Keep Alive line power in hot redundancy.

There is no automatic switch over from one current limiter (LCL) to the other (i.e. main to redundant)

5.3.2.3.2.2. PDU functions

5.3.2.3.2.2.1. Latching Current Limiter

5.3.2.3.2.2.1.1. LCL description common to SS-PDU & PL-PDU

A latching current limiter is a self contained unit which delivers power to a user load. The relay is commandable ON/OFF by command and provides protection from over-current and under-voltage.

There are 10 different LCL classes (A, B, C, D, E, F, G, 25W, 50W, 100W) which supply different levels of current.

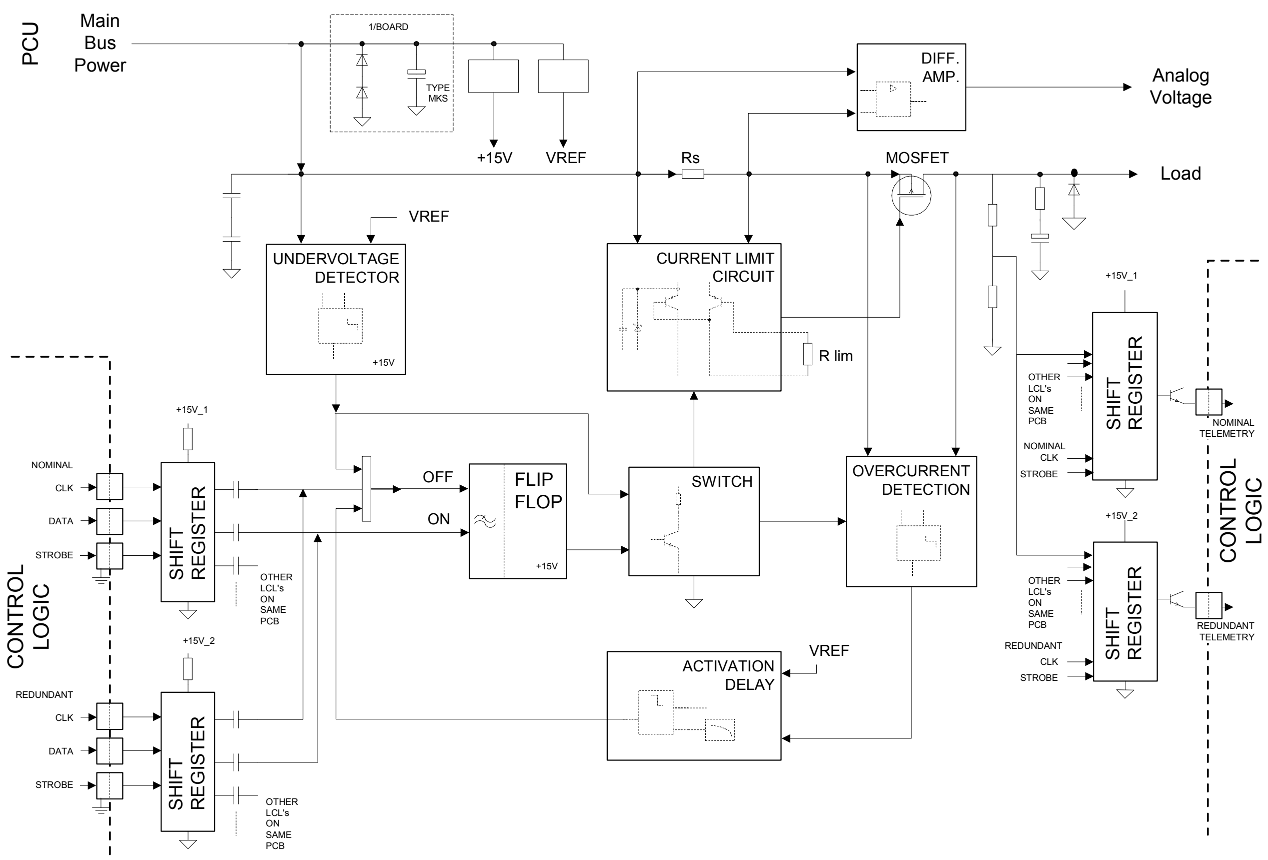


Figure 5-35: LCL circuit diagram

A current limit circuit senses the current across a sensing resistor and controls the series pas MOSFET Switch limiting the maximum output current to the predefined value. The voltage across the MOSFET Switch is also monitored and if the voltage is above a threshold level, the LCL is detected to be in current limitation mode and switched off to avoid excessive dissipation.

This same circuit is used to detect a short circuit at the and the LCL is switched automatically OFF after a predefined delay , which is a function of the LCL class.

The input voltage to the LCL is monitored by a separate circuit and if it is below 25.5V then the LCL is automatically switched OFF. The LCL will then remain OFF until the undervoltage is cleared and an ON command is given by the Control Logic.

There are separate memory load commands for each LCL ON and LCL OFF. The last given command is stored in a flip-flop

For telemetry an LCL status signal is provided as well as an analog signal proportional to the current through the LCL. The current is measured at each telemetry update. In addition, the current profile of an LCL can be measured over a 911.24 ms period by first selecting the LCL to be measured and then activating the measurement.

Each LCL has its own local auxiliary supply and operates independently of the PDU auxiliary supply.

5.3.2.3.2.2.1.2. LCL in the SS-PDU

Each side of the SS-PDU contains 30 individually switchable ON/OFF latching current limiters which deliver power to the user loads.

SS-PDU LCL ID	LCL CLASS	NOM. I(A)	TRIP I(A)	MAX LOAD(W)	LOAD NAME	REMARKS
SIDE A						
1	E	3.1	4	70	TWTA A	
2	D	2.3	3	31	TX A	
3	D	2.3	3	40.84	AIU - RCS 1	12x Thrs
4	D	2.3	3	42.2	NAV CAM / STR 1	
5	D	2.3	3	45.6	GYROS & ACC 1	
6	D	2.3	3	19.88	SADE A	
7	D	2.3	3	23.2	SSMM 1	
8	C	1.2	1.6	10.8	RTU S / S PS 1	
9	B	0.6	0.8	8	RTU PL PS1	
10	B	0.6	0.8	7.5	USO A	
11	B	0.6	0.8	9	AIU PS 1	
12	A	0.3	0.4	2.5	PRESS TRANS A	3x Ptrs
13	B	0.6	0.8	8.5	WDE HTR 1	
14	B	0.6	0.8	8.5	WDE HTR 3	

SS-PDU LCL ID	LCL CLASS	NOM. I(A)	TRIP I(A)	MAX LOAD(W)	LOAD NAME	REMARKS
15	100W	3.5	4.4	63	LBM **VIRTDEC	HW/SW HTRS
16	100W	3.5	4.4	12	+ZTNKG -ZTNKG UBM	HW/SW HTRS
17	50W	1.8	2.3	0.1	VIRTIS	HW/SW HTRS
18	50W	1.8	2.3	5.4	RW'S 1,2	HW/SW HTRS
19	100W	3.5	4.4	28.4	SST1-2/NAVCAM1-2	HW/SW HTRS
20	100W	3.5	4.4	9	BATT1-3	HW/SW HTRS
21	50W	1.8	2.3	7.5	SADM+Y SADM-Y	HW/SW HTRS
22	50W	1.8	2.3	17	OSIRIS	HW/SW HTRS
23	G	4.6	6	105	WDE 1	
24	E	3.1	4	N/A	SPARE	
25	D	2.3	3	33	GYROS & ACC 3	
26	C	1.2	1.6	N/A	SPARE	
27	C	1.2	1.6	23.6	APME A	
28	C	1.2	1.6	N/A	SPARE	
29	C	1.2	1.6	N/A	SPARE	
30	G	4.6	6	105	WDE 3	
SIDE B	CLASS	NOM I	TRIP I	LOAD(W)	LOAD NAME	REMARKS
1	E	3.1	4	70	TWTA B	
2	D	2.3	3	31	TX B	
3	D	2.3	3	40.84	AIU - RCS 2	12x Thrs
4	D	2.3	3	42.2	NAV CAM / STR 2	
5	D	2.3	3	45.6	GYROS & ACC 2	
6	D	2.3	3	19.88	SADE B	
7	D	2.3	3	23.2	SSMM 2	
8	C	1.2	1.6	10.8	RTU S / S PS 2	
9	B	0.6	0.8	8	RTU PL PS2	
10	B	0.6	0.8	7.5	USO B	
11	B	0.6	0.8	9	AIU PS 2	
12	A	0.3	0.4	2.5	PRESS TRANS B	3x Ptrs
13	B	0.6	0.8	8.5	WDE HTR 2	
14	B	0.6	0.8	8.5	WDE HTR 4	
15	100W	3.5	4.4	63	EXP BM 1B (LWR) *VIRTISDEC	HW/SW HTRS
16	100W	3.5	4.4	12	+ZTNKG -ZTNKG UBM	HW/SW HTRS
17	50W	1.8	2.3	0.1	VIRTIS	HW/SW HTRS
18	50W	1.8	2.3	5.4	RW'S 1,2	HW/SW HTRS

SS-PDU LCL ID	LCL CLASS	NOM. I(A)	TRIP I(A)	MAX LOAD(W)	LOAD NAME	REMARKS
19	100W	3.5	4.4	28.4	SST1-2/NAVCAM1-2	HW/SW HTRS
20	100W	3.5	4.4	9	BATT1-3	HW/SW HTRS
21	50W	1.8	2.3	7.5	SADM+Y SADM-Y	HW/SW HTRS
22	50W	1.8	2.3	17	OSIRIS	HW/SW HTRS
23	G	4.6	6	105	WDE 2	
24	E	3.1	4	N/A	SPARE	
25	D	2.3	3	45.6	SPARE	
26	C	1.2	1.6	N/A	SPARE	
27	C	1.2	1.6	23.6	APME B	
28	C	1.2	1.6	N/A	SPARE	
29	C	1.2	1.6	N/A	SPARE	
30	G	4.6	6	105	WDE 4	

Table 5-1: SS-PDU LCL allocation

Experiment Boom motor supplies are derived from SW heater outputs to provide 2 Off levels at the PDU. There is no ON/OFF switching at the motor.

If a user has a relay as input power switch, first the relay must be switched on to avoid a possible relay bouncing and after that the LCL is turned on. Affected equipment are the SSMM connected to SS-PDU LCL 7 and the AIU LCL connected to SS-PDU LCL 11.

The command to SS-PDU LCL 8, connected to SS-RTU, must be sent twice. The first command switches on LCL 8 and the input power relay of the RTU, however the relay close spike may trigger a LCL 8 off command. The second command will finally switch on LCL 8.

5.3.2.3.2.2.1.3. LCL in the PL-PDU

Each side of the PL-PDU contains 54 individually switchable ON/OFF latching current limiters which deliver power to the user loads.

The current LCL allocations with class, nominal and trip currents, maximum expected loads and specific load names are shown in the following table :

PL-PDU LCL ID	LCL CLASS	NOM. I(A)	TRIP I(A)	LOAD (W)	LOAD NAME	REMARKS
SIDE A						
1	G	4.6	6	126	SSP REL A 1	
2	F	3.8	5	103	SSP REL B 1	

PL-PDU LCL ID	LCL CLASS	NOM. I(A)	TRIP I(A)	LOAD (W)	LOAD NAME	REMARKS
3	100W	3.5	4.4	N/A	SPARE	HW HTRS
4	50W	1.8	2.3	N/A	SPARE	HW HTRS
5	C	1.2	1.6	12.8	SSP Lander. HTR A	
6	C	1.2	1.6	28	MIDAS PS 1	
7	25W	0.9	1.2	4.3	MIRO ME+SE HTRS	HW HTRS
8	25W	0.9	1.2	11.5	VIRT PEMH/OSIR WAC/ RXTX 1+2 HTRS //L	HW HTRS
9	25W	0.9	1.2	7	CONS EL/OSIR CRB/MIDAS HTRS	HW HTRS
10	25W	0.9	1.2	4.2	ROS/COS/RPC	HW HTRS
11	B	0.6	0.8	7.5	ALICE PS 1	
12	B	0.6	0.8	N/A	SPARE	
13	A	0.3	0.4	2.7	ALICE HIB HTR	
14	A	0.3	0.4	2	SREM PS 1	
15	D	2.3	3	48	SSP PS 1	
16	D	2.3	3	N/A	SPARE	
17	50W	1.8	2.3	5.3	SSP MSS HOUS HTR	HW HTRS
18	50W	1.8	2.3	4.3	SSP CCT /RPC IES HTRS	HW HTRS
19	D	2.3	3	N/A	SPARE	
20	C	1.2	1.6	4	BOOM HINGE HTRS	UPPER&LOWER
21	50W	1.8	2.3	8.8	STR1-2/NAVCAM1-2 A	HW HTRS
22	25W	0.9	1.2	N/A	SPARE	HW HTRS
23	25W	0.9	1.2	12.5	RCS 1-4 (LINES 1)	HW HTRS
24	25W	0.9	1.2	10.7	RCS 5-8(LINES 2)	HW HTRS
25	B	0.6	0.8	N/A	SPARE	
26	B	0.6	0.8	N/A	SPARE	
27	A	0.3	0.4	3.5	MIRO OPT. BENCH HTR A	Ext. HTR
28	A	0.3	0.4	3.5	VIRTIS PEMM HTRS	
29	E	3.1	4	70	MIRO PS 1	
30	E	3.1	4	50	OSIRIS PS 1	
31	E	3.1	4	78	ROSINA PS 1	
32	D	2.3	3	21	COSIMA PS 1	
33	C	1.2	1.6	28	GIADA PS 1	
34	B	0.6	0.8	1.3	ROSINA HTR DFMS	
35	25W	0.9	1.2	15.2	PROP TANKS +Z	HW HTRS
36	25W	0.9	1.2	16.9	PROP TANKS –Z	HW HTRS
37	25W	0.9	1.2	3.1	RCS 9-12 (Lines 3)	HW HTRS
38	25W	0.9	1.2	N/A	SPARE	HW HTRS
39	A	0.3	0.4	5.3	OSIRIS EL HIB HTR	

PL-PDU LCL ID	LCL CLASS	NOM. I(A)	TRIP I(A)	LOAD (W)	LOAD NAME	REMARKS
40	A	0.3	0.4	0.47	RPC IES HTR	
41	A	0.3	0.4	7	RPC ICA HTR A/SREM HTR //L	
42	B	0.6	0.8	6	ROSINA COPS HTR	
43	100W	3.5	4.4	8.5	** APM	HW & SW HTRS
44	100W	3.5	4.4	13.6	THRUSTERS 1-4	HW & SW HTRS
45	50W	1.8	2.3	13.6	THRUSTERS 5-8	HW & SW HTRS
46	50W	1.8	2.3	13.6	THRUSTERS 9-12	HW & SW HTRS
47	F	3.8	5	84	VIRTIS PS 1	
48	E	3.1	4	N/A	SPARE	
49	C	1.2	1.6	17	RPC PS 1	
50	D	2.3	3	N/A	SPARE	
51	B	0.6	0.8	N/A	SPARE	
52	B	0.6	0.8	14	CONSERT PS 1	
53	B	0.6	0.8	4	N.C.	
54	A	0.3	0.4	5.3	GIADA HIB HTR	
SIDE B	CLASS	NOM I	TRIP I	LOAD	LOAD NAME	REMARKS
1	G	4.6	6	126	SSP REL A 2	
2	F	3.8	5	103	SSP REL B 2	
3	100W	3.5	4.4	N/A	SPARE	HW HTRS
4	50W	1.8	2.3	N/A	SPARE	HW HTRS
5	C	1.2	1.6	12.8	SSP Lander. HTR B	
6	C	1.2	1.6	28	MIDAS PS 2	
7	25W	0.9	1.2	4.3	MIRO ME+SE HTRS	HW HTRS
8	25W	0.9	1.2	11.5	VIRT PEMH/OSIR WAC/ RXTX 1+2 HTRS //L	HW HTRS
9	25W	0.9	1.2	7	CONS EL/ OSIR CRB/MIDAS HTRS	HW HTRS
10	25W	0.9	1.2	4.2	ROS/COS/RPC	HW HTRS
11	B	0.6	0.8	7.5	ALICE PS 2	
12	B	0.6	0.8	N/A	SPARE	
13	A	0.3	0.4	2.7	ALICE HIB HTR	
14	A	0.3	0.4	2	SREM PS 2	
15	D	2.3	3	48	SSP PS 2	
16	D	2.3	3	N/A	SPARE	
17	50W	1.8	2.3	5.3	SSP MSS HOUS HTR	HW HTRS
18	50W	1.8	2.3	4.3	SSP CCT /RPC IES HTRS	HW HTRS

PL-PDU LCL ID	LCL CLASS	NOM. I(A)	TRIP I(A)	LOAD (W)	LOAD NAME	REMARKS
19	D	2.3	3	N/A	SPARE	
20	C	1.2	1.6	4	BOOM HINGE HTRS	UPPER&LOWE R
21	50W	1.8	2.3	8.8	STR1-2/NAVCAM1-2	HW HTRS
22	25W	0.9	1.2	N/A	SPARE	HW HTRS
23	25W	0.9	1.2	12.5	RCS 1-4 (LINES 1) B	HW HTRS
24	25W	0.9	1.2	10.7	RCS 5-8(LINES 2) B	HW HTRS
25	B	0.6	0.8	N/A	SPARE	
26	B	0.6	0.8	N/A	SPARE	
27	A	0.3	0.4	3.5	MIRO OPT. BENCH HTR B	Ext. HTR
28	A	0.3	0.4	3.5	VIRTIS PEMM HTRS	
29	E	3.1	4	70	MIRO PS 2	
30	E	3.1	4	50	OSIRIS PS 2	
31	E	3.1	4	78	ROSINA PS 2	
32	D	2.3	3	21	COSIMA PS 2	
33	C	1.2	1.6	28	GIADA PS 2	
34	B	0.6	0.8	1.3	ROSINA HTR DFMS	HW HTRS
35	25W	0.9	1.2	15.2	PROP TANKS +Z	HW HTRS
36	25W	0.9	1.2	16.9	PROP TANKS -Z	HW HTRS
37	25W	0.9	1.2	3.1	RCS	HW HTRS
38	25W	0.9	1.2	N/A	SPARE	HW HTRS
39	A	0.3	0.4	5.3	OSIRIS EL HIB HTR	
40	A	0.3	0.4	0.47	RPC IES HTR	
41	A	0.3	0.4	7	RPC ICA HTR A/SREM HTR A //L	
42	B	0.6	0.8	6	ROSINA COPS HTR	
43	100W	3.5	4.4	8.5	** APM	HW & SW HTRS
44	100W	3.5	4.4	13.6	THRUSTERS 1-4	HW & SW HTRS
45	50W	1.8	2.3	13.6	THRUSTERS 5-8	HW & SW HTRS
46	50W	1.8	2.3	13.6	THRUSTERS 9-12	HW & SW HTRS
47	F	3.8	5	84	VIRTIS PS 2	
48	E	3.1	4	N/A	SPARE	
49	C	1.2	1.6	17	RPC PS 2	
50	D	2.3	3	N/A	SPARE	
51	B	0.6	0.8	N/A	SPARE	
52	B	0.6	0.8	14	CONSERT PS 2	

PL-PDU LCL ID	LCL CLASS	NOM. I(A)	TRIP I(A)	LOAD (W)	LOAD NAME	REMARKS
53	B	0.6	0.8	4	N.C.	
54	A	0.3	0.4	5.3	GIADA HIB HTR	

Table 5-2: PDU LCL allocations

5.3.2.3.2.2.1.4. Types of heater LCL

There are two types of heater LCL, hardware controlled (H/W) LCL and combined hardware/software (H/W-S/W) controlled LCL.

H/W HEATERS

The H/W heater LCL type only exists in the PL-PDU. Each LCL has 4 H/W heater outlets as specified in the table below :

H/W LCL Class	25W	50W	100W	Totals
Heater outlet group				
20W+20W+20W+20W	0	0	2	2
20W+10W+10W+10W	0	0	0	0
10W+10W+10W+10W	0	4	0	4
10W+5W+5W+2W	16	0	0	16
5W+2W+2W+2W	6	0	0	6
20W+10W+10W+5W	0	4	0	4
PL-PDU total (nom+red)	22	8	2	32

COMBINED H/W-S/W HEATERS

Each combined H/W-S/W heater LCL is allocated to 4 heater circuits. Each heater circuit has 2 separate outlets, one directly from the LCL (for H/W control) and the other via a heater switch (HS) connected in series with the LCL (for S/W control).Therefore, each H/W-S/W LCL provides 4 hardware driven outlets directly and 4 software driven outlets via HS's

The PL-PDU has 8 combined H/W-S/W LCL's and 32 HS's (to provide 32 H/W-S/W outlets).

TCS combined H/W – S/W LCL Class (PL-PDU, nom+red)	25W	50W	100W	LCL Totals	HS Totals
	0	4	4	8	32

The SS-PDU has16 combined H/W-S/W LCL's and 64 HS's (to provide 64 H/W-S/W outlets).

TCS combined H/W – S/W LCL Class (SS-PDU, nom+red)	25W	50W	100W	LCL Totals	HS Totals
	0	8	8	16	64

5.3.2.3.2.2.2. Foldback Current Limiter

The FCLS are permanently ON current limiters for 'essential loads'.

The SS-PDU provides a total of 6 Foldback Current Limiter's (3 nominal and 3 redundant). There are 2 FCLs rated at 0.8 A for the Receivers and 4 FCLs at 1.24A for the CDMUs. There are no FCLs in the PL-PDU.

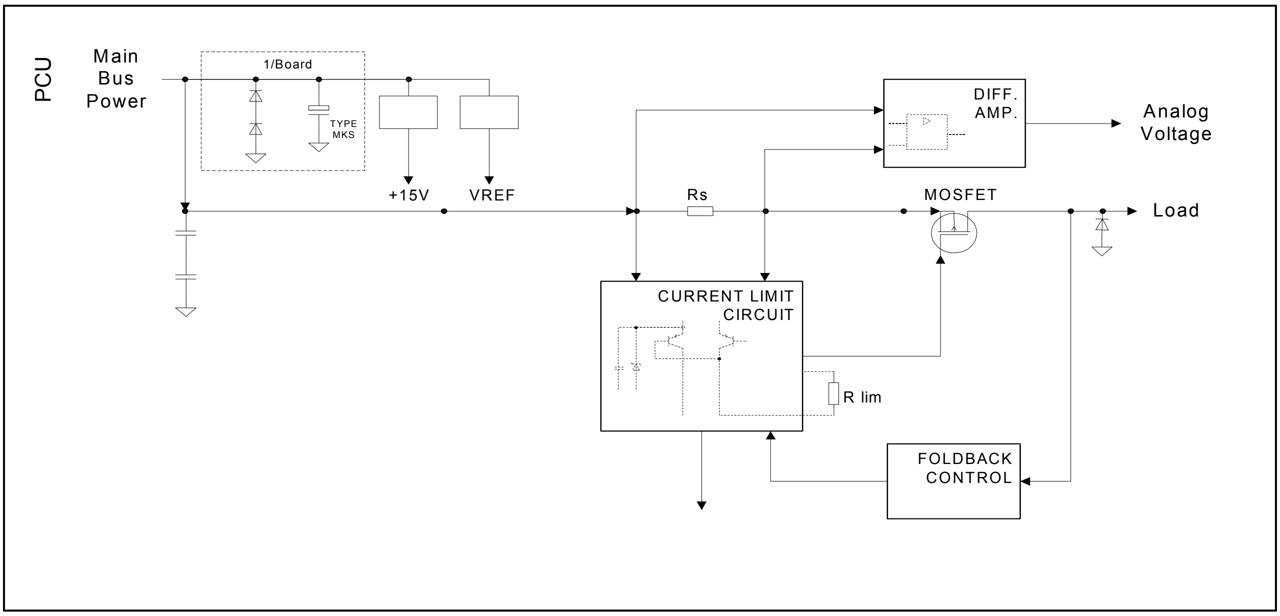


Figure 5-36: FCL circuit diagram

A Current Limit Circuit senses the input current across a sensing resistor and generates the control for a MOSFET series pas Switch to limit the output current to a predefined value.

A Foldback Control Block monitors the voltage at the FCL output and automatically reduces the current limit operating point proportionally to the output voltage. Since there is no switch-off function in case of an overload at the output, the circuit must withstand the increased power dissipation indefinitely. The foldback current level with a short-circuited output is low enough that the dissipation can be withstood by the circuit and the PDU indefinitely.

An analog signal proportional to the current through the FCL is provided for telemetry.

The FCL allocations with nominal and trip currents, maximum expected loads and specific load names are shown in the following table :

SS-PDU FCL ID	NOM. I(A)	TRIP I(A)	MAX LOAD(W)	LOAD NAME
SIDE A				
1	0.6	0.8	15.1	RX A
2	0.95	1.24	19.2	CDMU 1A
3	0.95	1.24	12.5	CDMU 2A
SIDE B				
1	0.6	0.8	15.1	RX B
2	0.95	1.24	19.2	CDMU 1B
3	0.95	1.24	12.5	CDMU 2B

Table 5-3: FCL allocations

Each FCL has its own auxiliary supply independent of the main PDU auxiliary supply.

5.3.2.3.2.2.3. Heater Switches

5.3.2.3.2.2.3.1. HS description common to SS-PDU & PL-PDU

The heater switch (HS) is a semiconductor switch controlling a single load. Four heater switches are connected after a common LCL. The purpose of the HS is to isolate a fault in one of the loads of the common LCL or to allow software control of a heater.

The HS comprises the following functional blocks:

- Shift registers which receive the local serial HS ON & HS OFF commands through optocouplers from the Control Logic, loaded via serial MLC. The Control Logic is powered by the secondary voltage and the HS electronic circuits are powered by the primary voltage. Each shift register is powered by two separate LCL's.

- A Flip-Flop stores the HS ON or HS OFF command from the Control Logic. The Flip-Flop output controls a switch, which again drives a MOSFET Switch controlling the state of the HS output.

The status of the HS is based on the existence of a voltage at the HS output. This is detected at the status receiving shift register input, nominal and redundant. Each status shift register receives its power in parallel with the corresponding command shift register (nominal or redundant). Note that if the HS is switched ON but its supplying LCL is OFF, the HS status will be OFF because there will be no voltage at the HS output.

After power-up of the PDU, the HS remains in the OFF state.

The HS block diagram is presented below.

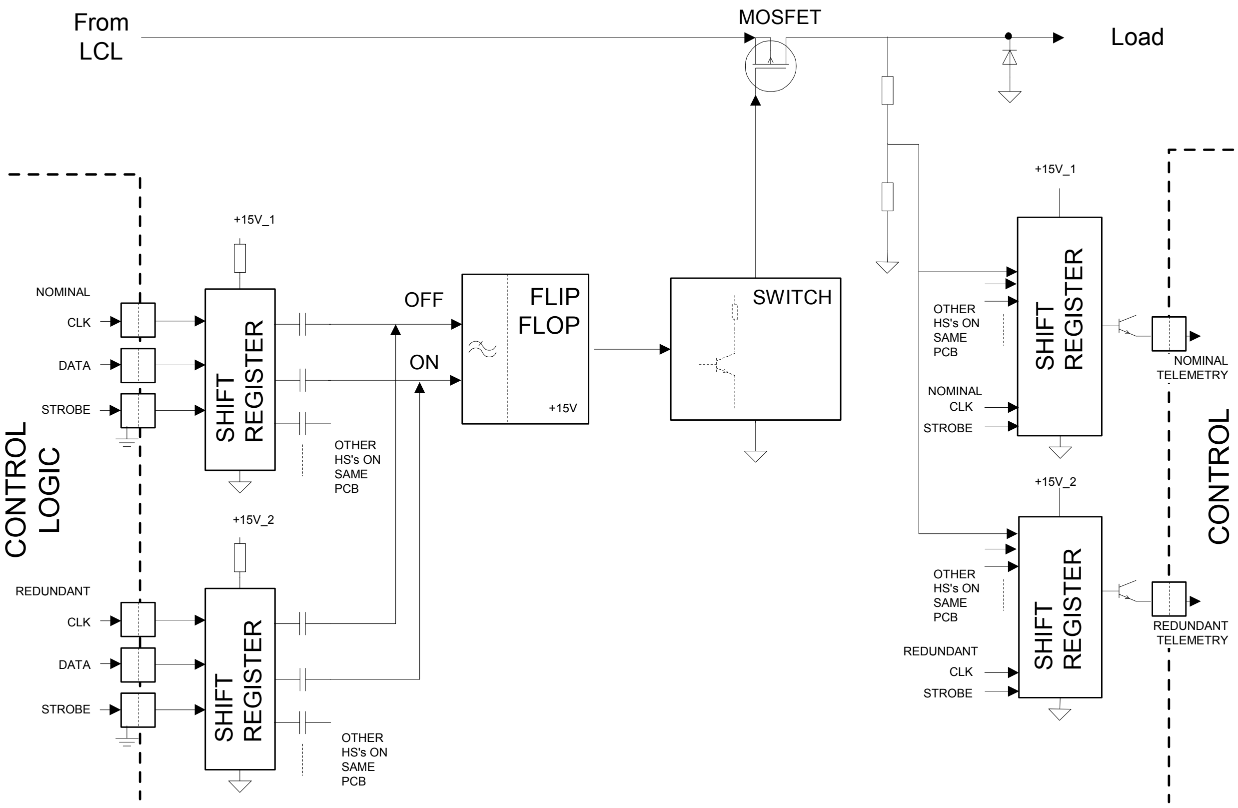


Figure 5-37: Heater Switch (HS) Block Diagram

Heater Switch Power Ratings

There are three different load levels for the loads after the Heater Switches. These are: 10W, 20W and 50W.

HS outlet power rating	10W	20W	50W
Max. nominal current	0.4A	0.7A	1.8A

5.3.2.3.2.2.4. Keep-Alive-Lines (KAL)

5.3.2.3.2.2.4.1. KAL description

The purpose of the KAL is to supply permanent "keep alive power" to particular equipments.

The KAL converter is sized to supply at least 150 mA secondary current (6 lines x 25mAmp). The output voltage is 17.5 V open-circuit and 12.3 V at 15mA load.

The KAL converter has an input current limiter, which is switched off in the case of undervoltage (voltage < 20 V). In such an event the converter can only be restarted by a specific RTU TC.

The current limiter can also be switched OFF by command.

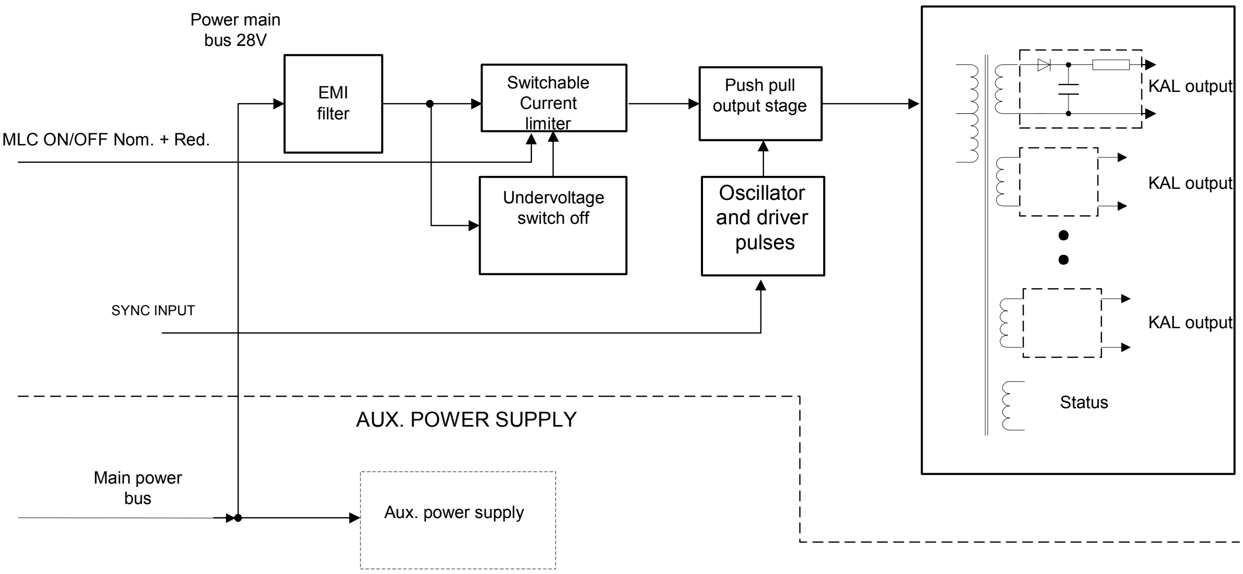


Figure 5-38: KAL Block diagram

5.3.2.3.2.2.4.2. KAL in the SS-PDU

The Keep Alive Lines (KAL) function in the SS-PDU have been deleted.

5.3.2.3.2.2.4.3. KAL in the PL-PDU

The Keep Alive Lines (KAL) function in the PL-PDU comprises a KAL converter and 9 output lines. The purpose is to supply permanent "keep alive power" to switched off instruments and experiments.

The PL-PDU KAL converter can be switched on and off by command. The command to either A or B side can be given by either an A or B side telecommand. In the PL-PDU the nominal and redundant KAL functions can operate in hot redundancy.

The PL-PDU provide KAL's to specific sub-system and payload users as shown in the following table:

KAL allocations	PL-PDU
KAL1A	COSIMA PS 1
KAL2A	GIADA PS 1
KAL3A	SPARE
KAL4A	SSP PS 1 A
KAL5A	SSP REL A1
KAL6A	SPARE

KAL allocations	PL-PDU
KAL7A	SPARE
KAL8A	SPARE
KAL9A	SPARE
KAL1B	COSIMA PS 2
KAL2B	GIADA PS 2
KAL3B	SPARE
KAL4B	SSP PS 1 B
KAL5B	SSP REL A2
KAL6B	SPARE
KAL7B	SPARE
KAL8B	SPARE
KAL9B	SPARE

Table 5-4: Allocation of KAL to loads

5.3.2.3.2.2.5. Pyrotechnic Power

5.3.2.3.2.2.5.1. Pyro power description common to SS-PDU & PL-PDU

Power is required from both the SS and PL PDUs to operate pyrotechnic devices (e.g. propellant line opening, mechanism release). The pyro electronics provide the necessary means to select a particular firing input power source and firing outlet, to fire the pyro device, monitor and control the pyro outlet current to actual pyro devices.

The pyro electronics block diagram is seen in the figure below.

Pyrotechnic power is provided from the batteries. Each redundant half of the pyrotechnic electronics receives input power from 2 batteries, (1 battery is dedicated to each half and the third battery is shared). A back-up energy source derived from the main bus consisting of a capacitor bank provides power in the case where no battery power is available. This source is sized for half the total needs in each PDU, which are combined in the harness so that their total energy is available to both units. All energy source inputs are protected by series diodes and the selection of the actual energy source to be used is provided by relay switching.

Several pyro relays are gathered together into related groups. To fire any particular device it is necessary to select the required device, enable the pyro group to which the device belongs, switch on the required power source and then finally send the FIRE command to operate the device.

The FIRE command and the power source OFF command(s) must be sent in one frame. After that, first the device relay and than the ARM group relay must be switched OFF.

For each pyro channel redundant pyros are provided.

The pyro electronics comprises following sections:

- Input power switches to select the power input source, battery 1 or battery 3, or main power bus with back-up energy source. The redundant side will be supplied by the battery 3 or battery 2 or main power bus. The design allows the use of possible three battery option. Also the returns are switched to the appropriate source.

- Back-up energy source to store energy for pyro electric devices, The back-up energy source consists of a bank of capacitors. This will be used if the batteries cannot be used. The back-up energy source is sized to allow at least 8 consecutive pyro firings.

- Protection device to limit recharging current between the main power bus and the capacitor bank, and also to limit the maximum current drawn from the main power bus during pyro firing as the capacitor bank.

- Reverse blocking diodes (2 in series) to protect the different energy sources.

- Nominal and redundant current limiters in series to limit maximum output current to required current level (4.5 to 6.0 Amps) in normal operation and also in event of short circuit in pyro circuit (6.0 Amp maximum).

- Arming relay to select output group and also to provide safety protection.

- Selection relays to select the pyro circuit to be fired and to provide anti-static resistor connection over pyro circuit when non-activated.

- Current measurement function to provide capability to sample pyro firing current.

- MLC interfaces for ON/OFF commands to power selection, arm and pyro selection relays, and for firing pulse. MLC commands are cross-coupled, to enable commanding from nominal and redundant sides.

- Relay switch status interfaces for the status of the relays to be sent in serial digital TM. The status signals are also cross-coupled to enable telemetry acquisition from nominal and redundant sides.

Pyro firing is initiated by MLC from the DMS. The pulse length (24 ms ± 2 ms) is controlled by the PDUs. The minimum time between consecutive pyro firings is > 100 msec. The pyrotechnic firing current can be measured on nominal and redundant lines in 100µs steps throughout the duration of the firing pulse and stored for later retrieval. Up to 8 consecutive firing pulses can be stored by each redundant half before transmission of the data to the DMS.

The pyro buffers can be reset to zero by telecommand, as outlined in procedures fcp-pw0040/ pw0050. If the pyro buffers have not been reset at the end of the last pyro sequence, the new information will overwrite the oldest information in the buffer.

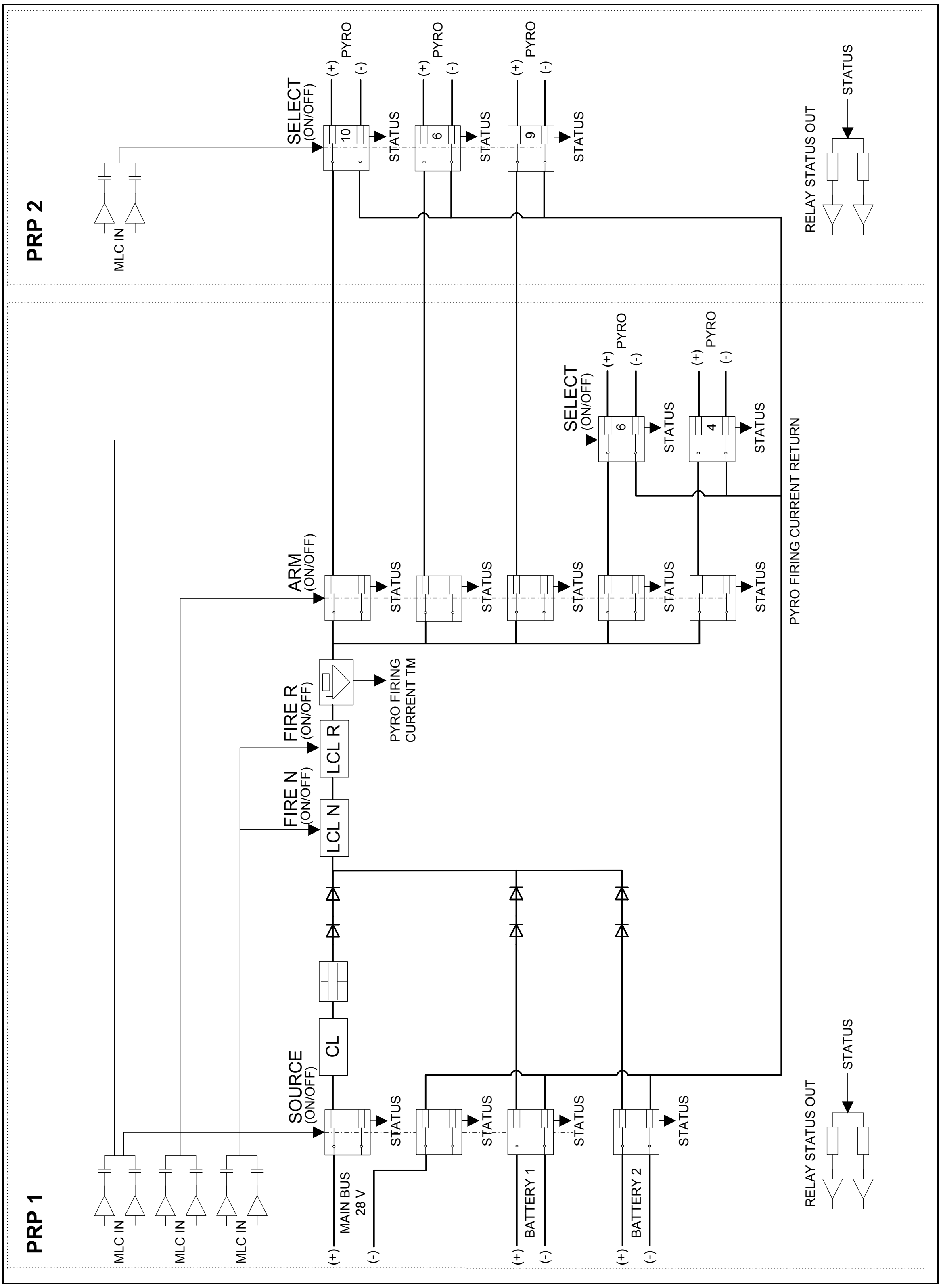


Figure 5-39: Pyrotechnic Block Diagram

5.3.2.3.2.2.5.2. Pyro power in the SS-PDU

The specific allocations of pyrotechnic outlets for the SS- PDU is shown below

SS-PDU PYRO GROUP NO.	PYRO NO.	PYRO FUNCTION	PYRO VALVE NO.
1	1	PRIMING	23
1	2	PRIMING	24
1	3	PRIMING	25
1	4	PRIMING	26
1	5	1st PRESS	2
1	6	1st PRESS	32
1	7	1st PRESS	12
1	8	1st PRESS	13
1	9	1st PRESS	18
1	10	1st PRESS	19
2	1	2nd PRESS.	3
2	2	2nd PRESS.	4
2	3	2nd PRESS.	14
2	4	2nd PRESS.	15
2	5	2nd PRESS.	20
2	6	2nd PRESS.	21
3	1	1st ISOL'N	1
3	2	1st ISOL'N	31
3	3	1st ISOL'N	11
3	4	1st ISOL'N	27
3	5	1st ISOL'N	17
3	6	1st ISOL'N	28
3	7	HGA HDRM1	n/a
3	8	HGA HDRM2	n/a
3	9	HGA HDRM3	n/a
4	1	PRESS. REG.	5
4	2	PRESS. REG.	6
4	3	PRESS. REG.	7
4	4	PRESS. REG.	8
4	5	PRESS. REG.	9
4	6	PRESS. REG.	10

SS-PDU PYRO GROUP NO.	PYRO NO.	PYRO FUNCTION	PYRO VALVE NO.
5	1	FINAL ISOL'N	16
5	2	FINAL ISOL'N	22
5	3	FINAL ISOL'N	29
5	4	FINAL ISOL'N	30
Note: All pyros are redundant.			

Table 5-5: Allocation of pyro circuit for SS-PDU

5.3.2.3.2.2.5.3. Pyro power in the PL-PDU

The specific allocations of pyrotechnic outlets for the PL- PDU is shown below

PL-PDU PYRO GROUP NO.	PYRO NO.	FUNCTION
1	1	SSP Emergency Release
2	1	Lower boom Release
2	2	Upper boom Release
2	3	Spare
3	1	Rosina DFMS Det
3	2	Rosina RTOF Det
3	3	Rosina DFMS (A)/RTOF Fail Safe (B)
3	4	Spare
3	5	Spare
3	6	Spare
3	7	Consert Ant Rel
4	1	Alice Det Door Rel
4	2	Alice Apert Uncage
4	3	Alice Fail Safe
4	4	MIDAS Cover
4	5	spare
4	6	spare
5	1	SSP Lander Rel 1
5	2	SSP Lander Rel 2
5	3	SSP Lander Rel 3
5	4	SSP Lander Rel 4
5	5	Spare
Note: All pyros are redundant. (A = Prime B = Redundant)		

Table 5-6: Allocation of Pyro circuit for PL-PDU

5.3.2.3.2.2.6. Thermal Knife Power

The SS-PDU provides a total of 24 (12 nominal and 12 redundant) thermal knife (TK) outlets. Each redundant TK power electronics has 1 arming and 12 selection relays. There are no TK outlets in the PL-PDU.

The thermal knives initiate the release of the solar array wings by cutting the hold-down Kevlar cables. Each thermal knife requires a nominal 20W at a regulated 20V ± 5% (at the knife) for a duration of 60s. There are 6 redundant knives on each array wing making a total of 24 knives. One knife per PDU unit half can be powered at any one time. The actual firing sequence is not important from the SS-PDU point of view. The supply output voltage is set nominally at 20.8V ± 3% to provide 20.0V at the knife with a 1A load to accommodate the harness voltage drops.

The power supply is provided with a switchable input current limiter, which can be switched ON/OFF in order to give the correct pulse length to the thermal knife filament. In case of over current or undervoltage of < 20 V the TK power is switched off.

The TK allocation is shown in the following table (each TK supply passes via a safe/arm skin connector) :

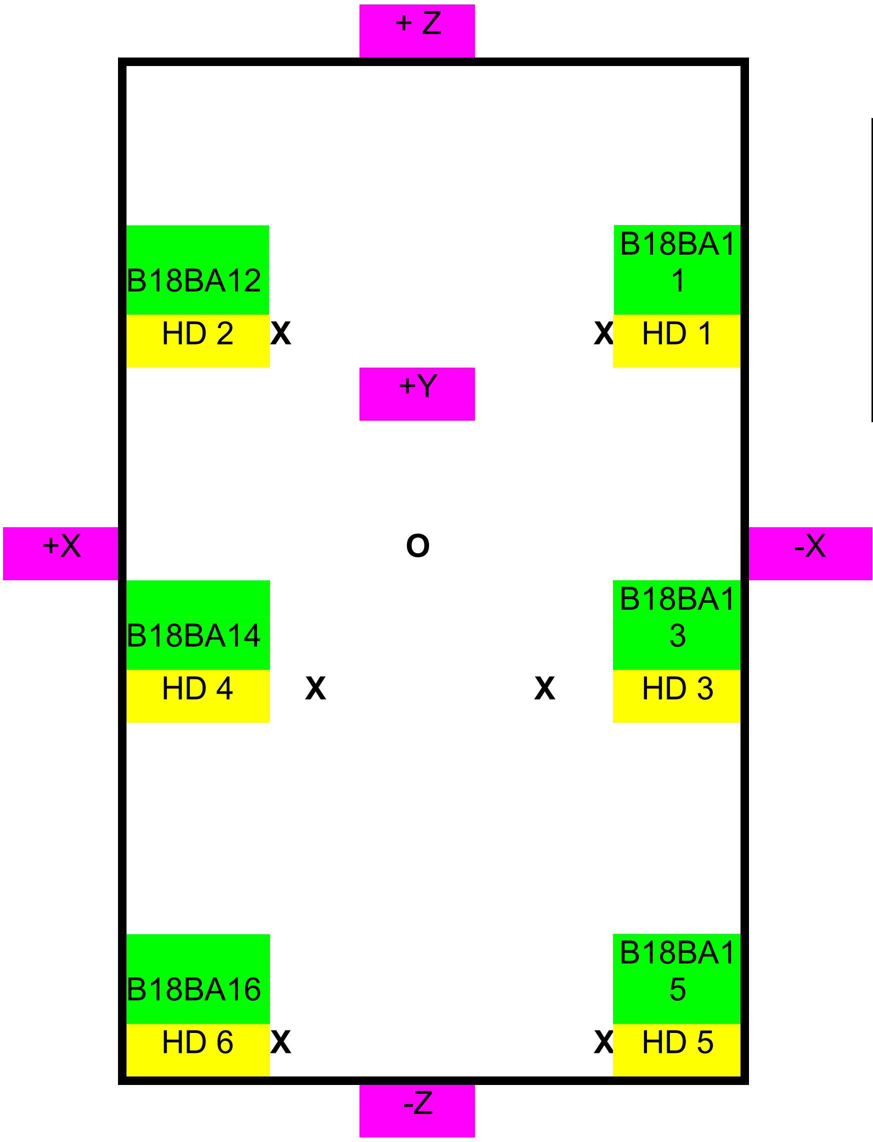
TK ID	H/DOWN	TK ID	H/DOWN
NO.	HD ID	NO.	HD ID
TK 1A RTN	-Y 1 P	TK 1B RTN	-Y 1 R
TK 1A SUPP	-Y 1 P	TK 1B SUPP	-Y 1 R
TK 2A RTN	-Y 2 P	TK 2B RTN	-Y 2 R
TK 2A SUPP	-Y 2 P	TK 2B SUPP	-Y 2 R
TK 3A RTN	-Y 3 P	TK 3B RTN	-Y 3 R
TK 3A SUPP	-Y 3 P	TK 3B SUPP	-Y 3 R
TK 4A RTN	-Y 4 P	TK 4B RTN	-Y 4 R
TK 4A SUPP	-Y 4 P	TK 4B SUPP	-Y 4 R
TK 5A RTN	-Y 5 P	TK 5B RTN	-Y 5 R
TK 5A SUPP	-Y 5 P	TK 5B SUPP	-Y 5 R
TK 6A RTN	-Y 6 P	TK 6B RTN	-Y 6 R
TK 6A SUPP	-Y 6 P	TK 6B SUPP	-Y 6 R
TK 7A RTN	+Y 1 P	TK 7B RTN	+Y 1 R
TK 7A SUPP	+Y 1 P	TK 7B SUPP	+Y 1 R
TK 8A RTN	+Y 2 P	TK 8B RTN	+Y 2 R
TK 8A SUPP	+Y 2 P	TK 8B SUPP	+Y 2 R
TK 9A RTN	+Y 3 P	TK 9B RTN	+Y 3 R
TK 9A SUPP	+Y 3 P	TK 9B SUPP	+Y 3 R
TK 10A RTN	+Y 4 P	TK 10B RTN	+Y 4 R
TK 10A SUPP	+Y 4 P	TK 10B SUPP	+Y 4 R
TK 11A RTN	+Y 5 P	TK 11B RTN	+Y 5 R

TK ID	H/DOWN	TK ID	H/DOWN
NO.	HD ID	NO.	HD ID
TK 11A SUPP	+Y 5 P	TK 11B SUPP	+Y 5 R
TK 12A RTN	+Y 6 P	TK 12B RTN	+Y 6 R
TK 12A SUPP	+Y 6 P	TK 12B SUPP	+Y 6 R

Table 5-7: Thermal Knife allocation

In the above table the nominal thermal knife relates to the nominal array hold down point. For example, outlet TK1A will release array point -Y1P, and outlet TK1B will release -Y1R.

The diagrams below show the respective positions of the hold-down points on each side of the spacecraft and should be used in conjunction with the table above to determine the correlation between hold-down points and their thermal knives:

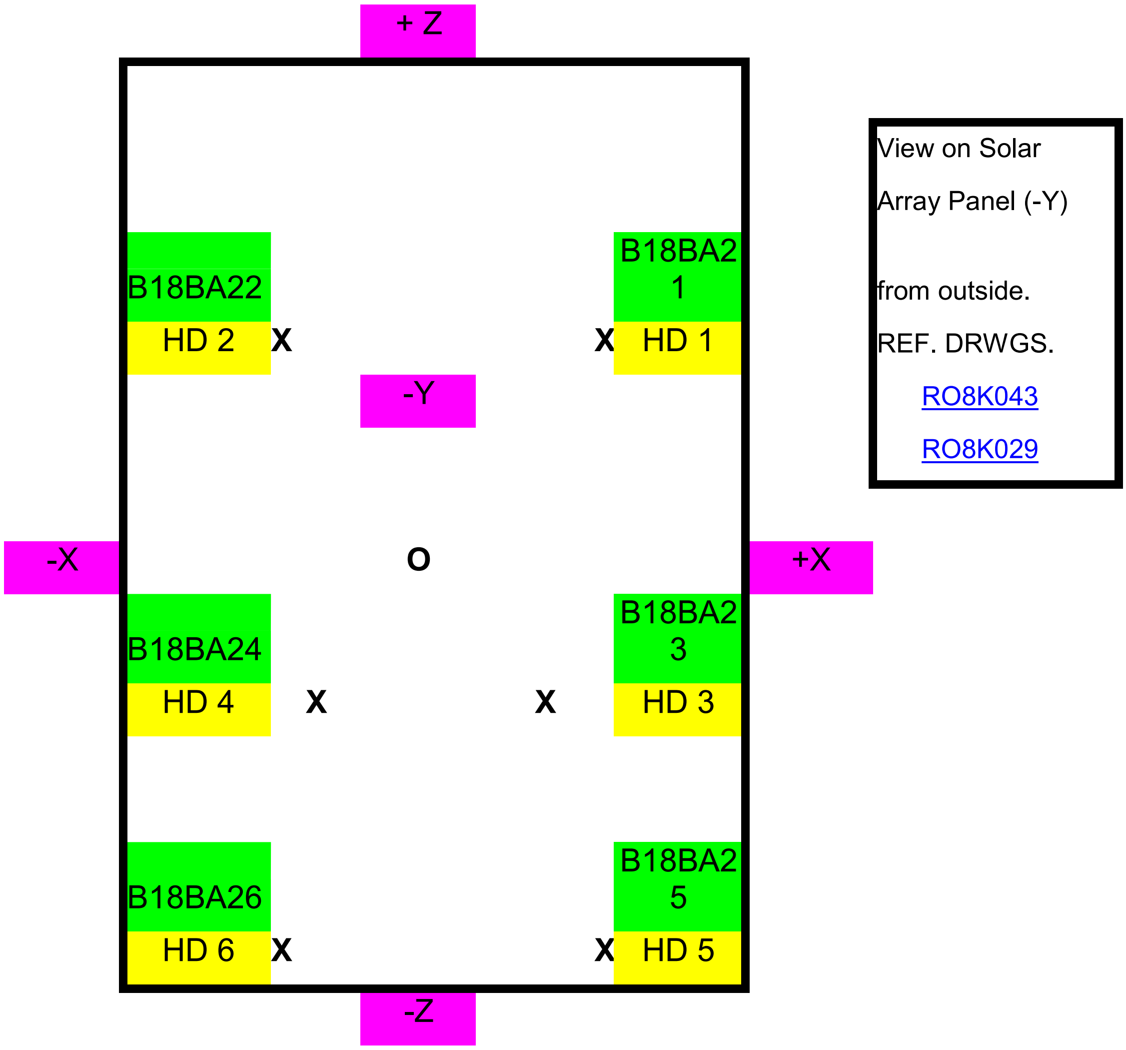


View on Solar Array Panel (+Y) from outside.

REF. DRWGS.

RO8K042

RO8K028



5.3.2.3.2.2.7. Auxiliary DC/DC Converter

The auxiliary DC/DC Converters provides power to the PDU internal electronics. The design is common to both the SS-PDU and PL-PDU.

The DC/DC Converter is a push-pull type converter providing the required PDU internal voltages of +5V, +/- 15V referenced to primary ground and +5V referenced to secondary ground.

The DC/DC converter has an undervoltage detection circuit and the converter is switched off in case of undervoltage (< 20 V). The converter will switch back on automatically when the voltage rises above 21.5V ± 0.5 V.

An input current limiter is added in front of the DC/DC Converter to provide protection to the Main Bus. The linear regulator is provided with overvoltage protection to prevent failure propagation in case of failure in the Auxiliary DC/DC. Overvoltage settings switch the converter off when the transformer primary voltage exceeds

18.7...22.0 V. This corresponds to the max output voltages: +15 V at 20.8 V, -15 V at 20.8 V, and + 5 V at 7.5 V.

Both the current limiter and overvoltage protection supply a signal to a common latch which controls the input LCL. The latch can be reset by high power command.

The auxiliary power supply of the PDU switches ON automatically at power-up.

5.3.2.3.2.2.8. Control Logic

The control logic board is designed to meet the needs of both the SS-PDU and PL-PDU. The control logic comprises Telecommand and Telemetry Interface, TM/TC Coder, Opto driver, Oscillator, Auxiliary DC Converter and Analog telemetry converter.

5.3.2.3.2.2.8.1. Oscillator

This block contains a power-up reset circuitry to initialise the control logic and the main frequency oscillator. Initialisation is needed only for communication circuitry, since all switches for current limiters are controlled autonomously. The oscillator frequency will be divided for internal communication bus and for DC converter synchronisation.

5.3.2.3.2.2.8.2. Telecommand Interface

The telecommand interface consists of:

- Delayed Memory Load command (DML) for 16 bit serial telecommands from the RTU
- Reconnection On Command interface for reconnection logic from the PCU
- High Power On/off Command interface (HPC) for priority-one on/off commands from the CDMU 1 and 2
- HPC reset command for Aux DC/DC latch current lifter / overvoltage protection.

5.3.2.3.2.2.8.3. Telemetry Interface

The telemetry interface consists of:

- Serial 16 bit Digital Telemetry interface (SDT) to the RTU
- Conditioned Analog TM interface (ANC) to the RTU

5.3.2.3.2.2.8.4. TM/TC Coder

Command decoding

The PL-PDU and SS-PDU each receive two DML channels. These channels are received and compiled in two separate but similar control units, A and B. Each compiled command controls an individual target either on A side or on B side. The target, its side, and the action is explicitly defined in the command. The communication channel does not affect the correspondence between the command and the target.

Figure 5-40 shows the phase relationship of signals and Figure 5-41 defines the bits of the 16 bit command word. The PDU does not analyse the timing of the communication signals, it relies only on the phase between the signals. An incorrect number of clock pulses occuring during the low level of the sample signal is detected and interpreted as a command failure.

Two successive commands shall be separated by at least 100 ms (see Figure 5-42). If a new edge on the sample signal occurs before the required 100 ms from previous one, the compilation is not activated and a corresponding error status bit is set. The next command must be delayed by at least 100 ms from a rejected command also, as shown in Figure 5-43.

When a command is accepted for compilation, its parity is checked and if it is as expected the corresponding bit pattern is loaded into a parallel/serial converter to be transferred to the addressed board containing the final target. Before serial conversion the validity of the command is verified. When a parity error is detected, or the command is not valid, the corresponding status bit is set and bit pattern is not sent to the addressed board.

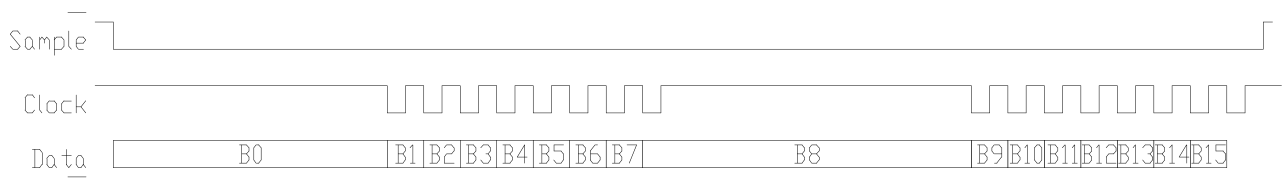


Figure 5-40: Phase relationship between signals in DML

bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TC format	Parity	A/B	Target						Command							F/N

A= Side A =0
B= Side B =1

F= OFF =0
N= ON =1

Figure 5-41: Format of Telecommand

Figure 5-42: Acceptance window of successive commands

Figure 5-43: Acceptance window after rejection caused by delay violation

LCL HS and KAL control

LCL and HS boards contain non-relay switches, as does the KAL board in the PL-PDU. These switches are controlled by RS flip-flops, that require quite a short set and reset pulse. A command from the RTU to these boards is a dedicated ON or OFF command. A compiled command is transferred to the board on either A or B side as a bit pattern with corresponding bit together with first and last bits activated. After pattern transfer an activation signal is delivered that connects received signal levels to set and reset inputs of all switches on the board. This connection is enabled only when the first received bit is active and the data signal is returned to stand-by level after 1st bit. The duration of activation signal defines the pulse width on the board.

Reconnection and priority-one commands

The SS-PDU contains specific LCLs (for SS-RTUs, two in total, and Avionics processors) which require additional reconnection and Priority-one on/off commands to increase reliability. Reconnection command is delivered via reconnection interact and it is received by an optoisolator.

Priority-one commands are received from the two CDMUs via HPC interface by opto-isolators. The resulting signal is connected to the LCL via a dedicated signal. In the LCL the two ON commands are connected to the 'set' input of the flip-flop and OFF command to the 'reset' input.

The Auxiliary DC/DC converter contains latching limiter against overcurrent and undervoltage. This latch can be reset via a HPC command from the RTU.

Pyro control

The control principle for Pyro circuits is the same as for LCL. Due to hazard safety requirements the activation of a selected Pyro requires four commands: Energy source activations, pyro selection, pyro arming and pyro firing. To optimise the safety, these commands are delivered from the control logic to the pyro board via three separate buses. One bus is used for energy selection and pyro selection, the second for arming and the third for firing.

To avoid any single failure of causing unintended pyro firing, these buses are separated in an external circuit. Also the bit patterns for each bus are of different length and the activation bits are not overlapping in these patterns. These precautions together with the enabling logic described in LCL control prevent any misdirected command to be activated.

Pulse signal durations for pyro selections and arming need to be quite long, since these switches are relays. The actual firing pulse shall be 24 ms long. This duration is controlled by the TM/TC Coder by sending an ON command for firing flip-flop as commanded and 24 ms after this a corresponding OFF command.

Thermal Knife control

The control of TK is similar to that of Pyro control. Differences are that there is no selection of the energy source and the control of pulse duration. The pulse duration of 60 seconds for TK are controlled by ON and OFF commands from the RTU.

5.3.2.3.2.2.8.5. Telemetry Generation

The Serial 16 Bit Data TM interface transfers a 16 bit data word in a serial form from a RAM in the unit to the RTU. The transfer is controlled by the RTU with data sample and transfer clock signals. The data format delivered from the PDU is NRZ-L, bit '1' corresponding to high level and bit '0' corresponding to low. The most significant bit is sent first.

The data content delivered from a RAM via the SDT interface depends on the commanded TM mode. The modes are:

- Status
- Continuous current
- Pyro profiles

The *status* mode is activated by a status updating command. This command activates also the status generation sequence. Sequence stores the command register and error status register into the beginning of the TM memory address and increments the ID count value in the last usable memory address. After this initialisation it scans the status information from all switches in boards of the whole PDU unit via an internal serial bus. After the switch status information the analog status is converted likewise from all signals in boards of the whole PDU unit.

Continuous current mode is activated by a 'Start analog Measurement' command to achieve a time-tag for the results. This command activates a sequence that first stores registers like in status mode and increments the ID count in the TM memory. After measurement activation the analog level of the selected signal is sampled, held, and converted every 5 ms for 182 times, resulting in a measurement profile over 0.9 seconds.

The signal to be converted is selected by command before the 'Start analog measurement' command is sent.

The format of the data packet after continuous analog measurement activation is shown in the table below.

Word count	Byte Addr	PL-PDU and SS-PDU	
0	00	PrevCmd*2	High byte
	01		Low byte
1	02	Error status	*3
	03		
2	04	Analog measurement	Sampled at T_H (=activation response)
	05		Sampled at T_H + 5 ms
3	06		Sampled at T_H + 10 ms
:	:		:
92	B8		Sampled at T_H + 900 ms
	B9		Sampled at T_H + 905 ms
93	BA	ID Count*3	High byte
	BB		Low byte

Table 5-8: Format for Continuous Analog Telemetry

*2 PrevCmd reflects only the latest accepted configuring command.

*3 Common ID counter with normal status mode.

Pyro profile mode is activated by a Pyro data command. This command only changes the data source to Pyro memory. Pyro current will be measured at 100 µs intervals whenever a firing command has been detected and there is a free buffer available. The first sample will be converted as a fire command is compiled and transmission to the Pyro LCL is initiated. The transmission will take 100 µs, so the next sample will be converted at the Pyro firing event. The duration of the fire pulse is 24 ms, but current sampling is continued for 3 ms to also measure the decaying current profile. Total number of converted samples for each firing is thus 270.

Each pyro current profile will be stored in successive buffers until all eight buffers are full. Subsequent current profiles will be lost. When a Pyro data reset command is received all buffers are reset and cleared to zero. This principle gives full control of data reading to the DMS. The existing data in the buffers will be read in successive order, whether there is data or the buffer is empty. After all eight buffers are read, reading will continue from the first buffer. Only the data reset command will reset the reading pointer to the beginning of the first buffer. To separate and identify the buffers, an ID will be included at the beginning of the buffer data.

Word count		HI Byte	LO Byte
0	Buffer ID	NULL	in range [0,7]
1	Measurement	sampled at T_0 - 100 µs	sampled at T_0
2	Measurement	sampled at T_0 + 100 µs	sampled at T_0 + 200 µs
3	Measurement	sampled at T_0 + 300 µs	sampled at T_0 + 400 µs
:	:	:	:
134	Measurement	sampled at T_0 + 26.5 mS	sampled at T_0 + 26.6 ms
135	Measurement	sampled at T_0 + 26.7 ms	sampled at T_0 + 26.8 ms

Table 5-9: Format for TM of Pyro Current Profile buffer

5.3.2.3.2.2.8.6. RAM Memory

The PDU needs memory function only for telemetry packet generation. Memory is divided into two pages, TM packet and Pyro buffers. The TM packet page is used both for actual TM packet and for continuous measurement data. Formation of these two packets is equal, i.e., first two words for command buffer and error status and the last word for ID Count value.

5.3.2.3.2.2.8.7. Channel Select

The Pyro and Thermal Knife are required to be hazard-free. For this purpose channel selection, arming and firing commands are delivered to target boards via separate buses. Unintended firing is prevented by generating a command bit pattern in a common generator and feeding it via a separate selector to dedicated channel. An addressing failure will not activate the command in the receiver, because they require an unique signature in the command pattern.

5.3.2.3.2.2.8.8. Opto Driver

All communication signals between control function and operative functions in primary voltage bus are isolated with optocouplers. These couplers are located near the operating function so that all signals delivered via the mother board are referred to secondary grounding. Additional buffer circuits are used for driving the optocouplers to isolate the current needs from logical operations.

5.3.2.3.2.2.8.9. Synchronisation Buffer

The control function delivered DC converter synchronisation signal to all three converters in the PDU (i.e. the TK, KAL and Auxiliary). The isolation of the synchronisation signal is done by transformers. An additional buffer is needed in the control function to drive inductive load.

5.3.2.3.2.2.8.10. Analog Data TM

All analog telemetry data samples (voltage and current) are acquired with 8 bit resolution, hence two data samples are transferred for each 16 bit telemetry word. The 8 most significant bits from a 12 bit A/D converter are used.

- The analog multiplexers are on the primary side. The multiplexers select the analog signal under interest according to commands coming from the control logic. The control logic signals can come either from the nominal or the redundant side, through digital isolation (opto-isolators)
- The analog signals on the secondary side are isolated from the primary side with digital isolation circuits.
- The TM Control Logic connects the analog signals successively from the nominal and redundant sides to the input of the A/D converter. Thus the measurement data of one side is read from both sides.
- Nominal and redundant signals are isolated with current limiting resistors.

In addition to the serial TM data there are also discrete TM data interfaces for Housekeeping thermistors to the RTU.

5.3.2.3.2.3. PDU Interfaces

Each PDU has external interfaces with the following units:

PDU	External unit	Interface function
SS & PL PDU	PCU	Main power bus Reconnection signals
SS & PL PDU	RTU	Telemetry & telecommand data
SS & PL PDU	Pyros	Pyro power outlets
SS & PL PDU	Batteries	Battery power for pyro power outlets
SS & PL PDU	Heaters	LCL outlets for heaters
SS & PL PDU	Various users	LCL outlets
SS PDU	RX & CDMU	FCL outlets
SS PDU	Solar Array	Thermal Knifes
PL PDU	Various users	KAL outlets

Further details can be found in the SS-PDU Electrical ICD (RO-FIN-IF-0002) and the PL-PDU Electrical ICD (RO-FIN-IF-0001).

5.3.2.3.2.4. PDU operational modes

5.3.2.3.2.4.1. General

There are six functional modes in the PDU:

- Power Up
- On
- Switch status mode
- Analog mode
- Continuous current measurement mode
- Pyro current profile measurement mode

The mode transition diagram for the PDU is given below.

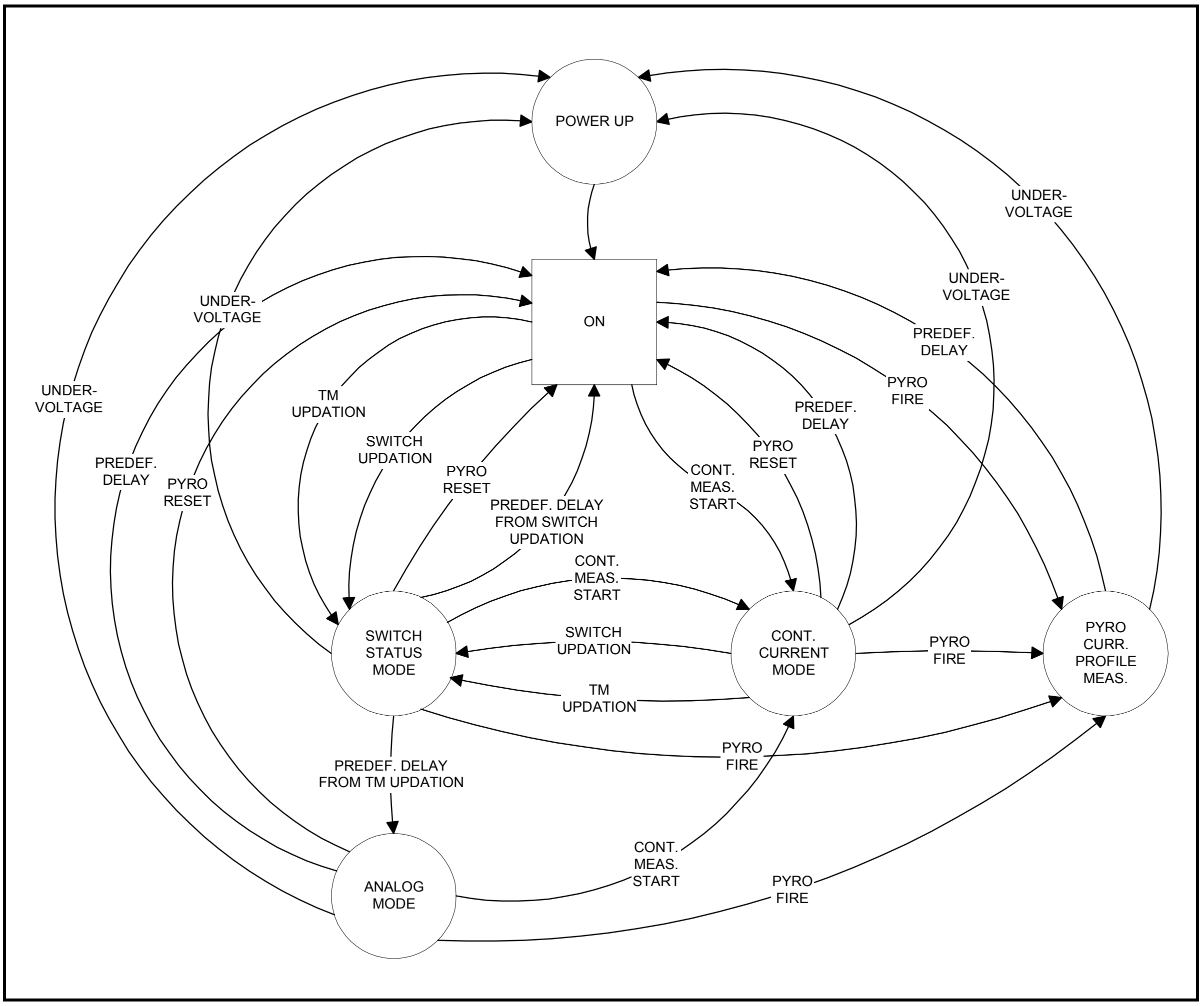


Figure 5-43a: PDU Mode Transition Diagram

5.3.2.3.2.4.2. PL-PDU Power Up

Nominal operation of the Unit after Power Up:

- The auxiliary power supply and the TM/TC interface are automatically switched ON
- All LCLS and HSs remain OFF
- KAL power remains OFF. The KAL power is switched ON by a telecommand (MLC) from the RTU
- Pyro release circuits maintain their status
- The generation of the first TM data package is started
- TM is enabled for the 1st interrogation only; to permanently enable TM send “enable” command

5.3.2.3.2.4.3. SS-PDU Power Up

At the Unit Power Up or after clearing an undervoltage condition, the SS-PDU is in the following state:

- The LCL for SS-RTU (LCL8A and B) is switched ON by the reconnection command received from PCU
- The LCL for PL-RTU (LCL9A and B) is switched ON by the reconnection command received from PCU
- All other LCLs and HSs remain OFF
- All FCLS are switched ON automatically
- KAL power is switched ON (but KAL function not used in SS-PDU
- Pyro release circuits maintain their status
- TK power circuits maintain their status
- The auxiliary converters are automatically switched ON
- The supply voltage for the TM/TC interface is automatically switched ON
- The generation of the first TM data package is started.
- TM is enabled for the 1st interrogation only; to permanently enable TM send “enable” command

In certain conditions of bus power up, the PDU may not initialise until after the PCU reconnect signal has been issued. To deal with this, the reconnect is also initiated by the DMS.

5.3.2.3.2.4.4. 2.3.2.4.4 ON mode

After Power Up mode, the PDU automatically enters ON mode. In this mode, the PDU is ready to receive telecommands and send telemetry information as requested. The PDU always returns to this mode after a pre-defined delay. The only exceptions are after PDU power up and undervoltage condition, where the PDU goes automatically to Power Up mode.

5.3.2.3.2.4.5. 2.3.2.4.5 Switch Mode status

The mode can be entered from various modes as follows:

From Mode	Command
ON	Update Switch
ON	Update TM
Continuous Current Measurement	Update Switch
Continuous Current Measurement	Update TM

If Switch Mode was entered via the Update Switch command, and updating of status information from each switch is performed. Analog information is cleared to contain only zeros. Status data is placed in the telemetry packet.

If Switch Mode was entered via the Update TM command, the PDU first executes Switch Status Mode and the automatically enter Analog Mode.

The updated telemetry packet is read out on the same side of the SDT interface as the command was received.

After performing the tasks of this mode, the PDU returns to ON mode. However the mode can be exited under the following conditions:

Command/condition	Target Mode
Predefined time delay	ON
Undervoltage condition	Power Up
ResetTMPyro command	ON
Start Profile command	Continuous Current Measurement
Pfire command	Pyro Current Measurement

5.3.2.3.2.4.6. Analog Mode

The PDU enters Analog mode from the Switch Status mode automatically upon receiving the UpdateTM command.

The updating of analog TM is started automatically after the status information is updated. Values of output currents and some voltages are sampled. The TM Power ON command should be given at least one minute before the UpdateTM command in order to get correct analog data. However as a back-up the UpdateTM command automatically switches TM power ON and OFF. However the delay for the first analog conversion is too short (about 110 ms) for the circuits to have

reached their correct operating conditions. The TM power ON and automatic TMpower outputs are combined in an OR-function.

The updated telemetry packet is read out on the same side of the SDT interface as the command was received.

Normally, after performing the tasks of this mode, the PDU returns to ON mode. However, the mode can be exited under the following conditions:

Command/condition	Target Mode
Predefined time delay	ON
Undervoltage condition	Power Up
ResetTMPyro command	ON
Start Profile command	Continuous Current Measurement
PFire command	Pyro Current Measurement

5.3.2.3.2.4.7. Continuous Current Mode

The mode can be entered from the ON or Switch Status Modes by sending the Start Profile command.

The LCL for profile measurement should be selected prior to the start Profile command. The selected LCL will remain until either another LCL is selected or the Update command is received.

On receipt of the Start Profile command a current profile measurement is performed for the selected LCL. The current is measured in 5.007 ms intervals over a period of 911.24 ms.

The TM Power ON command should be given at least one minute before the Start Profile command in order to get correct analog data. However as a back-up the Start Profile command automatically switches TM power ON and OFF. However the delay for the first analog conversion is too short (about 110 ms) for the circuits to have reached their correct operating conditions. The TM power ON and automatic TM power outputs are combined in an OR-function.

Current profile data is stored into the telemetry packet instead of status information. The profile measurement packet is read out on the same side of the SDT interface as the command was received.

Normally, after performing the tasks of this mode, the PDU returns to ON mode. However, the mode can be exited under the following conditions:

Command/condition	Target Mode
Predefined time delay	ON
Undervoltage condition	Power Up
ResetTMPyro command	ON
Update Switch command	Switch Status
Update TM command	Switch Status
PFire command	Pyro Current Measurement

5.3.2.3.2.4.8. Pyro Current Profile Measurement

The mode can be entered from ON, Continuous Current Measurement or Switch Status Modes by sending the PFire command.

The required pyro output selection, arming activation and power selection should be done prior to sending the PFire command. The PFire command executes a pyro current profile measurement and activates a 24 ms Pyro fire pulse.

The pyro current profile is measured in 100.14 µs intervals over a 26.836 ms period, starting 100.14 µs before the pyro is fired. The profile is stored into Pyro memory which has a capacity for 8 pyro current profile measurements. When the memory already contains eight profiles, any following current profiles will not be memorised. The data remains in memory until it is cleared by the dedicated ResetTMpyro command.

The TM Power ON command should be sent at least one minute before the PFire command in order to get correct analog data. However as a back-up the PFire command automatically switches TM power ON and OFF. However the delay for the first analog conversion is too short (about 110 ms) for the circuits to have reached their correct operating conditions. The TM power ON and automatic TM power outputs are combined in an OR-function.

The contents of the Pyro memory is selected to SDT output by the PyroTM command. The profile measurement packet is read out on the same side of the SDT interface as the command was received.

Normally, after performing the tasks of this mode, the PDU returns to ON mode. However, the mode can be exited under the following conditions:

Command/condition	Target Mode
Predefined time delay	ON
Undervoltage condition	Power Up

5.3.2.3.2.5. PDU Telemetry and telecommand

The following types of telemetry and telecommand are available in the PDUs.

Function	Type	comment
LCL		
ON/OFF Control	MLC	
Reconnection Logic	LPC	SS-PDU only
Priority One ON/OFF	HPC	SS-PDU only
ON/OFF Status TM	SDT	
Current TM	SDT	
Continuous current TM	SDT	

Function	Type	comment
Heater switch		
ON/OFF Control	MLC	
ON/OFF status	SDT	
Foldback Current Limiter		
Current TM	SDT	SS-PDU only
Keep Alive Line		
ON/OFF control	MLC	PL-PDU only
Voltage TM	SDT	
Primary Current TM	SDT	
Auxiliary DC/DC		
Primary current	SDT	
Voltage TM	SDT	
Convert latch reset	HPC	
Pyro Power		
Independent Pyro firing, arming and selection TC	MLC	
Pyro energy selection	MLC	
Reset of Pyro TM buffer	MLC	
Pyro switch monitoring TM	SDT	
Pyro firing current TM	SDT	
Thermal Knife Power		
Independent TK firing, arming and selection TC	MLC	SS-PDU only
TK switch monitoring TM	SDT	SS-PDU only
TK current and voltage TM	SDT	SS-PDU only
Other		
TM Mode selection TC	MLC	
TM Mode status	SDT	
TC Status register	SDT	
Error Status register	SDT	
2 thermistors	ANC	

Table 5-10: Types of PDU TM & TC

Each switch is provided with its own status signal.

The last command is mirrored in a command buffer and is part of the PDU telemetry format.

5.3.2.3.3. Batteries

5.3.2.3.3.1. General description

Rosetta has three Lithium-Ion battery modules which provide power in the early stages of the LEOP before the solar array has been deployed. These batteries also provide power to cope with transient loads, emergency bus support and MPPT/APR mode changes.

The system is tolerant to the loss of one of the three batteries. Each battery is able to support half the total spacecraft power requirement during the LEOP phase without exceeding 90% DOD.

The Li-ion battery does not require reconditioning during the mission or monitoring at cell level. The battery health is managed at battery level only.

5.3.2.3.3.2. Battery Configuration

Each battery comprises 11 strings of 6 Lithium-Ion (Li-ion) cells. Each cell has a nominal capacity of 1.5 Ah and a voltage range between 2.5 and 4.2 volts depending on the operating condition. The 6 cells are wired in series to provide the necessary battery operating voltage range of 16.5 to 25.2 Volts. The 11 strings are connected in parallel to give a nominal nameplate capacity of 16.5 Ah. The calculated watt-hours available from each battery over the required operational voltage range (25.2V to 16.5V) is in excess of 356 Wh.

The cells are cylindrical, ‘C’ style cells manufactured by SONY. The cells are mounted on non-conductive GRP plates which allow the cells to be thermally and electrically isolated from the aluminium battery structure. In addition the thermal gradient between the cells is minimised by the use of a thin aluminium strip bonded onto one of the GRP plates.

The Li-ion cell may be continuously charged and discharged at rates up to 1 C (1.5 Amps per battery string). Fault clearing or activation of pyro devices is possible at rates in excess of 10 C(15 amps) for durations of less than one second. The expected peak current is approximately 11 amps for worst case LEOP operation.

The PCU provides each battery with two commandable levels of charge rate from its BCR of 0.95A and 3.0A, (0.95 A corresponds to charge current level 1, 3.0A corresponds to charge current level 0) with the End of Charge level being set by 8 selectable voltages between 21V and 25.2V. The upper charge level of 3.0A is the default case and will be auto-selected at switch-on and after recovery from a Bus undervoltage.

It will be noted that the upper EOC voltage is above the nominal maximum for a fully charged battery. This is deliberate and has been incorporated to enable a boost charge to be given to a battery should it be found to be of lower than expected capacity later in the mission

A boost charge to the higher than normal setting could regain some of the lost capacity.
The discharge capability of the module depends on the state of charge, age and

temperature of the cells. These parameters affect the open circuit terminal voltage and the internal resistance and therefore the maximum deliverable energy.

Significantly more heat is generated during the discharge cycle than the charge cycle, indeed for low charge rates of about C/10 the cells become endothermic. Thus during discharge phase the cell temperatures increase significantly and then during rest/recharge the cell temperatures gradually fall back to the ambient temperature.

Below 10°C the internal resistance of the battery cell increases significantly. This means that the cell efficiency reduces as the temperature falls, limiting battery performance. However the increased internal resistance results in more thermal dissipation than at higher temperatures. As the battery cells are thermally isolated from the environment then as the cells dissipate heat, they increase in temperature, which reduces their internal resistance and increases their efficiency once more.

Each battery has a relay fitted which allows it to be connected across a resistive load, enabling the state of charge to be adjusted to 50% for the Hibernation phase, this being the recommended optimum for minimum self discharge whilst retaining sufficient energy for emergency operations. The load will also allow capacity checks to be carried out during the mission should it be found necessary. A discharge current of 100mA is anticipated for this purpose. The discharge rate is lower than the trickle charge value to avoid battery discharge in the event of a discharge load failing ON.

The State of Charge (SOC) of the battery is readily deduced from the terminal voltage without any temperature effects, as can be seen from the following diagram.

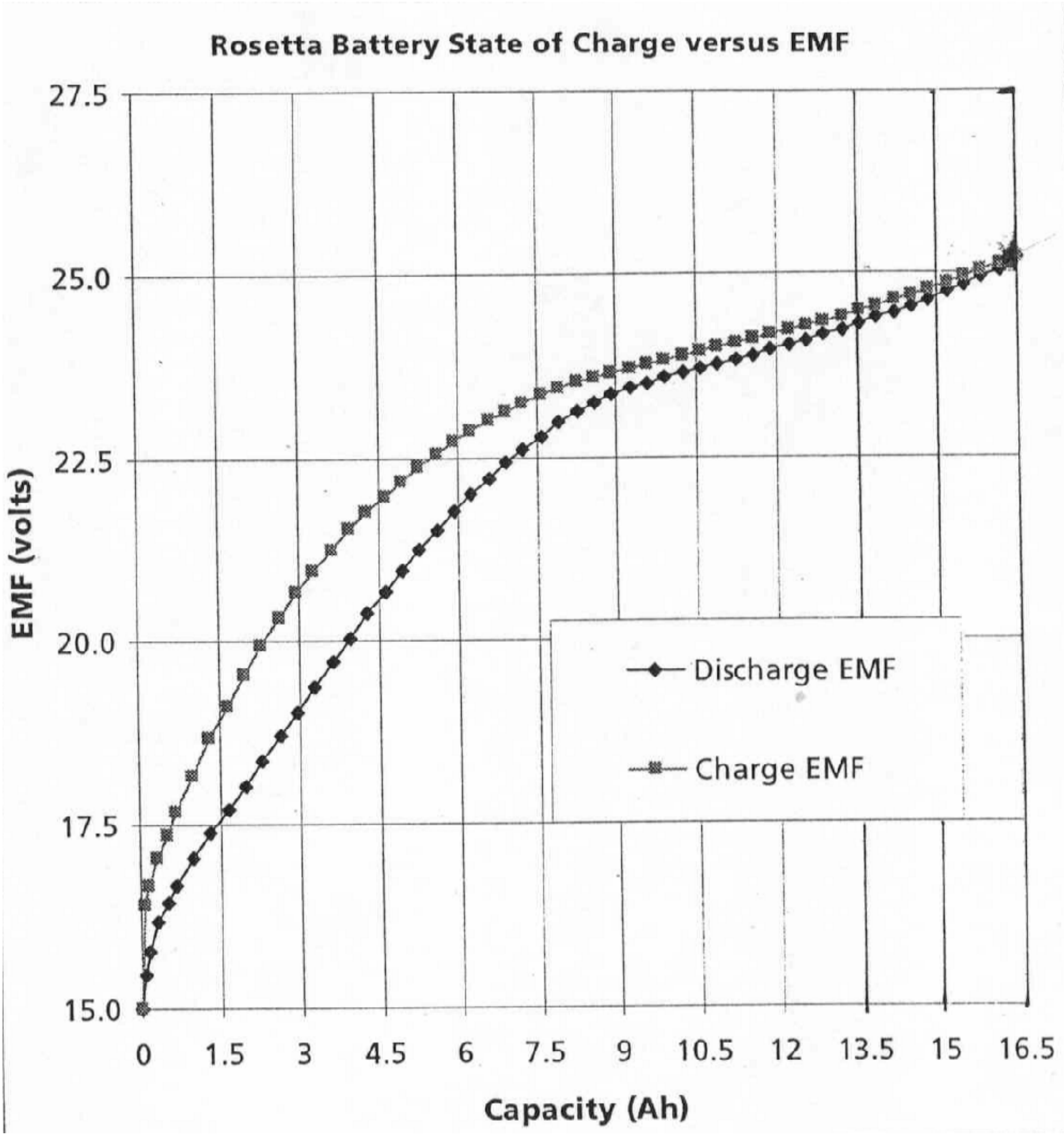


Figure 5-43b: Battery State of Charge

Failure mode

The main failure mode of the Li-ion cell is open circuit. Such a failure can be induced through over-charge beyond 4.5 V, at which point the cell disconnect mechanism operates. Open failure of a cell results in the open-circuit failure of a string which reduces the battery capacity by 1/11 (9.1%). Failure propagation as a result of one cell failing open circuit is not possible. In the unlikely event of a short circuit failure occurring, the additional overcharge of the remaining cells within a string would result in the operation of the open circuit disconnect mechanism.

5.3.2.3.3.3. Battery Interfaces

Each battery is connected to a dedicated BDR and BCR module in the PCU. There are no battery connect/disconnect relays in the PCU or separate interfaces for battery EGSE (battery charge/discharge/monitoring units).

Battery power to the PCU is routed via externally accessible battery safety skin connectors which are part of the Harness Subsystem.

All battery power lines are routed via Safe/Arm connectors, accessible from the outside of the spacecraft. In this way, monitoring and charging may be carried out using purpose built EGSE, and the safing and arming of the batteries may be performed as required without direct access.

5.3.2.3.3.4. Battery Operational Modes

The battery is managed automatically by the PCU according to the PCU operational phase (APR, BCR, BDR).

In addition, for state of charge management, it is possible to discharge the battery by using the battery discharge relays.

5.3.2.3.3.5. Battery Maintenance

There are no maintenance activities other than charging as required, and setting SOC before hibernation (85%) which is when the discharge loads will be used. Details to the setting of SOC can be found in the ESOC FOP (procedures pw-fcp-020, pw-fcp-021 and pw-fcp-022).

5.3.2.3.3.6. Battery Telecommand & telemetry

The following TM/TC allocation is made for the Batteries :

FUNCTION	Source	Type
BATTERY 1 DISCHARGE ON	SS-RTU	HPC
BATTERY 1 DISCHARGE OFF	SS-RTU	HPC
BATTERY 2 DISCHARGE ON	SS-RTU	HPC
BATTERY 2 DISCHARGE OFF	SS-RTU	HPC
BATTERY 3 DISCHARGE ON	SS-RTU	HPC
BATTERY 3 DISCHARGE OFF	SS-RTU	HPC
BATTERY 1 DISCHARGE STATUS	SS-RTU	RSS
BATTERY 2 DISCHARGE STATUS	SS-RTU	RSS
BATTERY 3 DISCHARGE STATUS	SS-RTU	RSS

- Battery 1 discharge ON and OFF can be commanded via RTU I/O A and B
- Battery 2 discharge ON and OFF can be commanded via RTU I/O B only
- Battery 3 discharge ON and OFF can be commanded via RTU I/O A only
- Telemetry of Battery 1 and 3 can be received via RTU I/O A only
- Telemetry of Battery 2 can be received via RTU I/O B only.

5.3.2.3.4. Solar Array & Solar Array Drive

5.3.2.3.4.1. General Description

The Solar Array is based around the Fokker ARA which has been used extensively on telecommunication satellites and has an established mechanical heritage. Each wing comprises 5 panels, and a “yoke”, hinged together and to the interface bracket which mounts the array to a drive mechanism.

Each panel is a composite made of locally stiffened carbon fibre skins and aluminium honeycomb core. Carbon fibre edge members provide stiffness at edges where hinges are attached. Titanium alloy cylindrical fittings are assembled into the panels at the hold down positions to resist the clamping forces of the hold down cables during launch, and to ensure the required gap between the stowed panels so that they do not self-degrade during the launch vibration environment. The hold down brackets contain the thermal knife assemblies and attach the stowed array onto the spacecraft body by means of spacer brackets to ensure the correct offset of the array from the spacecraft.

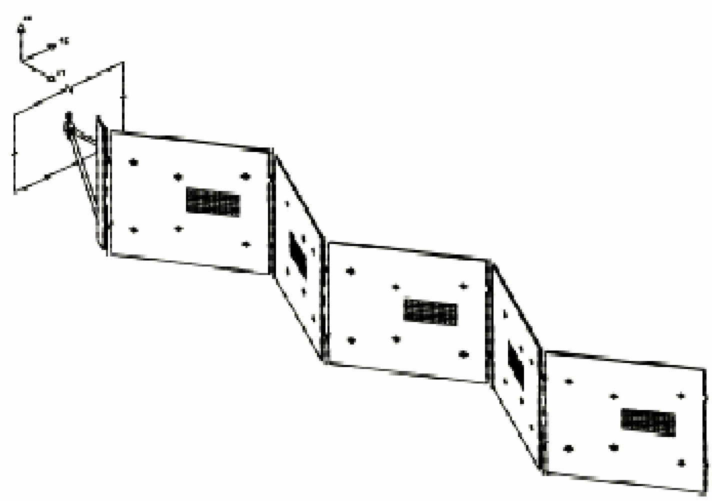


Figure 5-44: Solar array configuration

For launch, the five panels are folded concertina-style such that the outer panel has the solar cells facing outwards and held to the wall via six Kevlar cable hold-down elements.

When release and deployment is required, redundant thermal “knives” are activated which thermally degrade a pre-tensioned Kevlar cable in each hold down. Upon fracture of all 6 hold-down cables, a system of springs, damper mechanism, pre-tensioned cables and pulleys cause the yoke and panels to unfold in a controlled manner until fully extended. At this time, latches engage at each hinge line to prevent the wing folding up during spacecraft manoeuvres. Redundant micro-switches are mounted on the main yoke hinge to signal full deployment and latching of the array.

The array power is fed via two distinct harnesses, one along the top of the array, the other along the bottom, to a conventional harness on the yoke, and to connectors at the drive mechanism interface bracket. Each harness is ESD protected via a low coverage net screen braid. The harness runs along the rear face of the array.

The yoke of the array is connected to the SADM (Solar Array Drive Mechanism) which allows the power from the rotating array to enter the spacecraft via a twist capsule arrangement. The yoke is made of carbon fibre filament wound tubes. These are attached to the main hinge which mounts the entire array to the drive mechanism on the spacecraft. This hinge also supports the eddy-current deployment damper assembly and the connectors used to transfer power from the array to the spacecraft. Snubber brackets ensure that the yoke is partly restrained by the spacecraft body in order to relieve the loading on the hinges on the first panel. The hinges are of aluminium alloy with a stainless steel shaft and low-friction material between the moving surfaces.

The front face of each array panel comprises 2275 Si solar cells arranged as 25 strings of 91 series connected cells. Each cell is 200µ thick with an area of 24 cm^2 and a CMG cover glass of 100µ thickness. Each string is protected by a blocking diode and all strings are combined ultimately to form one overall power source for each wing (i.e. it is not partitioned into sections). This source is connected to all three APRs dedicated to that wing.

The solar cells have been specially developed for deep space use and maximise efficiency under poorly illuminated conditions. Particular features are extremely fine grid fingers (minimising optical obstruction) and extensive use of passivation, surface and edge, to minimise leakage effects. The resulting cell yields fill factors around 90% and efficiency around 26% in the deep space condition.

The solar array also provides two test strings per wing, one for Isc (short circuit current) and the other Voc (open circuit voltage). These are processed by the PCU and are available in telemetry.

Finally, each Solar Array wing supports a sun sensor package, mounted on the inboard edge of the 3rd panel, which is fed via the twist capsule to the avionics. The sun sensor information is not used by the platform.

Three thermistors provide monitor points for the temperature of critical zones of the panels.

5.3.2.3.4.2. Solar Array functional requirements

5.3.2.3.4.2.1. Power generation

The five main requirements for power generation are:

- Prior to array deployment, it shall the possible to transfer up to a maximum of 580 W from the outer panel of each wing at a minimum bus voltage of 34 V.
- After array deployment, from BOL until EOL it shall be possible to transfer power from an array wing up to a maximum of 1000 W at a minimum bus voltage of 34 V.
- At EOL condition (Low Intensity, Low Temperature: 5.25 AU corresponding to 0.0363 Sun and –130° C, after a lifetime of 7.7 years) the solar array must provide at least 393 W at a voltage load between 34 and 78 V.
- The maximum open circuit voltage during the mission must be lower than 78 V.
- ESD goal < 10 V considering a plasma current density of 5 nA/cm^2.

The electrical design has been performed in order to take into account all the electrical requirements, but a larger attention has been devoted to satisfy the requirement of the LILT phase, that represents the core of the mission, driving the choice of the type of the solar cells (10LiTHI-ETA©3ID Low Intensity Low Temperature type).

The other main driving factor in the electrical design is the Close to Sun (CTS) case. However the aim of reaching the requirement of available power at a voltage higher than 34 V is not compatible with the other requirement to limit the value of Voc to below 78 V for the whole of the mission. It has been necessary to compromise between the LILT and CTS requirements.

The electrical layout of each ROSETTA solar panel is composed of 25 strings connected in parallel. Each string composed of 91 solar cells connected in series.

The solar cell lay-out of a wing is described below:

	String Type		
Panel	Electrical	Monitoring	"Mechanical"
Y0	25 of 91 cells	1 of 8 cells(for Isc)	1 of 48 cells
Y1	25 of 91 cells	1 of 5 cells (for Voc)	1 of 48 cells
Y2	25 of 9 1 cells	none	1 of 48 cells + 1 string of 8 solar cells
Y3	25 of 91 cells	none	1 of 48 cells + 1 string of 8 solar cells
Y4	25 of 91 cells	none	1 of 48 cells + 1 string of 8 solar cells

Table 5-11: Array string layout

In order to satisfy a FOKKER ESD requirement at panel level and an homogeneous thermo-optical performance of the solar panel, the largest remaining room of the solar panel has been covered by mechanical strings composed of 48 identical solar cells not electrically connected by wiring but connected to the ESD network.

The electrical part of the ROSETTA solar panel consists of the following elements:

- covered interconnected solar cells, ground bars and ESD network on the front side of the panel
- One blocking diode per string
- three thermistors per wing
- 2 bleeder resistors per panel. Each one connected to 1 grounding point, all the electrical interconnections up to the panel termination bars and connectors
- transfer harness from the connectors of the panels up to the SADM connector
- ESD braid covering the transfer harness
- monitoring strings for Voc and Isc integrated respectively on the panels Y0 and Y1

The figure below shows the location of the monitor strings and thermistors on the solar array panels.

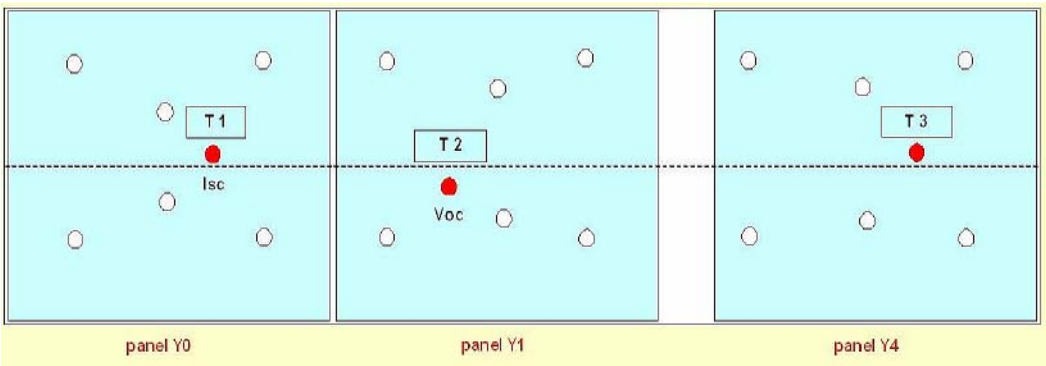


Figure 5-44a: SA monitor string and thermistor location

5.3.2.3.4.2.2. Electro-static Discharge Protection

During the mission the array will be surrounded by plasma which charges the wing surfaces. In order to protect the array from ESD phenomenon a discharge network has been provided.

The front side current generated by the plasma will flow through the ITO layer of the cover glass, the ground bars via the bleeding resistors to the satellite ground reference point. The ITO CMG cover glasses are bridged with circular conductive tapes; each tape being attached to four corners of different cover glasses. As sketched in the drawing below two ground bars are placed at the edges of the front side panel. Each ground bar is connected with two reference point via the panel substrate, placed on the rear side.

The rear side current flows though the panel conductive surface and the reference points via the bleeding resistors to the satellite ground reference point.

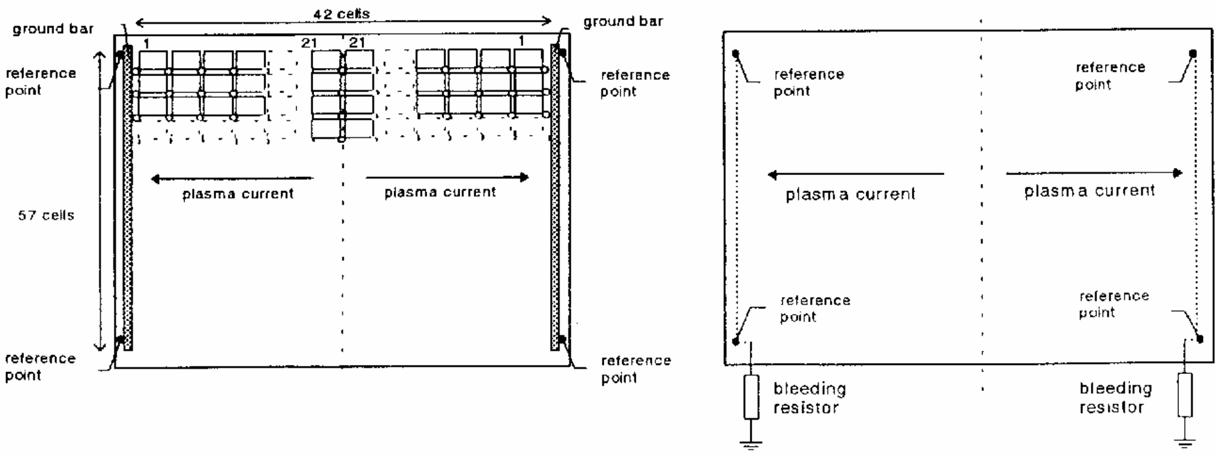


Figure 5-45: ESD control features

5.3.2.3.4.2.3. SADM Overview

See §5.4.5.1 for a description of the SA Drive Mechanism.

The Solar Array Drive Mechanism is based on a stepper motor driven pinion that drives the solar arrays through a crown wheel/shaft assembly. The shaft is supported by a pair of preloaded ball bearings. The power and signal harness is located centrally in the shaft and connected to a ±180° twist capsule. An optical encoder, located near the bearings, is used for position sensing.

5.3.2.3.4.2.4. SADE Design Overview

The detailed design for the Rosetta Solar Array Drive Electronics (SADE) is provided in RO-AEO-AN-8920, a brief overview is also given below:

The SADE provides the interface between the motors within the SADMs and the spacecraft. The SADE primary functions are to:

- Supply power to the motors from the spacecraft power bus.
- Translate telemetry signals from the motor shaft encoders and send them to the AIU (Avionics Interface Unit) via the MACS bus.
- Translate telecommand signals to the SADM motors sent by the AIU.

The SADE is completely redundant, the redundant part being a duplicate of the nominal one. The nominal and redundant SADE parts are housed within the same box and are used in cold redundancy.

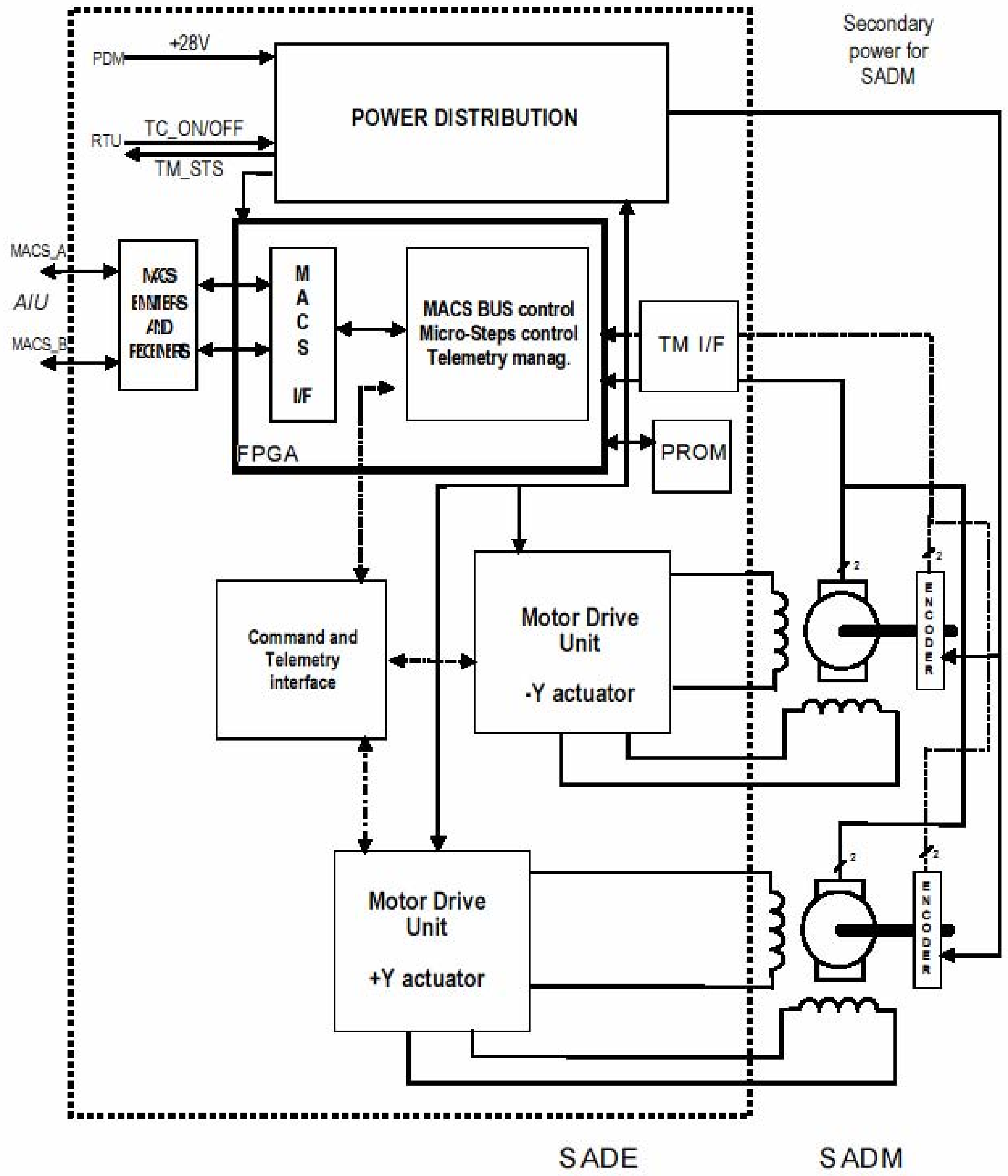


Figure 5-46: SADE Block Diagram (nominal only shown)

Functionally the SADE consists of the following modules (only the nominal part is described) which are illustrated above in Figure 5-46.

Power Distribution Module

This module provides primary power to the SADE itself and secondary power to the Shaft Encoders in the SADM. It receives the main power ON/OFF commands from the RTU and provides telemetry status back to the RTU. The PDM also provides current consumption, secondary voltage and status telemetry to the AIU via the digital control board and MACS bus.

FPGA Module

The FPGA module manages the two functions of interface with the AIU and control of the two SADM. Its basic functions are as follows:

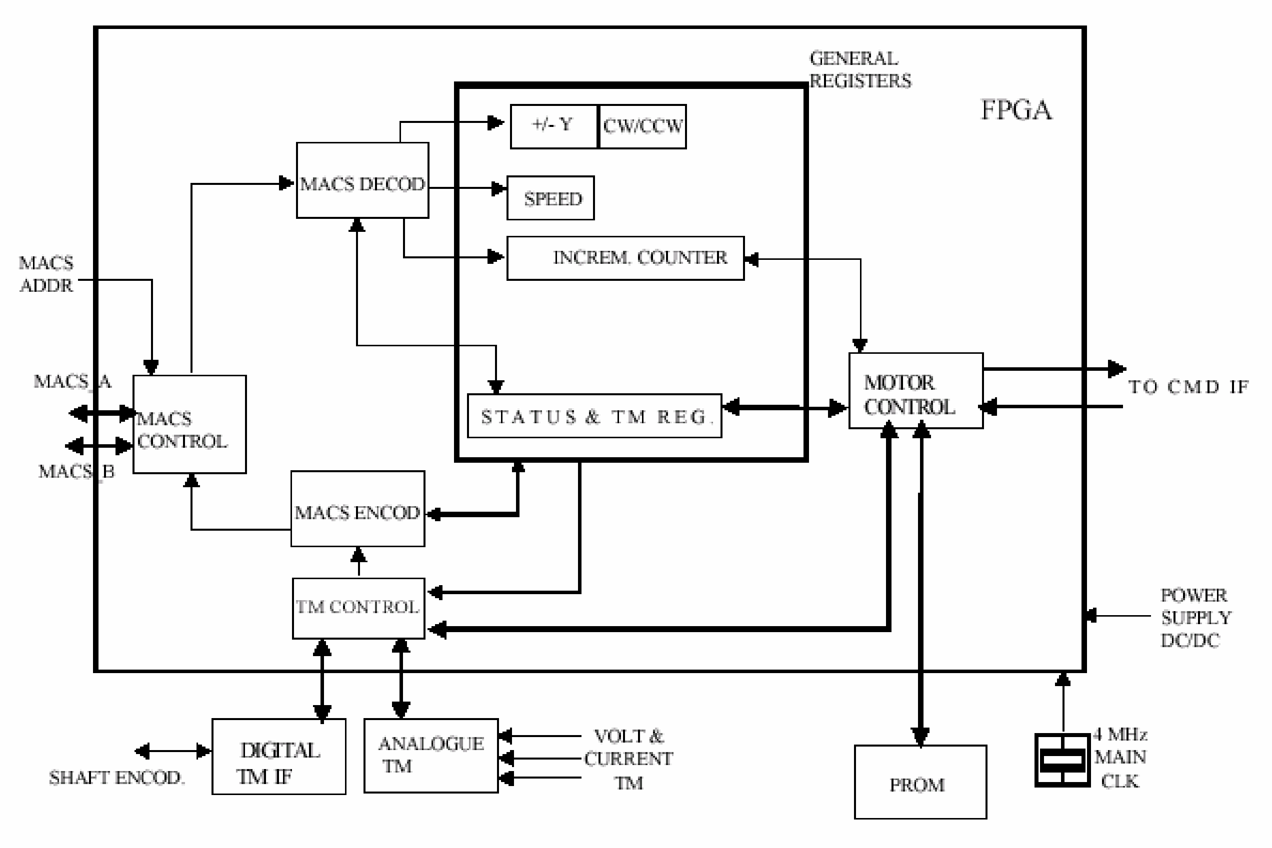


Figure 5-47: FPGA Block Diagram

- MACS bus interface management, This task is performed in the MACS Control. The FPGA detects the active MACS bus (A or B), receives data and telecommands from the AIU via the MACS receivers (A or B), and decides if they are correct. The interface also sends telemetries to the AIU module according to the MACS protocol, via the corresponding MACS emitter (A or B). The AIU is the master unit and the SADE is the slave so that only the AIU can start and control communication on the MACS bus.

- MACS data decoding, performed in the MACS Decoder. This block decodes the information included in the MACS words. With the information stored in the General Register Module it decides if the received word is correct for the MACS TC protocol for SADE. This functionality is implemented by means of a state-machine. If there is no problem, the decoder stores the received information in the General Registers Module.

- MACS data encoding, performed in the MACS Encoder. This module encodes the requested data to be sent in the MACS TC standard.

- Telemetry management. The TM Control takes the information requested in telecommands to be sent in an external telemetry through the MACS Control, and also sends information to the Motor Control as an internal telemetry. In order to do that, the TM Control module must read appropriate telemetry. Digital telemetry comes from the SADMs via a telemetry interface. The module also controls an ADC and a multiplexer that generate telemetries from analogue sources (DC/DC converter voltage and primary current).

- General Registers. This module stores general information for the correct operation of the interface between the MACS commands and the motor control. This information includes the MACS data for actuator movement, internal status for the MACS protocol and internal SADE status for TM control.

- Motor Control Module. The main purpose of this block is to generate appropriate signals to control the motor drivers (-Y motor and +Y motor), according to orders received on the MACS bus. In a continuous movement, the current in the motor winding responds to a sinusoidal waveform that it is approximated by a 64 micro-steps per Step (see Motor Module). The command module provides a sinusoidal voltage reference to the Drive Unit Module and signals to control the motor movement. To do this the module accesses a PROM which stores the eight-bit value for the sinus and cosine voltage reference; generates different signals for motor movement according to the General Register; sends status and telemetry back to the General Register and Telemetry Control.

Motor Drive Unit Module

The motor drive unit module takes the digital signals created by the Motor Control module in the FPGA, converts them into an analog motor current and supplies them to the motor coils for micro step movement.

There is one power regulator for each array wing. Each regulator is supplied with power by the DC/DC converter. There are prime and redundant windings (coils) but they both interface with the same motor.

SADE MACS bus interface

The MACS bus instructions to the SADE follow the standard RC (Receive Command), RD (Receive Data) and TI (Transmit Immediate) instructions protocol.

The instruction available for SADE control are as defined in Tables 5-12 … 5-13.

MACS commands to the SADE must follow the rules below:

- Correct command series are composed of RC and RD type commands. Command and series transitions are denoted below by the symbol =>. Correct series are any of the following:

  RD_0 => RD_1 => RC_0

  RD_0 => RD_1 => RC_0 => RC_1

- In each command and series transition it is possible to have one or more TI commands, which are not considered as a sequence by themselves

- No data acquisition (TI) command is permitted between the instruction word and data word of an RD command

- Command RC_0 (execute) can only go after the sequence => RD_0 => RD_1. Should it appear anywhere else it will be discarded.

- The RC_1 (STOP) command has two functions

  After a correct => RD_0 => RD_1 => RC_0 sequence, RC_1 will stop a command of movement and set the "Execution Stop" status bit.

  After a non-movement command, RC_1 will reset the on-going sequence, prepare for a new command sequence and set the "Sequence Stop" status bit.

- Command RC_4 (Update FPGA telemetries) must be sent to the SADE prior to issuing a TI data request instruction for external FPGA telemetry. The RC_4 command must be sent prior to each data request. The TI commands needing this RC_4 command are identified in Table 5-14.

INSTRUCTION WORD			DATA WORD	
TYPE	Subaddress (Bit 13 to 17)	CODE (Bit 18 to 20)	DATA (bit 5 to 20)	DEFINITION
RD_0	”10000”	”010”	Bit 16 to 20 ”YDV1V2V3”	Bit 16 (Y):actuator ”0” – >+Y “1” -> -Y
				Bit 17 (D): Direction ”0” – > CW ”1” – > CCW
			’000’ slowest speed ’111’ fastest speed	Bit 18-20 Speed (V1V2V3): Bit 18(V1): MSB Bit 20(V3): LSB
RD_1	”10001”	”010”	Bit *5* to 20 16 bits # of micro-step	Bit 5 is MSB Bit 20 is LSB

Table 5-12: RD DATA DISTRIBUTION COMMANDS

INSTRUCTION WORD				
TYPE	Subaddress (Bit 13 to 17)	CODE (Bit 18 to 20)	DESCRIPTION	DEFINITION
RC_0	”10000”	“000”	EXECUTE command	Start previous command Loaded by RD_O,RD_1
RC_1	“10001”	“000”	STOP command	Stop the Moving command that is performed in this moment
RC_4	“10100”	“000”	UPDATE TELEMETRIES	Update all the telemetries in the internal FPGA registers. Note: This RC must be sent prior to a TI request to the FPGA
RC_5	“1011Y”	“000”	DISABLE MOTOR	Disconnect the ENABLE motor signal Bit 17 (Y): actuator ”0” ->+Y “1” -> -Y

Table 5-13: RC – UNPROTECTED RECEIVED COMMANDS

TI Data Request Definition

The TI data request instructions available for SADE telemetry acquisition are as defined in Table 5-14. The encoder output is defined by TI_0 and the status word defined by TI_1.

INSTRUCTION WORD			DATA WORD		
TYPE	SUBADDRESS (Bit 13 to 17)	CODE (Bit 18 to 20)	DATA (Bit 5 to 20)	DESCRIPTION	
TI_0	“1Y000” Bit 14 “0” -> +Y “1” -> -Y	“100”	Bit 5 to 20 16 bits Shaft Encoder Telemetry	Bit 5 is MSB Bit 20 is LSB LSB = 360° / 2^16	Shaft Encoder Telemetry (needs RC_4 command first)
TI_1	“10001”	“100”	Bit 5 to 10	Bit 5: Word Error ”0” word is OK ”1” word has a Error Bit 6: Sequence Restart ”0” no restarted ”1” restarted Bit 7: Sequence Stop ”0” no stop ”1” sequence stopped Bit 8: Sequence Error ”0” sequence OK ”1” sequence has a error Bit 9: Execution Stop ”0” no stopped ”1” execution stopped Bit 10: Executed ”0” command is not executed ”1” command is executed	Status Bits Telemetry
			Bit 13 to 15	+ Y Shaft Encoder Status Bit 13: Start Bit Bit 14: Parity Bit 15: Alarm	Positive Actuator Shaft Encoder Status Telemetry (needs RC_4 command first)

INSTRUCTION WORD			DATA WORD		
TYPE	SUBADDRESS (Bit 13 to 17)	CODE (Bit 18 to 20)	DATA (Bit 5 to 20)	DESCRIPTION	
			Bit 16 to 18	-Y Shaft Encoder Status Bit 16: Start Bit Bit 17: Parity Bit 18: Alarm	Negative Actuator Shaft Encoder Status Telemetry (needs RC_4 command first)
			Bit 19 and 20	Bit 19: -Y motor disable Bit 20: + Y motor disable "0" motor activated "1" motor deactivated	Motor Disable Telemetry
TI_2	"10010"	"100"	Bit 5 to 12 8 Bit Motor power supply Voltage Telemetry	Motor Voltage Telemetry Bit 5: MSB Bit 12: LSB	Secondary Voltage Telemetry (needs RC_4 command first)
			Bit 13 to 20 8 Bit +5V secondary Voltage	+5V Voltage Telemetry Bit 13: MSB Bit 20: LSB	
TI_3	"10011"	"100"	Bit 13 to 20 8 Bit Primary Current consumption Telemetry	Primary Current Telemetry Bit 13: MSB Bit 20: LSB	Primary Current Telemetry (needs RC_4 command first)
TI_4	"10100"	"100"	Bit 5 to 20 16 Bit Incremental Counter	In this counter is loaded the last value from RD_1 Bit 5: MSB Bit 20: LSB	SADE internal Incremental counter Telemetry
TI_5	"10101"	"100"	Bit 16 to 20	Last value from RD_0 Bit 16 actuator "0" -> +Y "1" -> -Y Bit 17 Direction "0" -> CW "1" -> CCW Bit 18 to 20: Velocity Bit 18: MSB Bit 20: LSB	SADE internal Command control StatusTelemetry

Table 5-14: TI Data Request Definition

5.3.2.3.4.3. Solar Array & SADE Interfaces

- Solar Array End switches to RTU
- Solar Array Temperature to RTU (3 channels per wing)
- Reference Strings to PCU
- Solar Array Power to PCU
- SADE data interface to AIU (via MACS bus)

5.3.2.3.4.4. Operational Modes

5.3.2.3.4.4.1. Solar array

The solar array has no internal operational modes. At launch the array panels are in the stowed position. About 3 hours after launch the solar array panels will be deployed by cutting the cables which hold-down the array panels. The cable-cutting is performed by the thermal knives.

5.3.2.3.4.4.2. SADE/SADM

The orientation of each array wing, implemented by the SADM, is controlled by the SADE which receives commands from the avionics subsystem (AOCMS).

The array zero position is defined in Figure 5-48 and Figure 5-49. At zero (reference) position the array wing shall be aligned such that the array surface is in the spacecraft Y-Z plane, with the face (cells) aligned such that the array normal is parallel to the +X axis of the spacecraft.

Array rotation is limited to approximately ±180 degrees relative to the reference position. The direction of positive rotation for both array wings is such that the motion is clockwise when viewed from the array side of the SADM.

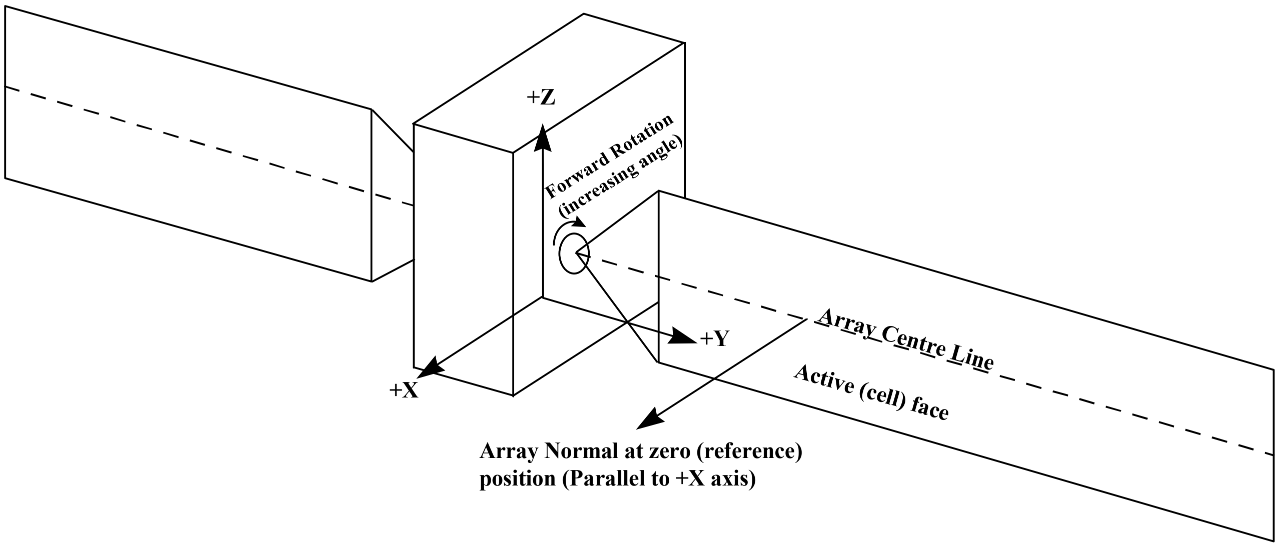


Figure 5-48: +Y Solar Array Drive Reference Axis

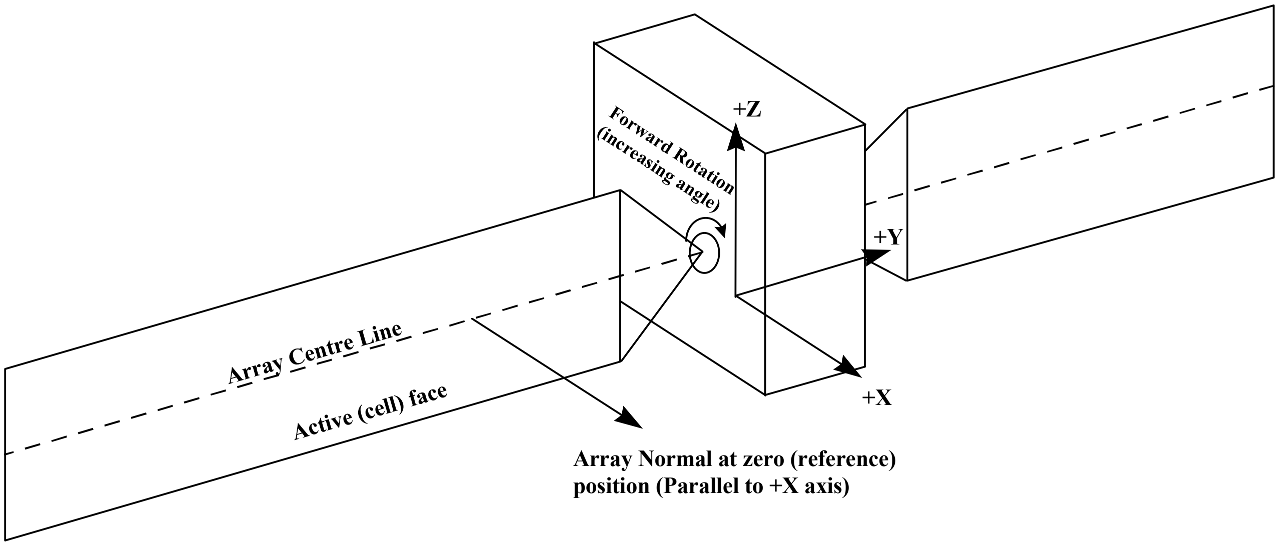
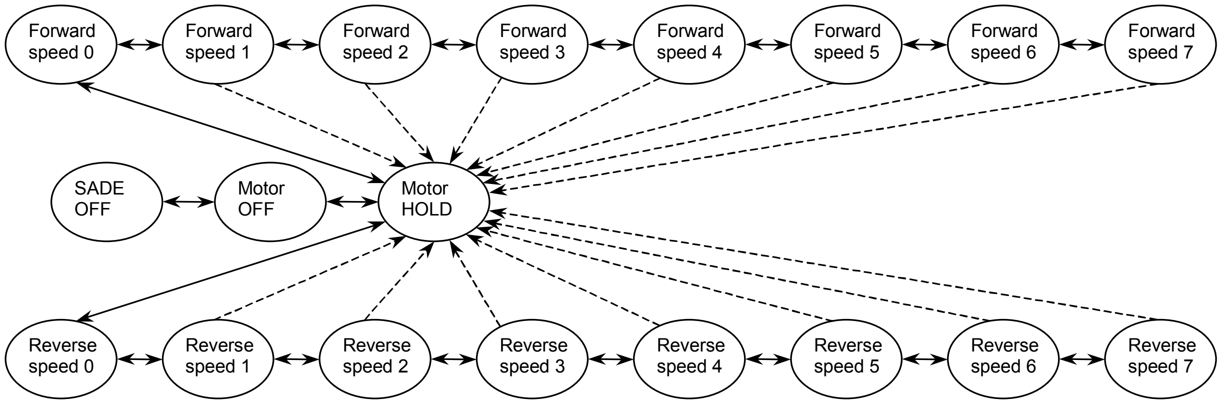


Figure 5-49: -Y Solar Array Drive Reference Axis

The motor control system has eight forward and eight reverse speeds as well as two stationary modes, STOP, in which the motor is powered and held in position, and DISABLE in which the motor is un-powered. The permitted motor control transitions are as given in the figure below. It is not permitted to change the direction of the motor speed without first going through MOTOR HOLD. Transition from any speed other than 0 to the MOTOR STOP mode shall only be performed in an emergency.



Note 1: The dashed lines represent non-nominal transitions.

Note 2: Apart from the SADE OFF mode, all the modes can be set independently for the +Y and -Y drives.

Figure 5-50: Permitted Motor Mode Control Transitions

SADE Switch ON

The SADE is switched ON by sending the appropriate SADE power supply command. With the main power on then the MACS bus interface is powered, the shaft encoders secondary power supply is ON and the motors are in MOTOR OFF mode.

SADE switch OFF

The normal procedure for switching off the SADE is to first disable both +Y and -Y motors and then to switch off the SADE power supply.

SADE speed control

The control interface contains speed (eight levels encoded as 3 bits), direction and angular movement required as a number of steps. The interface allows the selected speed to be adjusted on a cycle-by-cycle basis, but this would not be compatible with the acceleration profile acceptable to either the mechanism or the spacecraft, so the speed adjustment is controlled by the AOCMS software such that disturbance torque requirements are met.

The basic scheme for speed control is given in the table below

Speed Setting	Angular Velocity		
	°/min.	°/sec.	Micro-steps /sec
7	90	1.500	8320
6	33	0.550	3050
5	18	0.300	1664
4	3	0.050	277
3	1.2	0.020	112
2	0.9	0.015	84
1	0.6	0.010	56
0	0.3	0.005	28

Table 5-15: SADE permitted speed levels

5.3.2.3.4.5. Solar Array & SADE Telemetry & Telecommand

5.3.2.3.4.5.1. Telemetry

5.3.2.3.4.5.1.1. Array Telemetry

- Deployment status
- Short Circuit string current monitor
- Open circuit string voltage monitor
- Array temperatures

5.3.2.3.4.5.1.2. SADE telemetry

Via the MACS bus

- Shaft encoder telemetry for +Y position (16 bit)
- Shaft encoder telemetry for -Y position (16 bit)
- Internal SADE configuration status information.
- Motor Voltage and +5V secondary voltage, both 8 bits.

- The primary current consumption (8 bits).
- SADE internal incremental counter (16 bit) – reflecting RD command
- SADE internal command control status (5 bits) – reflecting RD command

Via the RTU

- the ON/OFF status of the SADE power supply (relay switch status type)

5.3.2.3.4.5.2. Telecommand

5.3.2.3.4.5.2.1. Solar array telecommands

There are no commands relating to the operation of the solar array wings, although the thermal knife commands to release the array could be considered as commands to the array.

5.3.2.3.4.5.2.2. SADE telecommands

High power commands (HPC)

- SADE A POWER ON
- SADE A POWER OFF
- SADE B POWER ON
- SADE B POWER OFF

MACS Bus :

- RC “Receive Command” type, specifying:
  - ▹ Execute previous RD command
  - ▹ STOP command – stop moving the motor
  - ▹ Update telemetries in internal registers
  - ▹ DISABLE the motor
- RD “Receive Data” type , specifying:
  - ▹ Specify actuator (+/- Y wing), direction & speed in the RD command data word (bits 16- 20). The speed is encoded as 8 levels using 3 bits.

  - ▹ Specify the number of micro-steps, up to 65535, to be moved by the specified motor at the specified speed in the specified direction. The number of micro-steps commanded must be multiples of 64 (in order to achieve a full step). Encoded in the RD data word bits 5 – 20..

- TI "Transmit Immediate" type, requesting:
  - ▹ The +Y shaft encoder telemetry, absolute position to 16 bit resolution.
  - ▹ The -Y shaft encoder telemetry, absolute position to 16 bit resolution.
  - ▹ SAD internal status, encoder status, motor status
  - ▹ Secondary voltage telemetries
  - ▹ One internal power supply voltage.
  - ▹ Primary current consumption

5.3.2.3.5. APM-E

The main function of the APM-E is the accurate control of the APM-M unit. Its main interfaces are to the motor drives and the encoder units on one side and to the AOCMS on the other. The APM-E unit is made redundant by use of two main blocks of identical architecture per APM unit. Its main components can be seen in figure 5-51. A detailed description can be found in the Electrical Analysis and Design Definition Report for the Rosetta APM-E (RO-ETL-RP-0003).

The MACS bus is used to carry all the telemetry, and telecommands except those required for hardware reconfiguration. The control interface contains speed (eight levels encoded as 3 bits), direction and angular movement required as a number of steps.

The motor control system has two stationary modes, HOLD in which the motor is powered, but held in position, and OFF in which the motor is unpowered.

The APME has a hardware ramp function built in. Generally when a change in speed from level j to level j+/-1 is commanded, the actual speed changes at R°/sec/min. The value of R is approx. 0.12 °/sec/min. The permitted motor speed transitions are shown in Figure 5-51a. The basic scheme for speed control is given in the table 5-15a.

The APME design uses a principal flyback DC/DC converter with a MosFet input switch to transform the original 28 volt supply to the voltage necessary to feed control and command units.

The position of the antenna is measured by an encoder and transmitted to the AOCMS in response to a request for data on the MACS bus. This data is available when the APME is powered, independent upon whether the elevation or azimuth drive motors are in HOLD, or OFF mode.

A dedicated push-pull converter supplies the motor drives. EMI filtering is implemented. Input current protection is realised by diodes.

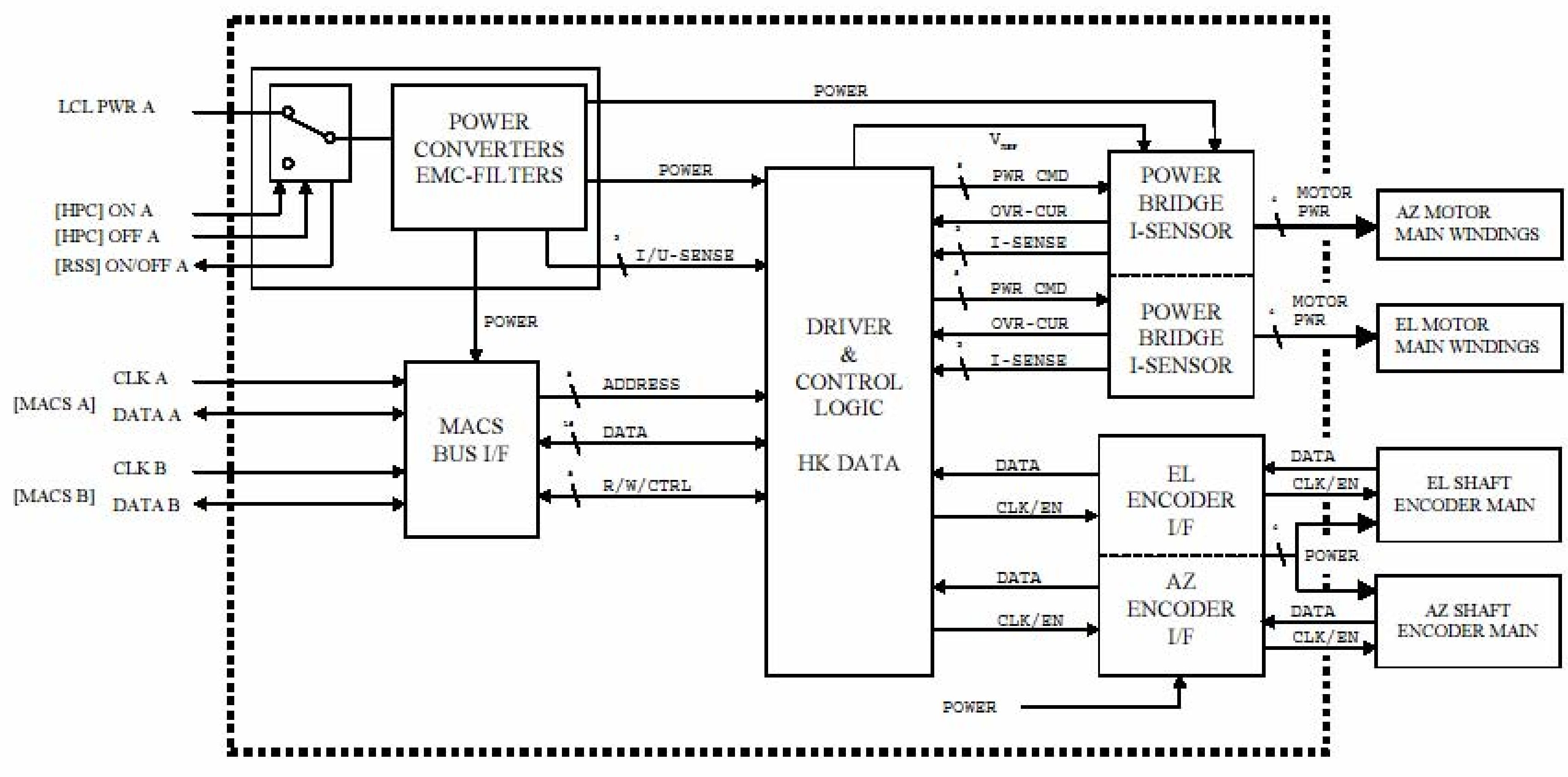


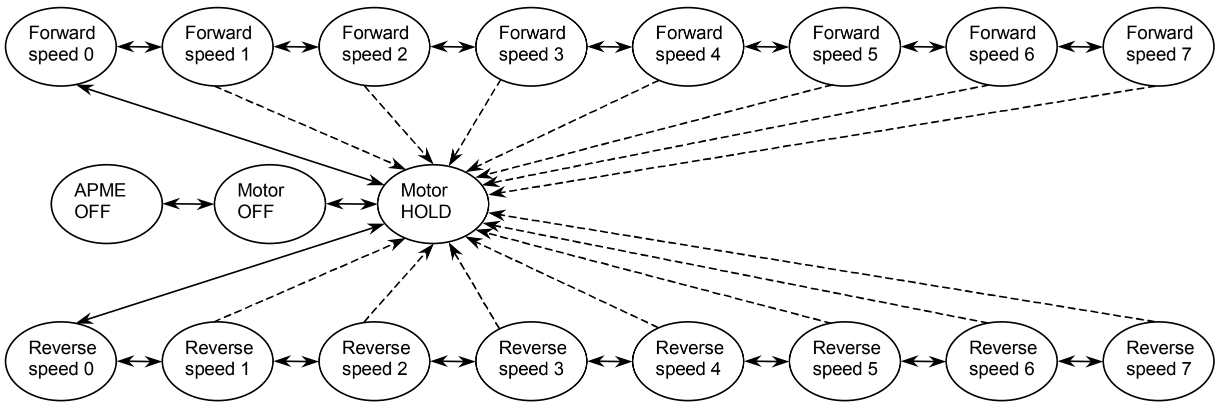
Figure 5-51: APM-E Layout

The power driver consists of two independent power bridges that feed the motor windings, one for each motor phase. Each power bridge incorporates four MosFet units and a diode bypass which allows freewheeling of the rotor.

The current control loop steers the motor units and processes information from the encoders, and the control unit. These control arguments are fed via a MACS bus to the AOCMS from where they are routed via a Free Programmable Gate Array (FPGA) which ramps the micro stepper motors. A detailed description of the FPGA design can be found in the APME High Reliability FPGA Controller document.

APME speed level	Number of steps/sec	Nominal rate in °/sec
0	0.19809575	0.00228572
1	0.39604086	0.004569702
2	0.79147988	0.00913246
3	1.58055787	0.018237206
4	3.15155182	0.03636406
5	6.26519309	0.07229069
6	12.3814476	0.142862857
7	46.0642689	0.531510795

Table 5-15a: APME speed levels



Note 1: The dashed lines represent non-nominal transitions.

Note 2: Apart from the APME OFF mode, all the modes can be set independently for the elevation and azimuth drives.

Figure 5-51a: Permitted Motor Mode Control Transitions (APME)

5.3.2.4. Power Subsystem Performance

5.3.2.4.1. Array Performance

5.3.2.4.1.1. Low Intensity Low Temperature Case

425 W per array are provided for LILT condition at the EOL. The value of Voc (open circuit voltage) is 97.6 ~~78.9~~ V.

If the solar cells will have a performance equal to the TAT (test) data, then the worst case value of Voc is 79.9 ~~3~~ V.

The TAT data is test data at, group C, - 130°C, and no fluency occurring on the solar array.

5.3.2.4.1.2. Close To Sun Case

3288 ~~962~~ W per wing are provided at a voltage of about 31.8 V.

The wing power at 34 V is about 2000 ~~121~~ W.

The wing power at 35 ~~32.5~~ V is about 1000 ~~810~~ W. The Voc is 37.2 ~~35~~ V.

If the solar cells will have a performance equal to the TAT data, then 1000 W at wing level will be obtained at a voltage of 33.2 V.

5.3.2.4.1.3. Nominal Beginning of Life Case

1000 W per wing are provided at 48 ~~47~~ V. The Voc is 51 ~~49.3~~ V.

5.3.2.4.1.4. Outer Panel Beginning of Life Case

The maximum panel power is 768 ~~542.3~~ W at 32.9 ~~23.9~~ V. The Voc is equal to 51 ~~42.5~~ V.

5.3.2.4.2. Battery performance

See figure 5-43B. More details will be provided after the life test.

5.3.2.5. Subsystem Operations Modes

5.3.2.5.1. Overview

The power system operates in a number of configurations during the mission.

Pre-launch, Launch (and ascent.)

In this phase, the spacecraft is encapsulated in the fairing and no illumination of the solar array is possible. The spacecraft is initially supported from the ground equipment via the umbilicals. These are removed shortly before lift-off and the power system then operates on battery power

Assuming no battery failure at the time of launch, a launch abort with no ground charging can be sustained for almost 400 minutes before the batteries are fully discharged. In the more practical case of ground support, provided that ground power is enabled within 60 minutes, the batteries can be recycled to 100% SOC within about 6 hours.

Coast

During LEOP the solar array is stowed against the spacecraft Y walls. In this configuration only the outer panel is exposed to sun. In the coast phase, the spacecraft is spinning about Z at approximately 1 rpm. This allows the power system to utilise array power for charging and power bus support whenever the cyclic panel power exceeds the load requirement.

Power generation in the coast phase is interrupted by an eclipse prior to T=26:40 mins (+ possible delay of 600s, see Timeline in §3.8) and after T=115 minutes.

Injection

This phase is assumed to despin the spacecraft and then orient the spacecraft with +X axis facing the sun. No solar power is assumed as the Y walls are no longer facing the sun.

Activation, Initial Acquisition and SA Deployment

These phases are assumed to have the sun on the +X face. No solar power is assumed.

About 2.5 hours after lift-off the solar arrays will be deployed. The deployment itself will take about 12 minutes to cut the six Kevlar hold-downs on each wing and begin SADM rotation. Note that once deployed, the wings only have to rotate 9° or so to support the Bus load (250W) so the sun acquisition by the arrays can be largely ignored.

Rest of mission

Once the arrays are deployed then the subsystem operational mode depends on the array orientation with respect to the sun and the power demand from the users. The PCU automatically controls the energy balance with no interaction necessary from the ground.

5.3.2.5.2. Detailed Mode Descriptions

5.3.2.5.2.1. PCU Mode Summary

To maintain correct and required energy balance in the spacecraft power subsystem, the PCU provides three different modes of operation:

5.3.2.5.2.1.1. APR regulation mode

This mode is operating when the load demand, including battery charge, is less than that available from the solar arrays

- The APRs are controlled by the MEA and feed the power necessary to maintain the 28V main bus line within its regulation
- The BCR function takes the necessary power from the main bus to provide the required charging of the batteries. In other words the BCR is just a load on the main bus
- The BDRs are not active

5.3.2.5.2.1.2. BCR Mode

This mode is operating when the load demand, including requested battery charge, exceeds that available from the solar arrays

- The APRs operate as MPPT controlled power regulators and feed the maximum available power to the 28V main bus line
- The BCR function takes the remaining power available for battery charging from the main bus
- The BDRs are not active

Main bus regulation is formed by the BCRs and the MEA function only

5.3.2.5.2.1.3. BDR Mode

This mode is operating when the load demand, excluding battery charge, exceeds that available from the solar arrays

- The APRs operate as MPPT controlled power regulators and feed the maximum available power to the 28V main bus line
- The BCRs are not active

- The BDRs operate as MEA controlled power regulators and derive the power necessary to maintain the 28V main bus line within regulation from the batteries.

5.3.2.5.2.2. PDU operational modes

See section 5.3.2.3.2.4 of PDU description

5.3.2.5.2.3. SADE operational modes

See section 5.3.2.3.4.4.2 of SADE description

5.3.2.6. Subsystem Interfaces

See individual unit descriptions.

5.3.2.7. Subsystem Failure

See Volume 2, Contingency Recovery Procedures.

5.3.2.8. Subsystem On-Board Software

The power subsystem does not have any functions implemented in software.

5.3.2.9. Summary of Power Subsystem Telecommand and Telemetry

5.3.2.9.1. Summary of Telecommand Packets

All commands come from the SS-RTU except where a specific comment is noted.

5.3.2.9.1.1. PCU Telecommands

See Annex 2, sections 8.1 (PCU-A) and 8.2 (PCU-B).

5.3.2.9.1.2. SS-PDU Telecommands

See Annex 2, section 8.3.

5.3.2.9.1.3. SS-PDU Telecommands via TM/TC Interface B

See Annex 2, section 8.4.

5.3.2.9.1.4. PL-PDU Telecommands

See Annex 2, section 8.5.

5.3.2.9.1.5. PL-PDU Telecommands via TM/TC Interface B

See Annex 2, section 8.6.

5.3.2.9.1.6. Battery commands

TC ID Miscellaneous	Description	Related TM Parameter
ZPWH1000	BATT 1 DISCH RELAY ON (via SS-RTU I/O A)	NPWDB101 (via SS-RTU I/O A)
ZPWH1001	BATT 1 DISCH RELAY OFF (via SS-RTU I/O A)	NPWDB101 (via SS-RTU I/O A)
ZPWH2002	BATT 2 DISCH RELAY ON (via SS-RTU I/O B)	NPWDB201 (via SS-RTU I/O B)
ZPWH2003	BATT 2 DISCH RELAY OFF (via SS-RTU I/O B)	NPWDB201 (via SS-RTU I/O B)
ZPWH1002	BATT 3 DISCH RELAY ON (via SS-RTU I/O A)	NPWDB301 (via SS-RTU I/O A)
ZPWH1003	BATT 3 DISCH RELAY OFF (via SS-RTU I/O A)	NPWDB301 (via SS-RTU I/O A)
ZPWH2000	BATT 1 DISCH RELAY ON (via SS-RTU I/O B)	NPWDB101 (via SS-RTU I/O A)
ZPWH2001	BATT 1 DISCH RELAY OFF (via SS-RTU I/O B)	NPWDB101 (via SS-RTU I/O A)

5.3.2.9.2. Telecommand Parameter Summary

NA

5.3.2.9.3. Telemetry Packet Summary

For details of the allocation of telemetry to telemetry packets see document RSDB TM/TC Data (RO-DSS-LI-1018).

In summary the power subsystem telemetry appears in the following packets

YDM00003 - Housekeeping SS RTU

YDM00005 - Housekeeping PDU Normal

YDM00006 - Housekeeping PCU & TRSP

YDM00007 - Housekeeping PDU Current Profile

Solar array telemetry is provided in the YDM00003 packet.

5.3.2.9.4. Telemetry Parameter Summary

5.3.2.9.4.1. PCU Telemetry

See Annex 2, section 8.14.

5.3.2.9.4.2. SS-PDU Telemetry

See Annex 2, section 8.15.

5.3.2.9.4.3. PL-PDU Telemetry

See Annex 2, section 8.16.

5.3.2.9.4.4. Miscellaneous Telemetry

TM ID Misc	Description	ID	Bi-level value
NPWDB101	BATT 1 DISCH RELAY ST		
NPWDB201	BATT 2 DISCH RELAY ST		
NPWDB301	BATT 3 DISCH RELAY ST		
NHADFP01	BSM FLIGHT PLUGS		
NHADFP02	PSM FLIGHT PLUGS		
NHADFP03	RCS FLIGHT PLUGS		
NHADFP04	BATT FLIGHT PLUGS		

TM ID Misc	Description	ID	Bi-level value
NHADFP05	TK SADM FLIGHT PLUGS		
NHADFP06	HV INHIB FLIGHT PLUGS		

5.3.2.9.4.5. SADE Telemetry

TM ID SADE	Description		Bi-level value
NSADSE01	SADE NORMAL STATUS		
NSADSE02	SADE REDUND STATUS		
NSADSE01	SADE TEMP 1		
NSADSE11	SADE TEMP 2		
NSADSE21	SADE TEMP 3		
NSADSE31	SADE TEMP 4		

5.3.2.10. Subsystem Budgets

See Annex 10, Power Budgets.

5.3.3. TT&C

5.3.3.1. TTC RF Subsystem Overview

The Telemetry, Tracking and Command (TT& C) subsystem communicates with the earth during the mission using of three antennae concepts, each operating at various stages throughout the mission timeline. The antennae are combined with a number of electrical units performing command reception, telemetry transmission and ranging functions.

5.3.3.1.1. Subsystem Physical Configuration

The subsystem is split into several discreet units and interconnecting cables, waveguides etc. a block diagram of the subsystem is shown in Figure 5-52.

The individual units and components together with their manufacturer are shown below.

Units	Number	Supplier
S/X-Band Transponder	2	Alenia
Ultra Stable Oscillator (USO)	1	TimeTech
Travelling Wave Tube Amplifier	2	Alcatel ETCA
Attenuators	2	Astrium
RF Distribution Unit (RFDU)	1	Alcatel Espacio
Waveguide Interface Unit	1	Alcatel Espacio
3dB Hybrid	1	Alcatel Espacio
Coax	See Table below	Alcatel Espacio
Waveguide	See Table below	Alcatel Espacio
Waveguide Test Couplers (Non flight)	2	Alcatel Espacio
HGAMA	1	HTS
MGA-S	1	CASA
MGA-X	1	CASA
LGA +Z Stand-off -Z Stand-off	2 1 1	Saab Ericsson Space Astrium Astrium

Table 5-16: TT&C Subsystem Hardware List

Identifier	Cable Type	Source Equipment	Destination Equipment
Coax 1	Gore G42	TRSP-1 STx	RFDU
Coax 2	Gore G42	TRSP-1 XTx	3dB Hybrid
Coax 3	Gore G42	TRSP-1 SRx	RFDU
Coax 4	Gore G42	TRSP-1 XRx	WIU
Coax 5	Gore G42	TRSP-1 USO In	USO
Coax 6	Gore G42	TRSP-2 STx	RFDU
Coax 7	Gore G42	TRSP-2 XTx	3dB Hybrid
Coax 8	Gore G42	TRSP-2 SRx	RFDU
Coax 9	Gore G42	TRSP-2 XRx	WIU
Coax 10	Gore G42	TRSP-2 USO In	USO
Coax 11	Gore G42	LGA-1	RFDU
Coax 12	Gore G42	LGA-2	RFDU
Coax 13	Gore G42	MGA-S	RFDU
Coax 14	Gore G42	HGA	RFDU
Coax 15a	Gore G42	TWTA-1	Inline Attenuator
Coax 15b	Gore G42	Inline Attenuator	3dB Hybrid
Coax 16a	Gore G42	TWTA-2	Inline Attenuator
Coax 16b	Gore G42	Inline Attenuator	3dB Hybrid

Table 5-17: TT&C Coax Cable List

Identifier	Waveguide Type	Source Equipment	Destination Equipment
Waveguide 1	WG WR112	MGA-X	WIU
Waveguide 2	WG WR112	HGA	WIU

Table 5-18: TT&C Waveguide List

5.3.3.1.2. Functional Objectives

The TT&C subsystem supports the following modes of operation for the uplink and downlink :

Uplink

- Carrier only
- Telecommand
- Ranging
- Simultaneously Telecommand and Ranging.

Downlink (selectable by Telecommand)

- Carrier only
- Telemetry
- Ranging
- Simultaneously Telemetry and Ranging.

5.3.3.1.3. Subsystem External Interfaces

Ground Stations

The TT&C subsystem is required to interface with the ESA ground segment in normal operational mode and with the NASA Deep Space Network during emergency mode. The mission will be controlled from two ESA ground stations.

- S/X-Band 15m Kourou used during LEOP and gravity assist phases
- S/X-Band 35m New Norcia used throughout the mission
- Also, Deep Space Network (DSN) may be used for the following
- DSN 34m during rendezvous for tracking and as a potential add-on for science data collected during the mission
- DSN 70m for emergency S-Band back-up

The transponder is designed to be compatible with the ESA and with the NASA DSN ranging systems.

5.3.3.1.4. TTC Subsystem Design

- A pair of identical transponders provide command and ranging signal reception in either S-Band or X-Band and telemetry and ranging signal transmission in either, or both, S-Band and X-Band. The Two Transponders interface with the RF Distribution Unit (RFDU) for S-Band RF signals, and with the WIU for X-Band receive and with Travelling Wave Tube Amplifiers (TWTA's), for X-Band transmit signals. The Transponders also interface with the Data Management System (DMS), which decodes and distributes commands and collects and formats telemetry. The Transponders modulate and transmit the Telemetry stream coming from both parts of the redundant Data Management System either in S or X-Band or both simultaneously and transpond the ranging signal in S and X-Band. The Transponders provide hot redundancy for the receiving functions and cold redundancy for transmitting functions . Both transponders have their receivers permanently powered for the duration of the mission, even during hibernation periods, to allow them to be simultaneously operable (i.e. in hot redundancy) to achieve this, they are fed by foldback current limiters which cannot be switched off. The selection of S-Band or X-Band front-end operation is via telecommand. The configuration is such that both receivers can receive and send the Telecommand signals to both decoders, which can decode simultaneously. The transmitters are also able to receive the telemetry stream from both parts of the redundant DMS. Each transponder is capable of operating in a “pseudo” coherent or non-coherent mode.

- An RF Distribution Unit (RFDU) provides a flexible S-Band transmit/receive switching function between the HGA, MGA, and both LGA antennae, and the two Transponder units via two diplexers.

- A Waveguide Interface Unit (WIU) comprising of X-Band diplexers, two transfer switches and high power isolators, allows switching the TWTA between HGA and MGA X antennae. The isolator protects the TWTA in case of switching with RF applied.

- The telemetry transmission can also be synchronised to the external Ultra-Stable Oscillator (USO), which has a superior stability and noise specification to the Transponder internal oscillator, and is used for one-way ranging as part of the Radio Science Investigations (RSI).

- Redundant 28.5W X-Band TWTAs are fed from the redundant X-Band transmitters, one within each transponder, via a 3dB passive hybrid. These TWTAs are used as amplifiers on the output telemetry signal path which is then distributed to the X-Band antennas via the WIU. Attenuators are fitted between the 3 dB hybrid and TWTA to feed the TWTA at or around saturation.

The antenna subsystem consists of two Low Gain Antennas (LGA), a High Gain Antenna (HGA) and two Medium Gain Antennas (MGA).

- Two Low Gain Antennas (LGA +Z / LGA -Z) provide a near omni-directional coverage for any attitude of the satellite which may be used for:

- ▹ the near earth mission phase at S-Band for uplink telecommand and downlink telemetry.
- ▹ the telecommand Uplink at S-Band during emergency and nominal communications over large ranges up to 6.25 AU.

- A High Gain Antenna (HGA) providing the primary communication for Up and Downlink at S-Band and X-Band throughout the mission.
- Separate S-Band and X-Band Medium Gain Antennas (MGA) providing backup Uplink and Downlink communications. The MGA may also be used to perform some mission communications functions at various phases throughout its lifetime due to MGA's much larger coverage area.

The use of the MGAs as a body-mounted antennas enable a limited back-up capability in case of HGA articulation failure and a simplification of operation during most hibernation entry and exit phases.

5.3.3.1.5. Operating Principles

It is expected that only one S-Band transmitter or one X-Band transmitter will be operated at any one time (i.e. cold redundancy). However, it is possible to operate both X-Band TWTAs simultaneously due to the presence of high power isolators in the circuit providing sufficient power is available, and it is thermally acceptable.

Both transponders have their receivers permanently powered for the duration of the mission, even during hibernation periods, to allow them to be simultaneously operable (i.e. in hot redundancy). The selection of S-Band or X-Band front end operation is via telecommand.

Communications with the spacecraft are primarily performed via the X-Band telecommand uplink and telemetry downlink through the HGA. The X-Band up and downlink is also possible, at any distance, through the MGA-X as back up. At small Earth distances the two S-Band LGAs provide near omni-directional coverage and also serve as emergency commanding up to the maximum earth distance. For recovery operations S-Band up and down link is also possible through the HGA and the MGA-S.

Use of the MGA

The main purpose of the MGA is to provide a back-up to the HGA, as a redundant antenna in case of HGA failure or as an back-up in recovery situations. Since the MGA boresight is fixed parallel to the spacecraft +X axis, it use is restricted to phases where Earth and Sun are sufficiently close together, such that thermal constraints on attitude are satisfied. Fortunately this is always possible except during short phases near Earth.

5.3.3.2. Subsystem Configuration

5.3.3.2.1. Overall Layout

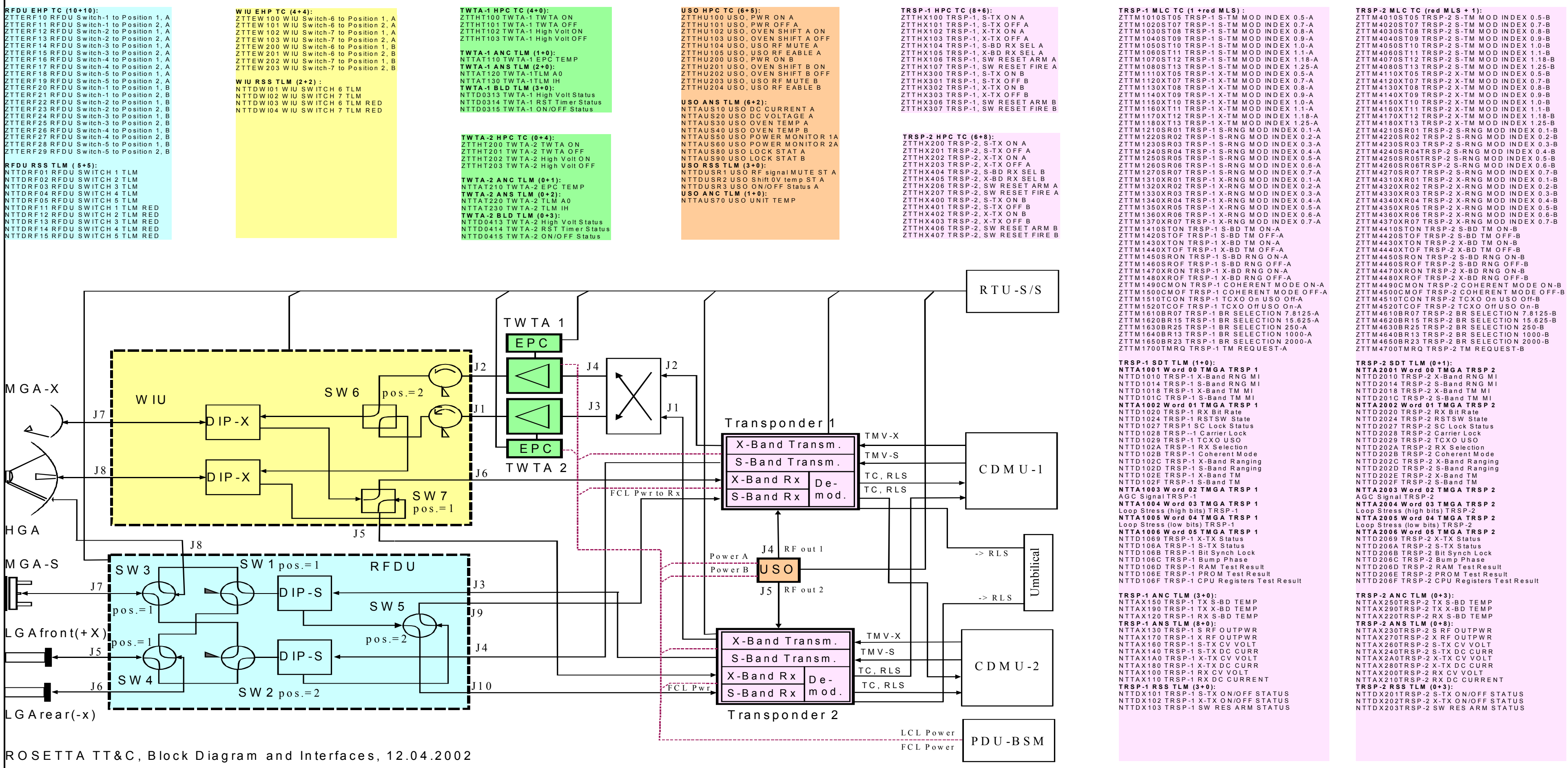


Figure 5-52: TTC RF Subsystem Block Diagram

5.3.3.2.2. Unit Descriptions

5.3.3.2.2.1. High Gain Antenna Major Assembly (HGAMA)

The major function of the High Gain Antenna Mechanical Assembly(HGAMA) is the reception and transmission of data in X-Band and S-Band between the Rosetta spacecraft and the groundstations. The High gain antenna is steerable, has a high data rate and will be used as the nominal TM/TC link while the SC is near the comet.

The HGA is designed at S-Band to receive in the region 2.11 to 2.12 GHz and to transmit at 2.29 to 2.30 GHz and also at X-Band to receive in the region 7.15 – 7.19 GHz, and transmit at 8.4 to 8.44 GHz.

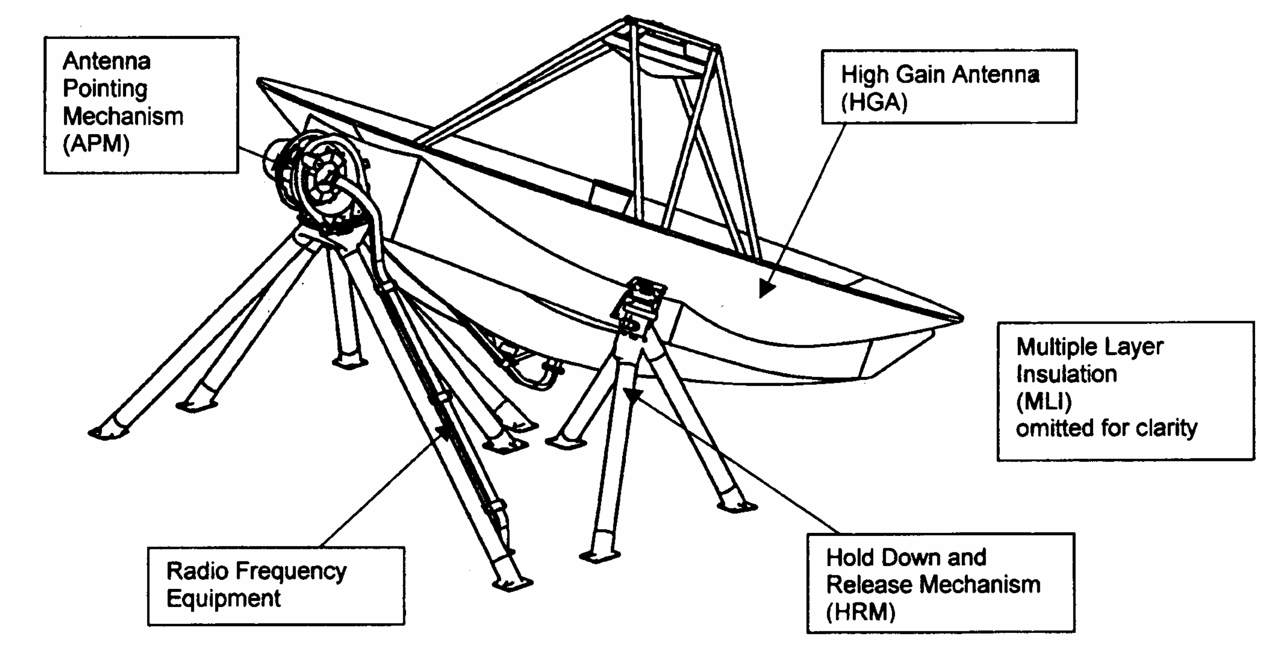


Figure 5-53: HGA Major Structure

5.3.3.2.2.1.1. HGAMA Mechanical Design Description

For a description of the HGAMA from the mechanical point of view, see §5.4.6.

5.3.3.2.2.1.2. Performance Data

The following table gives a summary of the performance data of the HGA. Further data can be found in RO-HTS-AN-0010.

Characteristic	Value
Main reflector diameter	2.2 m
Sub reflector diameter	0.34 m
Main reflector focal distance	0.88 m

Characteristic	Value
Inter-foci length	0.71 m
Boresight Gain (EOL): X-Band At HGAMA / SC interface. S-Band	Rx: 41.6 dBi Tx: 44.2 dBi Rx: 31.0 dBi Tx: 31.1 dBi
3 dB Beamwidth X-Band (full cone) S-Band	Rx: 1.14 degrees Tx: 0.98 degrees Rx: 4.42 degrees Tx: 4.12 degrees
Sidelobe Level relative to peak gain X-Band S-Band	Rx: -13.4 dB Tx: -14.2 dB Rx: -19.8 dB Tx: -17.7 dB
Cross Polarisation XPD /Axial Ratio X-Band at -3 dB contour S-Band	Rx: 23.1 / 1.2 dB Tx: 28.2 / 0.7 dB Rx: 24.6 / 1.0 dB Tx: 17.7 / 2.3 dB

Table 5-19: PFM HGAMA Performance

The following graphs give typical antenna coverage patterns.

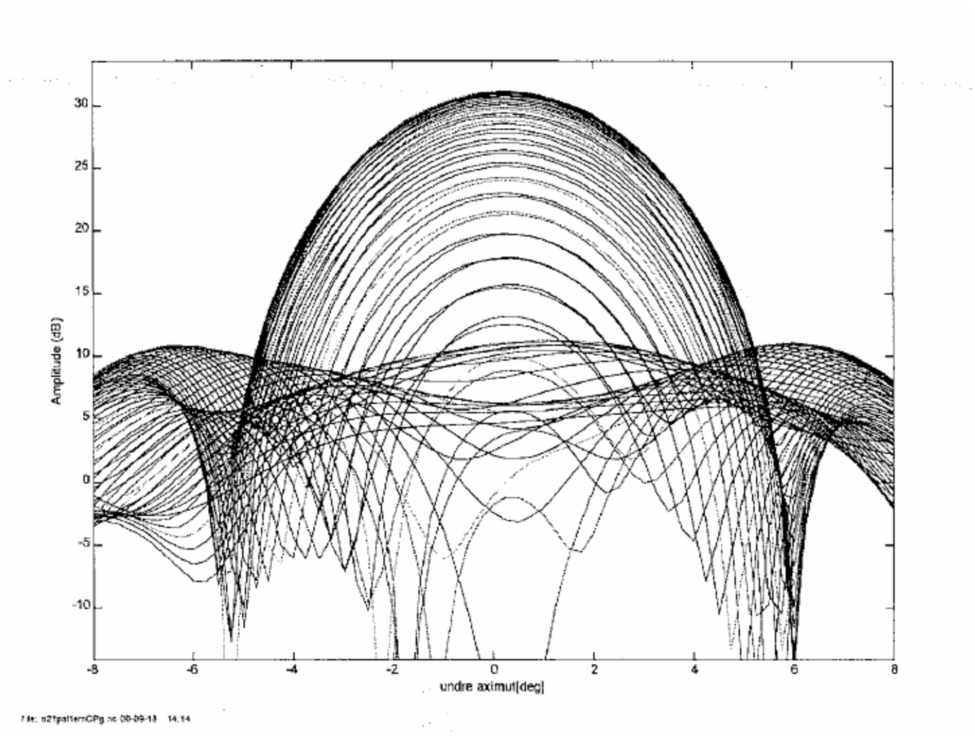


Figure 5-54: HGA Antenna Coverage S-Band Rx

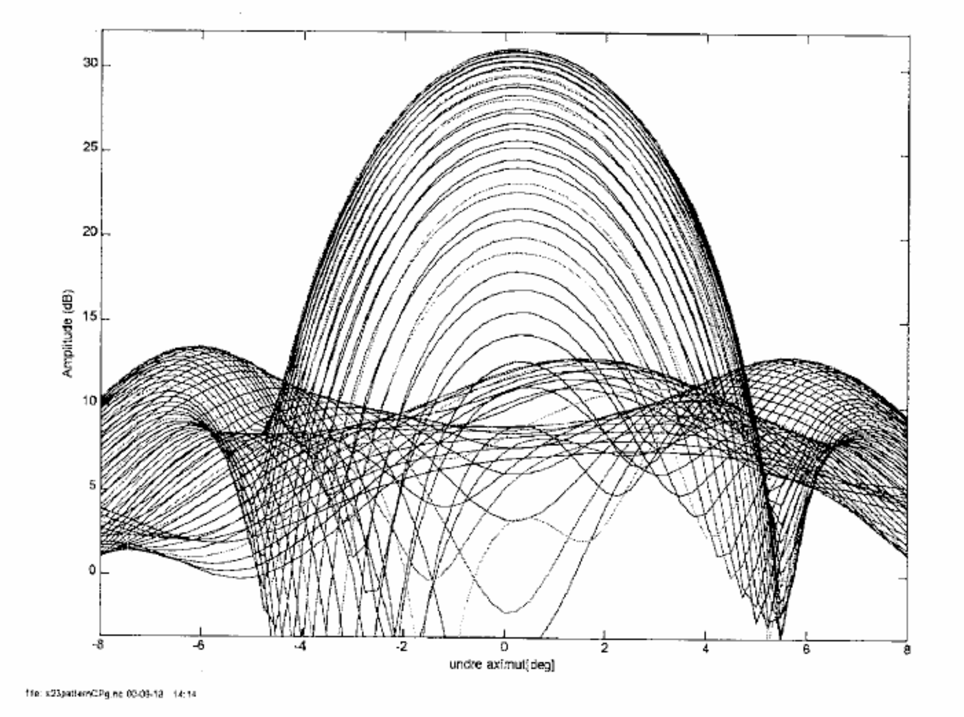


Figure 5-55: HGA Antenna Coverage S-Band Tx

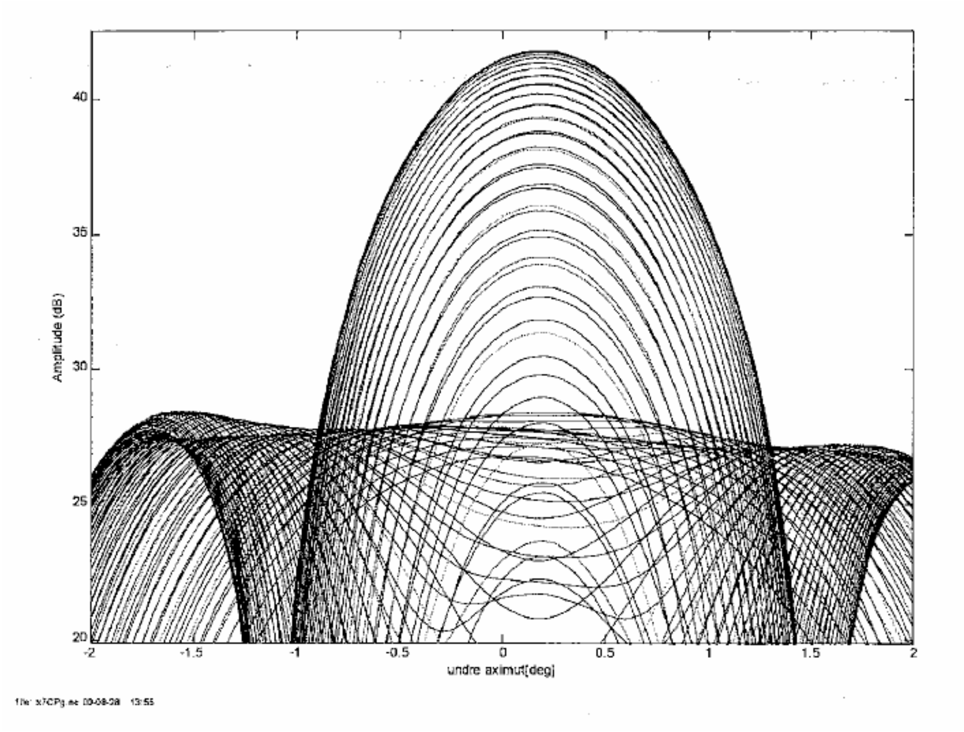


Figure 5-56: HGA Antenna Coverage X-Band Rx

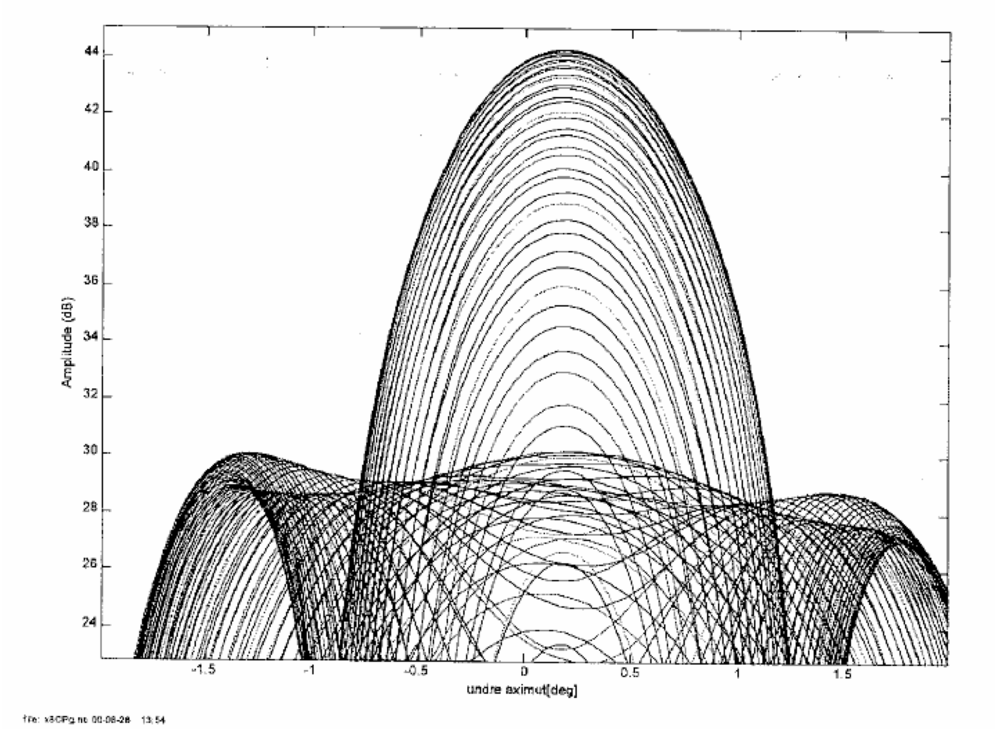


Figure 5-57: HGA Antenna Coverage X-Band Tx

5.3.3.2.2.1.3. Coverage

The useable coverage area of the HGAMA is shown in §3.5.5.

5.3.3.2.2.2. Medium Gain Antenna (MGA)

Two separate MGA antenna designs are used on the Rosetta spacecraft one for S-Band operation and the other for X-Band operation. Both antennas are mounted on the +X face of the spacecraft with nominal boresights parallel to the spacecraft +X axis.

5.3.3.2.2.2.1. MGA-S

5.3.3.2.2.2.1.1. Overview

The MGA-S antenna consists of an hexagonal array of patch antenna elements. The configuration has 6 radiant elements with connecting feed.

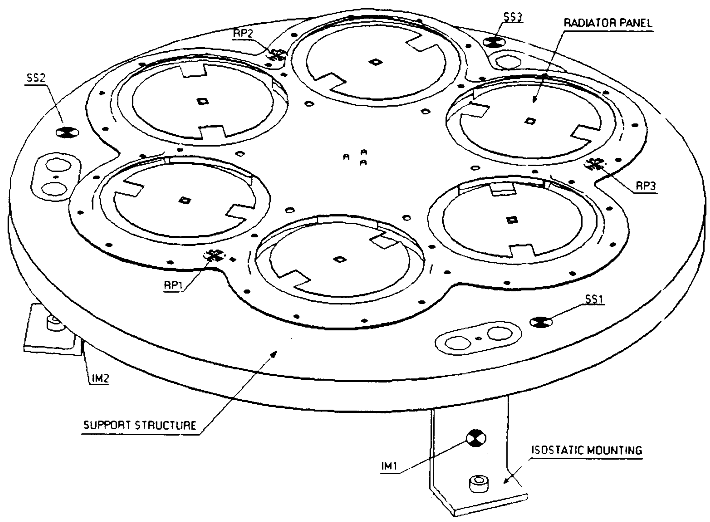


Figure 5-59: MGA-S Configuration

5.3.3.2.2.2.1.2. Function

The use of the MGA-S as a body-mounted antennas provides a limited back-up capability in case of HGAMA articulation failure and a simplification of operation during most hibernation entry and exit phases. The MGA-S may also be used to perform some mission communications functions at various phases throughout the mission lifetime due to the MGA's much larger coverage area.

5.3.3.2.2.2.1.3. Physical Configuration

The antenna can be split into two parts, the RF active part and the support structure. The RF active part consists of a hexagonal array made from a machined aluminium plate. The separation between the lower ground plate and the six elements is maintained by Teflon spacers. Each upper element has a diameter of 60.65mm. The six elements are placed at a diameter of 0.164m.

The antenna element is supported by a CFRP structure with an aluminium honeycomb core. The structure is mounted to the spacecraft via 3 titanium isostatic mountings.

5.3.3.2.2.2.1.4. Interfaces

The RF is transferred from the radiator panel to the lower ground plate via a coaxial cable which runs under the support structure and through the isostatic mounting where it terminates in a coaxial SMA connector. The RF will be transferred to the RFDU via this connector, using coaxial cable.

The MGA-S is supplied with MLI thermal blankets fixed using a combination of pins and Velcro.

5.3.3.2.2.2.1.5. Performance Data

A detailed description of the performance of the antenna can be found in RO-CAS-RP-3003 The following table gives the main points.

Characteristic	Value
Operational Frequency Uplink Downlink	 2115 MHz 2297 MHz
Axial Ratio at -3dB contour	Rx: 1.4 dB Tx: 2.4 dB
Side Lobe Levels	Rx: -13.0 dB Tx: -14.0 dB
RF boresight Alignment	± 0.4° (Rx) ± 0.23° (Tx)
Gain	Rx: 14.1 dB Tx: 14.7 dB
3 dB beamwidth (half cone)	Rx: 16.2° Tx: 14.0°
Polarisation	RHCP
Approximate Mass	0.880 kg
Approximate Dimensions	Height: 75.8 mm Dia: 300 mm

Table 5-20: Performance Data Summary (FM)

The following diagrams show typical Antenna coverage patterns for transmit, and receive frequencies.

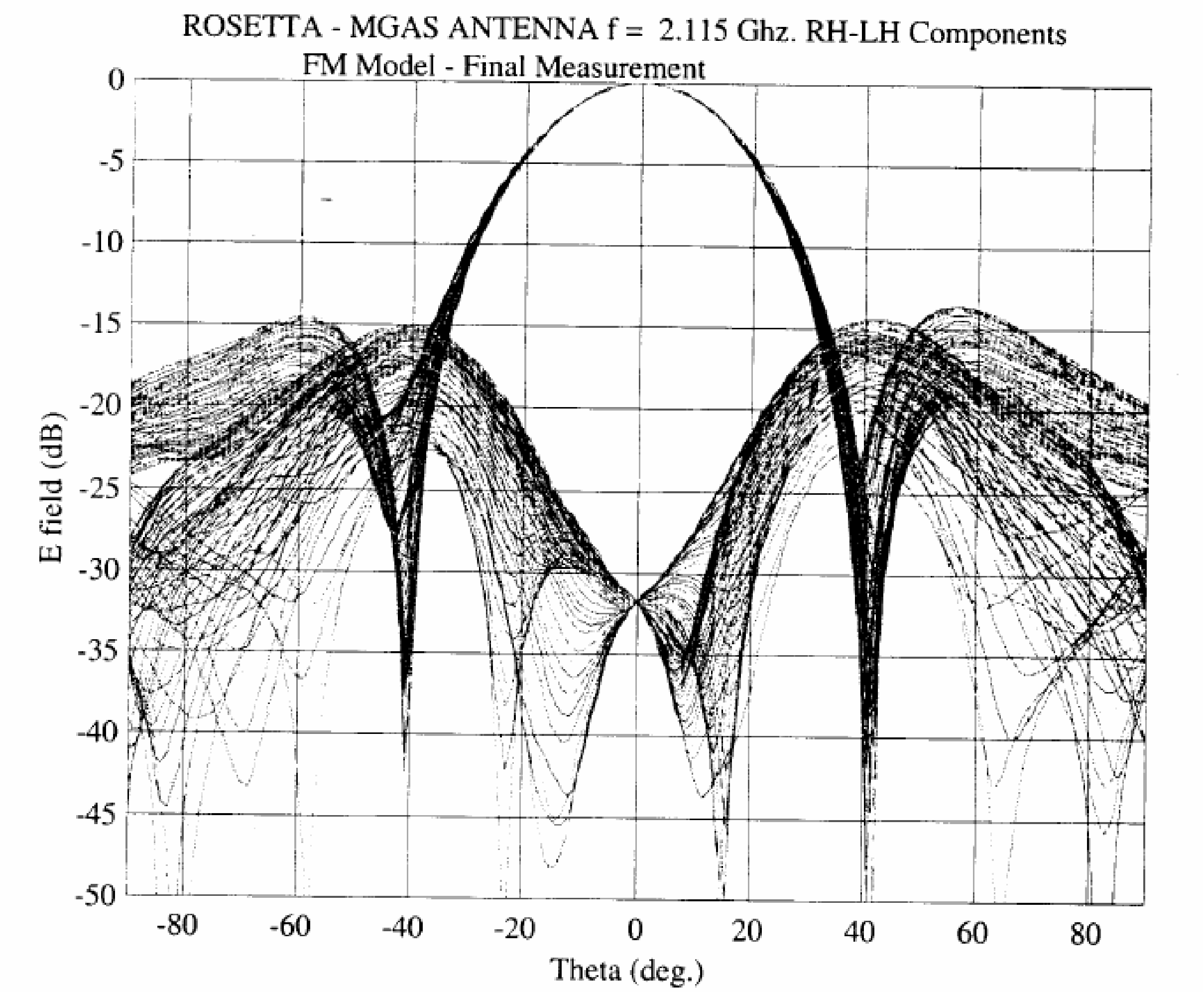


Figure 5-60: MGA-S Antenna Coverage Rx (f = 2115 MHz), FM Antenna

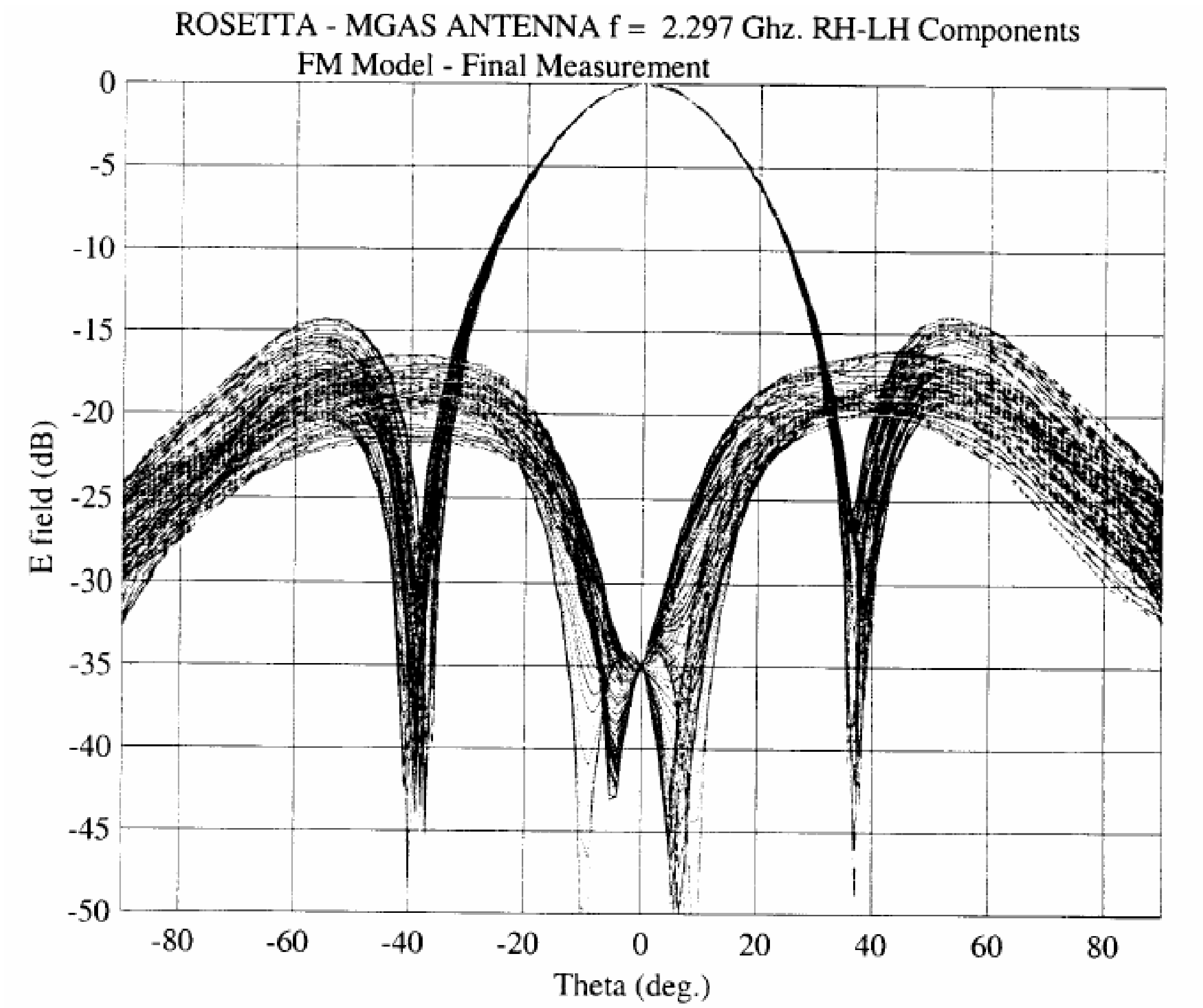


Figure 5-61: MGA-S Antenna Coverage Tx (f = 2297 MHz), FM Antenna

5.3.3.2.2.2.2. MGA-X

5.3.3.2.2.2.2.1. Overview

The MGA-X antenna is composed of two subassemblies, a reflector and a feeder, joined by means of a platform which allows a correct alignment on the spacecraft. The reflector has a parabolic surface with focal length 186mm. The feeder has a corrugated horn orientated to the central point of the reflector, and a polariser with a waveguide.

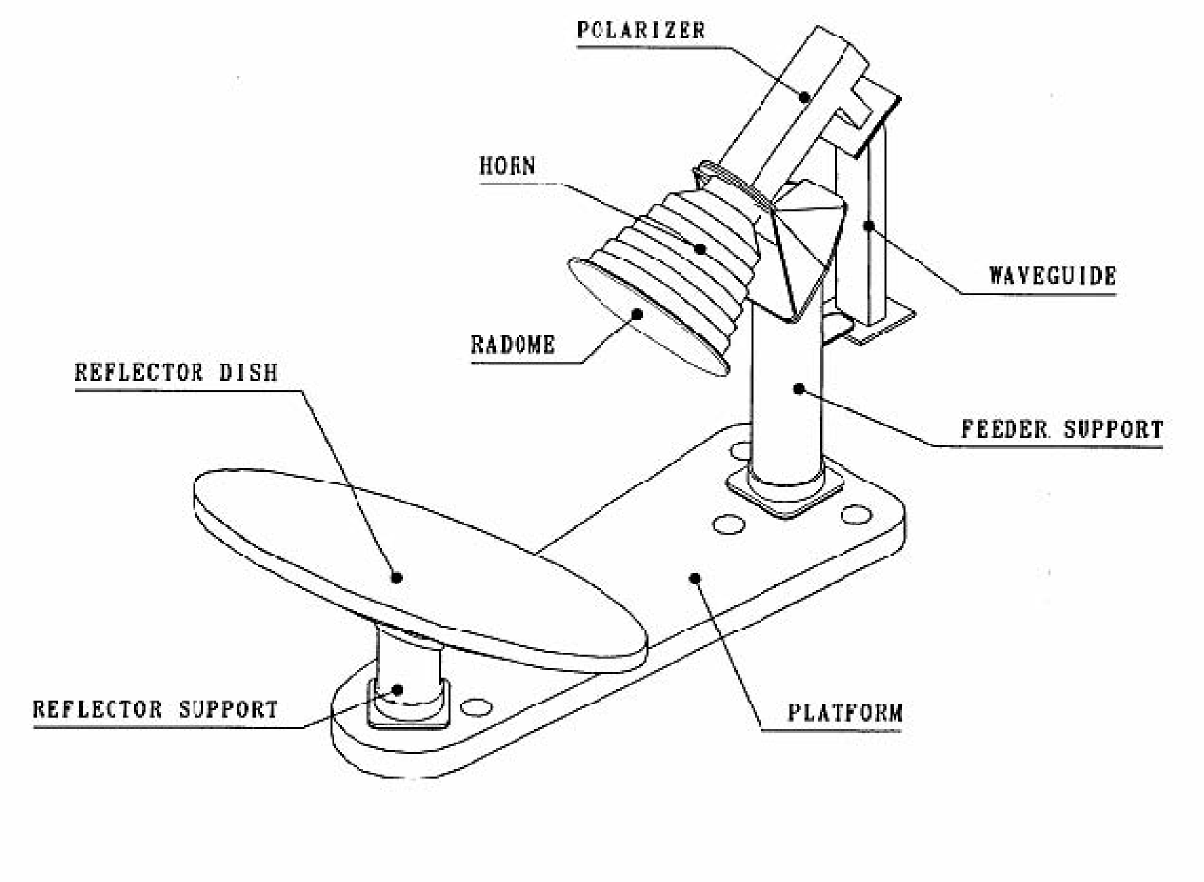


Figure 5-62: MGA-X Configuration

5.3.3.2.2.2.2.2. Function

Similar to the MGA-S, the X-Band Medium Gain Antenna (MGA-X) provides backup Uplink and Downlink communications. The MGA-X may also be used to perform some mission communication functions at various phases throughout its lifetime due to the MGA's much larger coverage area than the HGAMA. The use of the MGA-X as a body-mounted antenna provides a limited back-up capability in case of HGAMA articulation failure and a simplification of operation during most hibernation entry and exit phases, as they do not need to be steered.

5.3.3.2.2.2.2.3. Physical Configuration

The reflector dish is made of a sandwich with skins of CFRP and aluminium honeycomb core. The reflector has 4 threaded inserts on the back side, which are used to join it to the reflector support.

The reflector support consists of a truncated cylinder of CFRP, with two titanium end fittings.

The interface between the reflector and support is via four inserts which allow adjustment of the position of the two elements before launch.

The corrugated horn of length 99mm and aperture 123.5mm is made of aluminium. The aperture of the horn is covered by a germanium radome to prevent dust entering the waveguide. The reflector dish has a focal length of 196mm, and an aperture diameter of 288mm.

The polariser is a thin wall square aluminium waveguide. It also contains a load, which is glued and screwed to the end wall of the polariser.

At the output of the polariser a further aluminium waveguide is used to transmit the RF signal to the transponder.

5.3.3.2.2.2.2.4. Interfaces

The MGA-X interfaces with the Waveguide Interface Unit (WIU) via waveguide. The waveguide is type WR-112, as can be seen in Figure 5-62 it is attached to the feeder support tube using a titanium support. The interface with the waveguide which connects the antenna to the WIU is via a square flange, which will be attached with 4 bolts.

The MGA-X is supplied with MLI thermal blankets which are fixed using a combination of pins and Velcro.

The antenna is attached to the +X wall of the spacecraft using 5 bolts.

5.3.3.2.2.2.2.5. Performance Data

A detailed description of the performance of the antenna can be found in RO-CAS-RP-3002. The following table gives a summary of the main characteristics.

Characteristic	Value
Operational Frequency Uplink (Rx) Downlink (Tx)	 7149 – 7188 MHz 8402 – 8441 MHz
Polarisation	RHCP
Axial Ratio at -3dB contour	Tx: < 0.94 dB Rx: < 0.89 dB
Minimum Gain	Tx: 26.6 dBi Rx: 25.5 dBi
3 dB beamwidth	Tx: 4.2° Rx: 4.6°
Sidelobe level	Tx: -20.9 dB Rx: -21.5 dB
Approximate Mass	1.724 kg
Approximate Dimensions	Height: 340mm Width: 157mm Length: 442mm
Cross Polarisation at Boresight	Tx: -30.4 dBc Rx: -33.6 dBc

Table 5-21: Performance Data Summary (FM)

The following figures give typical antenna coverage patterns for transmit, and receive frequencies.

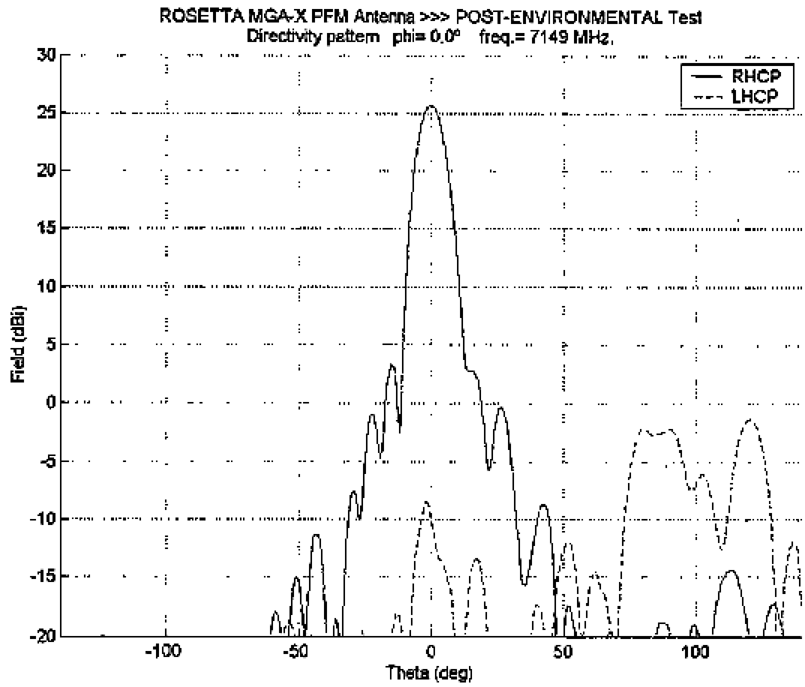


Figure 5-63: MGA-X Antenna Coverage Rx

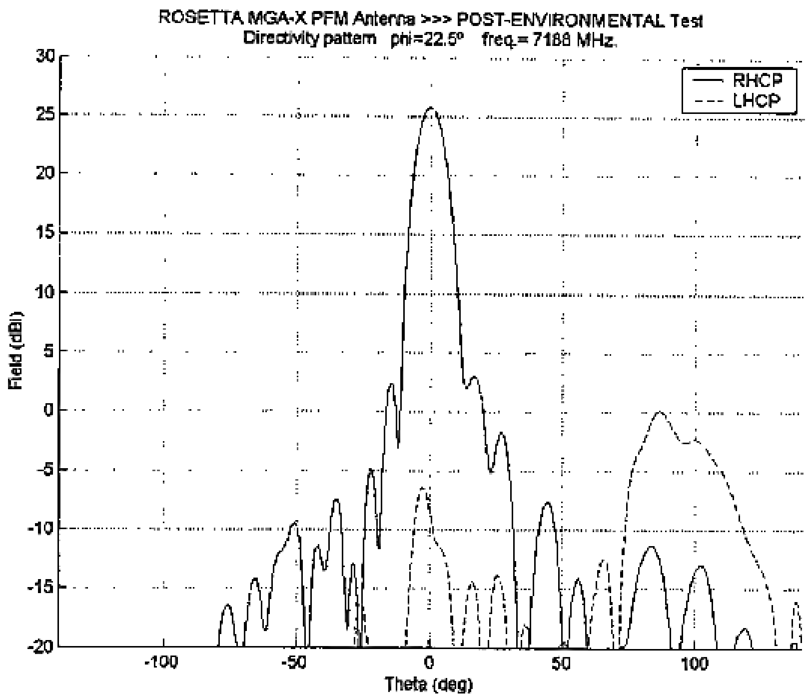


Figure 5-64: MGA-X Antenna Coverage Tx

5.3.3.2.2.3. Low Gain Antenna (LGA)

5.3.3.2.2.3.1. Overview

Two identical S-Band LGAs are used on the Rosetta spacecraft. One is mounted on the +Z face of the spacecraft orientated in the +Z+X direction and the other is on the –X wall and is orientated in a –X-Z direction. Two different designs of mounting supports are used, the +Z being 350mm tripod, whilst the –X uses a machined, angled bracket. The combination of the two LGAs provides a near omni-coverage.

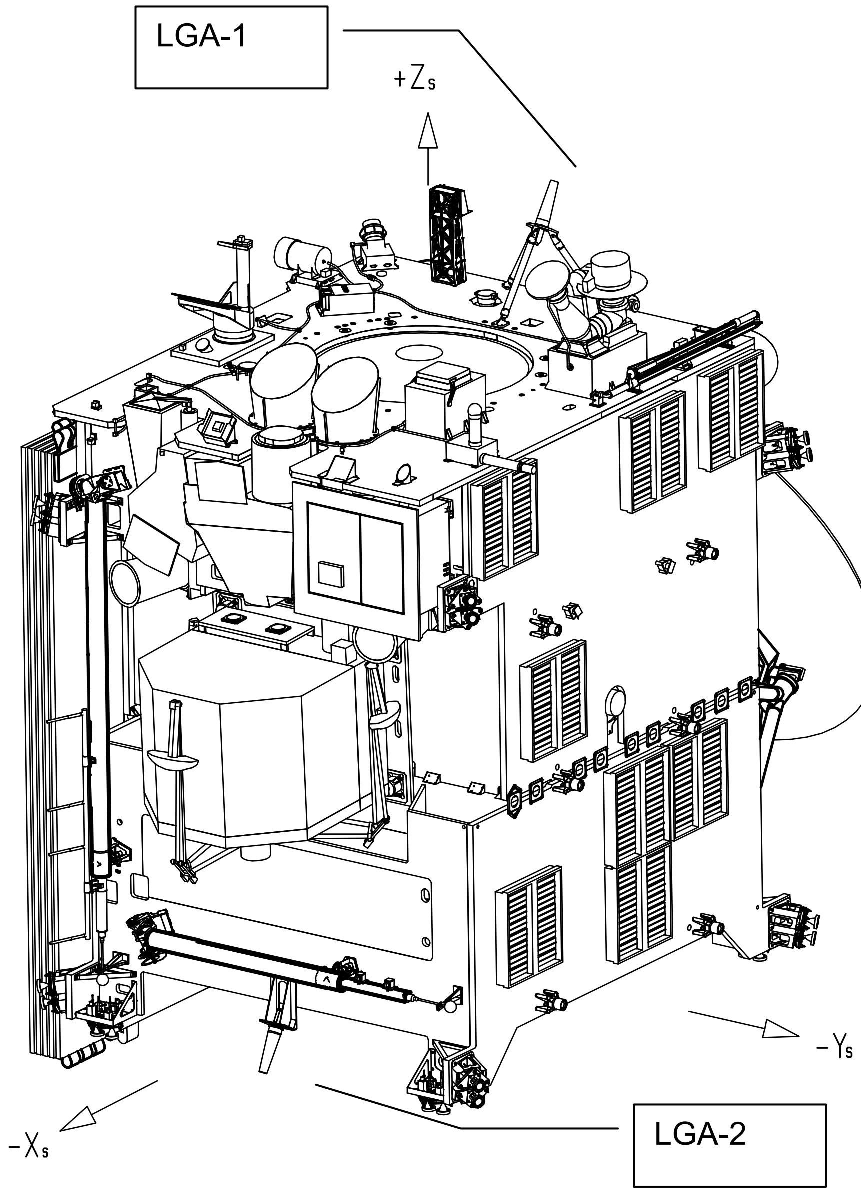


Figure 5-65: LGA Locations on spacecraft

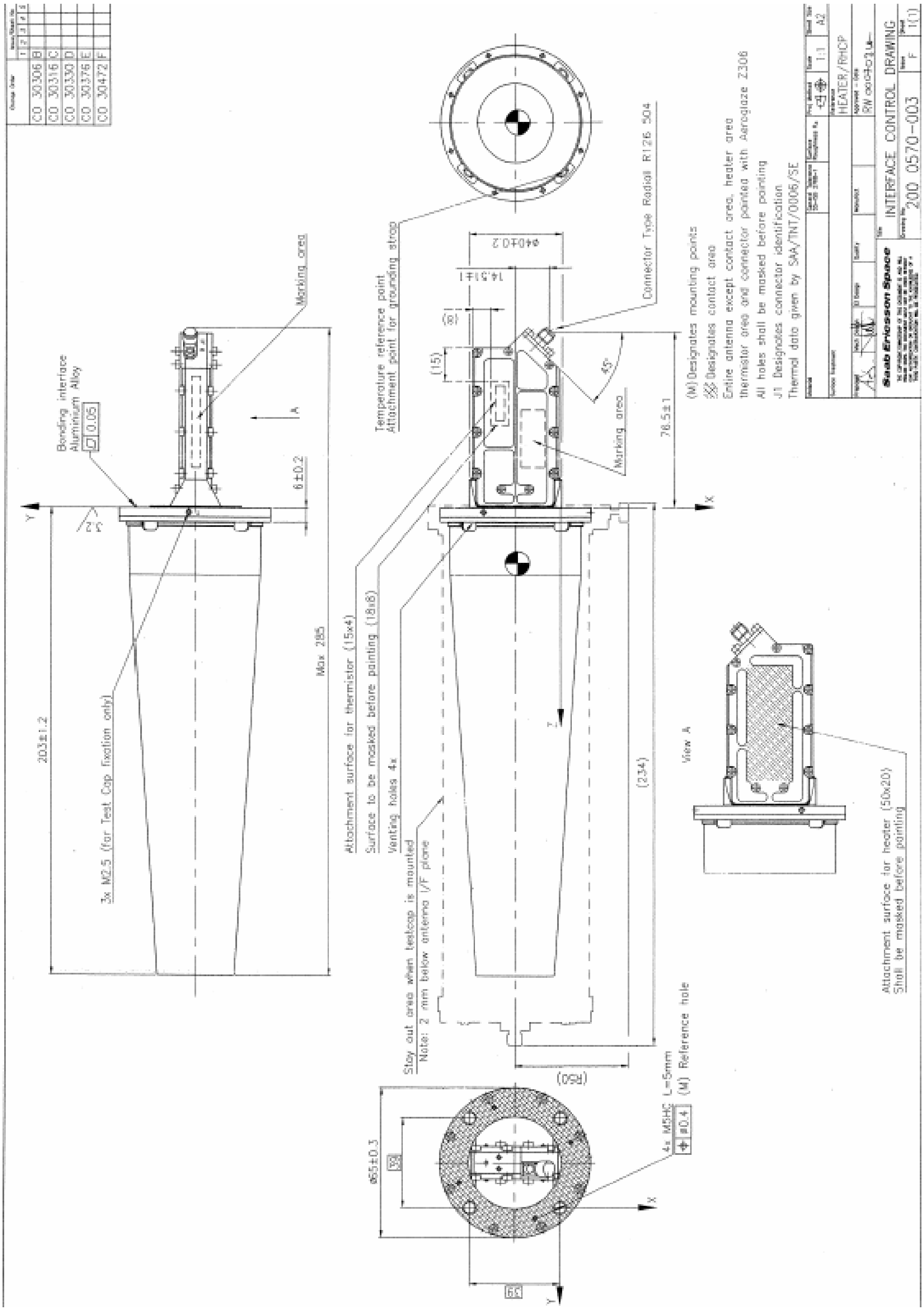


Figure 5-66: LGA Configuration

5.3.3.2.2.3.2. Physical Configuration

Each LGA is a conical quadriilar helix antenna, consisting of a helix/feeding cable assembly, a radome and a hybrid box/feeding network/mounting plane.

The antenna helices are manufactured in beryllium copper. The four central coax cables are bonded together with a GFRP cross structure to a stiff support. The hybrid box are machined out of aluminium. The radome of GFRP together with conductive paint provides the antenna with thermal and mechanical protection and prevents electrostatic discharge. The total length of the antenna is 285mm, the height from the interface surface to the top of the radome is 204mm.

5.3.3.2.2.3.3. Interfaces

The LGAs interface with the RF Distribution Unit via coaxial cable. The RF interface on the LGA is via a SMA female connector which can be seen in figure 5-66. The +Z/+X pointing LGA is attached to a 350mm tripod, which along with the base of the LGA is wrapped in MLI to provide thermal protection. Similarly the –Z-X LGA which is attached to a angled bracket, is also thermally protected using MLI. Neither of the black painted radomes of the LGAs are covered by MLI.

5.3.3.2.2.3.4. Performance Data

The typical antenna performance is listed below.

	Performance	Units
Operating Frequency	Rx: 2000-2150 Tx: 2200-2300	MHz
Polarisation	RHCP	-
Coverage	Azimuth 0-360° Elevation 0-95°	-
VSWR	Rx: < -36.5 Tx: < -22.9	dB
Power Handling	10	W
Corona	16	W
Thermal Dissipation at 5W at 10W	1.13 2.26	W
Overall Height	285	mm
Height from Interface	<204	mm
Interface Connector	SMA Female	-
Temperature Range	-145 to +140	°C
Axial Ratio	Rx: < 3.5 Tx: < 4.2	dB
Minimum co polar Gain	Rx: -1.5 Tx: -2.5	dBi
Approximate Mass	< 250	g

Table 5-22: Low Gain Antenna Performance Summary

The following figures give typical antenna coverage patterns for transmit, and receive frequecies.

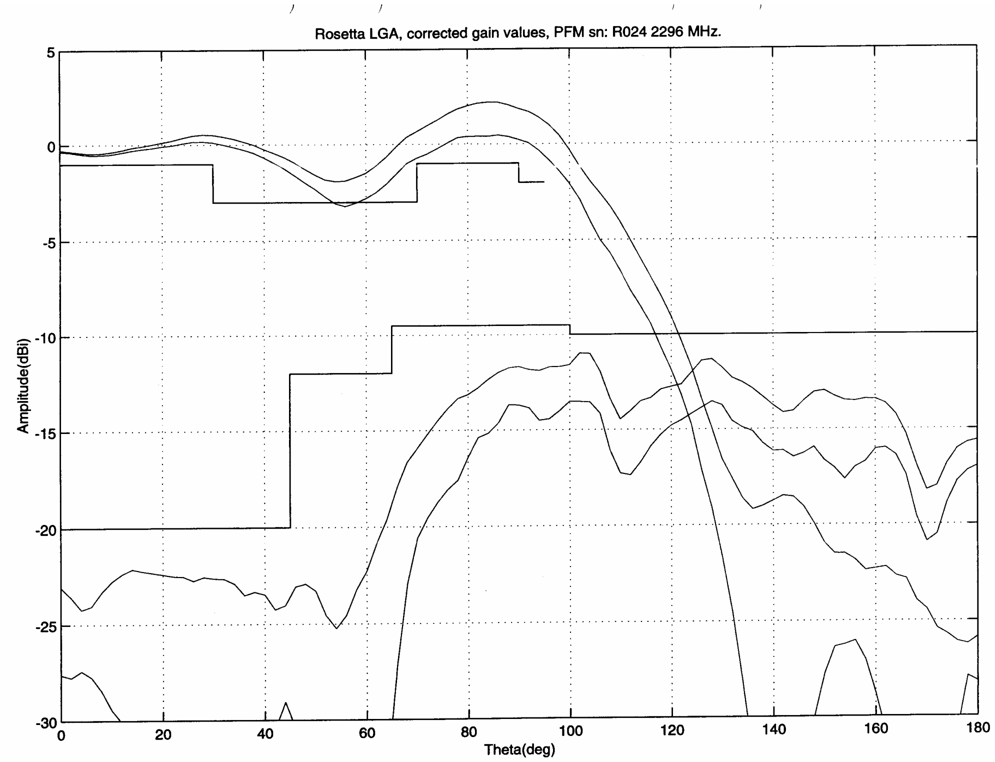


Figure 5-67: LGA Antenna Coverage Rx

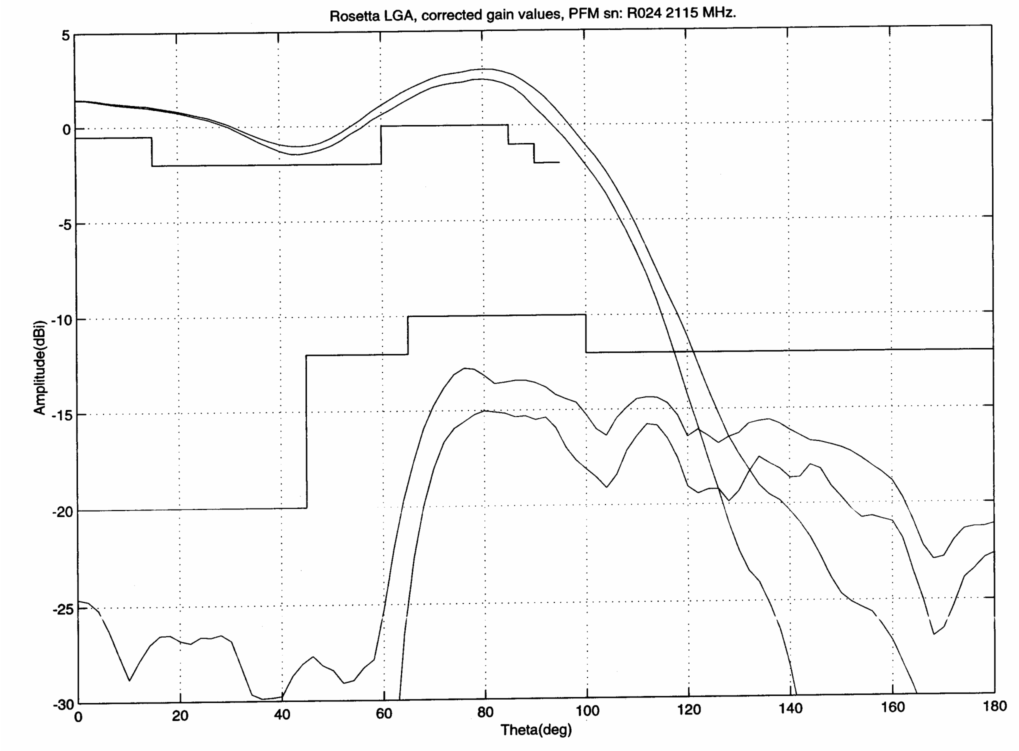


Figure 5-68: LGA Antenna Coverage Tx

5.3.3.2.2.4. S/X-Band Transponder

5.3.3.2.2.4.1. Overview

The S/X-Band Deep Space Transponder (DST) is designed to interface with the ESA and DSN ground station networks. The transponder performs the following functions:

- Reception and demodulation of the telecommand data stream from the S-Band or X-band uplink carrier providing the NRZ PSK modulated sine-wave sub-carrier to the telecommand decoder which is also part of the TRSP. The use of the S-Band or X-band for the uplink will be determined by the Ground Control Station, and will depend on various mission parameters. The Transponder Receiver will be set to operate at the appropriate frequency band by Ground Control, with the default Transponder power-up receive mode being at S-Band.
- Reception and demodulation of the Ranging uplink signal from the uplink carrier.
- Modulation of the telemetry data stream received from the telemetry encoder onto an S-Band or X-Band carrier with a selectable Modulation Index (MI).

- Modulation of the Ranging downlink signal, derived from the Transponder Receiver, onto the same S-Band or X-Band carrier as for the telemetry data stream, with an independently selectable Modulation Index

Two identical separate transponder units are installed on the Rosetta Spacecraft, to provide prime and redundant functions. The nominal operation frequencies for the transponder being :

S-Band Uplink: 2115.017747 MHz DSN CH 19

X-Band Uplink: 7168.091821 MHz DSN CH19

S-Band Downlink: 2296.851852 MHz DSN CH 19

X-Band Downlink: 8421.790124 MHz DSN CH 19

5.3.3.2.2.4.2. Physical Configuration

Each transponder is comprised of three main sections:

- Receiver Section (with selectable S-Band or X-Band front-ends)
- S-Band Transmitter
- X-Band Transmitter

The main receiver section is always powered with selection between the S-Band and X-Band front ends being by telecommands, which apply power to the selected front-end.

Within each transponder the receiver is capable of operating with either of the S-Band or X-Band transmitters. The transmitter and receiver of each transponder also has its own power supply. The S-Band and X-Band transmitters in any one transponder can be separately switched ON/OFF and can also be operated simultaneously.

The transponder also provides a number of operating modes described below:-

Coherent operation (two-way) : whereby the DST provides downlink carrier signals which are frequency coherent with the received carrier signal. The receiver provides a receiver lock status signal to indicate the presence of an uplink signal which is used by the operator to determine if satisfactory coherent operation of the transmitter can be achieved.

The relationships between the receive frequency (fu) and transmit frequencies (fd) are defined in the following table.

Frequency band for fu/fd	Frequency ratio fu/fd
S/S	221/240
S/X	221/880
X/S	749/240
X/X	749/880

- **Non-coherent operation (one-way)** : where the DST provides simultaneous receive and transmit operation at frequencies close to those of the coherent mode, but without the precise frequency relationship provide by the coherent mode.
- **High stability downlink operation:** where the simultaneous generation of the S-Band and X-Band downlink carriers is derived from an external Ultra-Stable-Oscillator source.

Note 1 : During transponder mode changes via suitable telecommands uplink carrier lock may be lost, leading to the need for the ground station to reacquire the spacecraft via the appropriate receiver.

Note 2 : The Transponder is specified in such a way that the Receiver and Transmitter together shall provide operation in a coherent mode defined as follows:

- The specified integer ratio relationship for the receive and transmit frequencies shall be met.
- The deviation of phase of the downlink signal from the theoretically predicted phase shall be limited to a value well below that necessary to meet the specified Allan Variance and shall not grow with time.

The Transponder Receiver Architecture is based on a mixture of analogue RF signal processing for the low-noise amplifier, down-conversion and IF filtering/ amplification followed by digital sampling and signal processing for the receiver acquisition, demodulation, data timing/ recovery and NCO implementation of the receiver local oscillator stages. This approach allows software control of all the critical functions of the receiver, with consequential optimisation of performance combined with flexibility.

The Transponder Transmitter Architecture is based on a SPLL followed by phase modulator and amplifier stages.

5.3.3.2.2.4.3. Interfaces

All boxes and covers are machined from an aluminium alloy block. The surface treatment is gold plated over nickel plated for RF boxes, and covers. All other parts are nickel plated.

The transponders are attched to the spacecraft wall by two “L” beams M3 screwed along the short side of the boxes. This reduces thermal resistance towards the spacecraft.

The RF interface is via SMA connectors. “DM” connectors are used for connections to the power bus, and for digital signals.

5.3.3.2.2.4.4. Performance

Key RF parameters of the Transponder allowing definition of the RF link parameters. More data can be found in RO-MMB-RP-3106.

Transponder parameter		Value
S-Band	Rx Frequency	2115.017747 MHz
	Tx Frequency	2296.851852 MHz
X-Band	Rx Frequency	7168.091821 MHz
	Tx Frequency	8421.790124 MHz
S-Band Noise Figure		2.0 dB nom
X-Band Noise Figure		1.9 dB nom
S- Acquisition Threshold		-146 dBm
X- Acquisition Threshold		-145.0 dBm
S-Band Tracking Range		+/- 100 kHz
X-Band Tracking Range		+/- 250 kHz
TC Recovery Implementation loss		3.0 dB typically, up to 4.5 dB for low bit rates
Ranging channel implementation loss		1.5 dB (X-band nom) 2.0 dB (S-band nom)
S-Band RF output power		37.7 dBm nom
X-Band RF output power		6 +/- 1 dBm

Transponder parameter	Value
Acquisition/Doppler characteristics For carrier > -146dBm For carrier > -126dBm	97% or better acquisition probability for Doppler sweep not greater than 20Hz/s 97% or better acquisition probability for Doppler sweep not greater than 500Hz/s
Approximate Dimensions	254 x 184 x 160 mm
Approximate Mass	6.25 kg

Table 5-23: Transponder Performance (FM)

5.3.3.2.2.4.5. Initial Settings of Transponder

The initial transponder status after

- Power-On Reset
- External Reset
- Watchdog Reset

has triggered, the starting configuration is the following:

<u>TX Section</u>

- Telemetry Modulation OFF;
- Ranging Modulation OFF;
- Telemetry Modulation Index 0.8 rad peak;
- Ranging Modulation Index 0.7 rad peak;
- S-Band TX ON/OFF: state before reset is re-established
- X-Band TX ON/OFF: state before reset is re-established

RX Section

- The S band RX is selected
- Bit Rate = 7.8125 bps
- Non Coherent Mode
- Internal TCXO is selected

Initial transmitter status after Transmitter ON command

When the transponder S-Band Transmitter is switched ON, the transponder enters following initial transmitter status :

- Coherency : Last state remains
- S-Band Telemetry OFF
- S-Band Ranging OFF
- S-Band TM modulation index = 0.8rad
- S-Band Ranging modulation index = 0.7 rad

When the transponder X-Band Transmitter is switched ON, the transponder enters following initial transmitter status :

- Coherency : Last state remains
- X-Band Telemetry OFF
- X-Band Ranging OFF
- X-Band TM modulation index = 0.8rad
- X-Band Ranging modulation index = 0.7 rad

5.3.3.2.2.4.6. Uplink Acquisition of Transponder

The methods, how to acquire the receiver during the different flight phases are described in RO-DSS-TN-1180, "Rosetta Acquisition Procedure".

5.3.3.2.2.5. Ultra Stable Oscillator (USO)

5.3.3.2.2.5.1. Overview

The prime purpose of the USO is to act as a phase coherent frequency source for the simultaneous S-Band and X-Band downlink transmission operated in one-way transponder mode, for the purpose of Radio Science experiments. The main requirements of the USO are to have a very good short term frequency stability (Allan Variance), and a very low phase noise.

The USO design is based on a unique crystal resonator design, using a 5MHz resonator, frequency synthesiser and VCXO to achieve a 38.28076977 MHz output.

The USO is a non-redundant equipment with redundant TC interfaces allowing it to be controlled via either RTU and provides redundant frequency outputs, one dedicated to each transponder.

5.3.3.2.2.5.2. Physical Configuration

The USO is housed in a single, aluminium shielded box flat mounted using four mounting feet. It is divided into two compartments, the lower one is in mechanical and thermal contact with the mounting plate. This lower compartment accommodates the power input filter, and the power conditioning circuitry. The individual circuits are shielded to achieve EMC requirements.

The upper compartment comprises the USO unit itself, which resembles closely the PRARE USO design. Again, this USO compartment is subdivided into two units:

- An output compartment, which holds the non-ovenised elements of the oscillator including the 'high' power dissipating electrical elements.
- The oscillator compartment, which encapsulates in Aluminium sidewalls the glass dewar.

Inside the dewar, the oven and ovenised elements of the oscillator are located. The dewar is fully surrounded by a damping and thermal insulation medium. The dewar itself is made from DURAN glass, with 4 supporting studs at the end opposing the opening. This design has been verified to sustain the launch environment and to support the rather heavy oven and internal electronics. The dewar is silver coated and a magnetic shield is wound around the outside of the dewar. The dewar opening is closed with a thermal insulating open cell foam.

The complete unit is vented.

5.3.3.2.2.5.3. Functions

The USO can be muted via telecommand, to prevent breakthrough of the signal in the cases when the transponder's own oscillator will be used. This will stop any possible errors being introduced to the downlinked signal while ranging for example.

5.3.3.2.2.5.4. Interfaces

RF output from the USO is via a female SMA connector located on the unit's case.

TM/TC and power are provided to the USO via a single sub miniature D type connector.

For thermal reasons, the unit is painted black.

5.3.3.2.2.6. Performances

Parameter	Value
Frequency Synthesiser Output	38.28086420 MHz -2.631/+0.15 ppm
Output Level	0 dBm +/- 1 dB in 50 Ohms
Approximate size	152 x 130 x 90 mm
Approximate Mass	1.45 kg
Approximate power consumption	4 – 5.5 W (Steady state) 6.5 – 8 W (Warm up)

Table 5-24: USO Performance

5.3.3.2.2.7. X-Band Travelling Wave Tube Amplifiers (TWTA)

5.3.3.2.2.7.1. Overview

The TWTA consists of :

- TWT (Travelling Wave Tube)
- EPC (Electrical Power Conditioner)
- High Voltage (HV) cable connecting the TWTA and EPC

The EPC is a high voltage converter providing the various voltages required by the TWT, and the secondary functions such as TM/TC interfaces.

The housing is made of an aluminium milled box. A central wall separates the low voltage and the high voltage sections. The EPC contains the following modules:

- Hybrid circuit containing the input regulator, power transistor and drivers
- One low-voltage board containing the input filter, EPC control and the auxiliary converter
- One high-voltage stacked module containing the high-voltage transformer and rectifier circuits
- One high voltage module containing the high voltage filters and helix regulator
- One high voltage module containing the filament and Wehnelt transformer and the cathode current regulator.

The EPC contains a cavity for the TWT cable interconnection.

The TWT consists of an electron gun, a delay line, and a collector. The structure of the EPC, and TWT with the RF interfaces and connecting HV cable can be seen in Figure 5-69

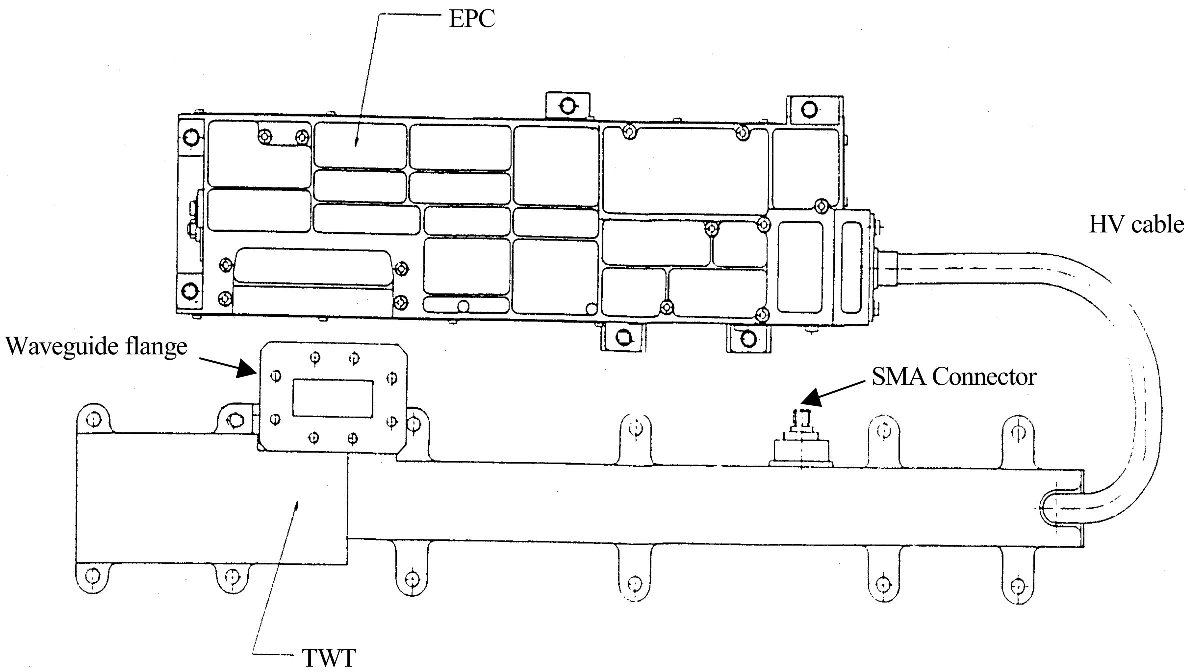


Figure 5-69: TWTA Schematic

5.3.3.2.2.7.2. Physical Configuration

The Travelling Wave Tube is an off-the-shelf product from Thomson Tubes Electroniques (TWT TH3908a), as used on the METOP programme. This TWT is optimised for delivering an output power in the range 15-30W with a flat response in the 7.5 to 8.5 GHz frequency range. The X-Band TWTAs guaranteed power output is 28.5 W, typically 29W is achieved.

The saturated gain of the TWT is in the range 53-58dB. Once the final value of saturated gain is known, from the flight TWT data and transponder X band output power, an input attenuator will be selected to ensure that the TWT operates at or close to saturation. To allow late selection of value, a range of attenuators is supplied to AIV.

The EPC is a high efficiency high voltage converter which provides the various voltages required by the TWT and the secondary functions such as TC and TM interfaces and protection interfaces.

5.3.3.2.2.7.3. Functions

The main functions of the EPC are

- Telecommand Interface
- Telemetry Signals
- Process adapted for TWTA operations (optimised start up, and shutdown sequence, IK regulation)
- Protection of circuits for spurious switch off of TWTA as well as high voltage circuit
- Power Bus Interface
- Auxiliary Voltages generation

5.3.3.2.2.7.3.1. High Voltage Generation

The high voltages for the TWT are provided by the High Voltage Transformer. The circuit consists of several layers including diode rectifiers, voltage doublers, high voltage capacitors and helix and anode regulators.

The EPC is able to sustain short TWT arcing up to ~1ms without causing any spurious switch off. For longer arcs the EPC will enter the auto-start mode or will switch off.

5.3.3.2.2.7.3.2. Helix Regulator

The helix regulator provides the very high stability helix to cathode voltage which is essential to the RF performance of the TWT. It also suppresses the ripples from the high voltage converter.

5.3.3.2.2.7.3.3. Cathode Current Regulator

In order to compensate the degradation of the cathode characteristics over the life of the TWT, the EPC includes a regulator that adapts the anode voltage in order to provide a constant cathode current.

5.3.3.2.2.7.3.4. TWTA Switch On/Off

During the first 30 seconds after start-up, the auxiliary supply provides only half the nominal voltage. This is used to limit the tube filament current to ~1A when the filament is cold. After 30s the nominal voltages are provided:

- The pre-heating phase is started by the TWTA_ON command. The pre-heating phase continues for 3 minutes, during which the high voltage switch ON is inhibited.
- At the end of the 3 minutes pre-heating, the ASIC waits for an HT_ON command after which the high voltages are enabled.
- If a HT-ON command is received during the pre-heating phase, it is memorised and the high voltages are switched on as soon as the 3 minutes pre-heating phase is complete.
- A HT-OFF command removes the high voltages, but the pre-heating supply remains ON.
- A TWTA_OFF command firstly removes the high voltage generation and then the auxiliary pre-heating supply is shut down.

5.3.3.2.2.7.3.5. EPC Protection circuits

The following protections are implemented within the EPC:

- High Voltage Protection
- Helix Overcurrent protection (Disabled at harness level)
- Bus Under-voltage Protection
- Input Current

<u>Bus Current Limiter</u>

The bus current is not directly limited , but by the limitation of the primary regulator output current. In case of a short circuit at the EPC secondary high voltage output, the limited bus current will cause a reduction of the buck voltage, that will trigger the under-voltage protection circuit.

Primary Over-voltage

If the HV Primary voltage exceeds 22V (±10%) a signal is sent to the ASIC which starts the switch off sequence.

Primary Under-voltage

If the HV Primary voltage reduces below approximately 17.6V a signal is sent to the ASIC to start the switch off sequence.

Bus Under-voltage

If the bus voltage drops below approximately 24.4V a signal is sent to the EPC to start the switch off sequence.

Auxiliary Under-voltage

If the auxiliary 10V supply voltage drops below approximately 7.6V a signal is sent to the EPC to start the switch off sequence.

TWT Short Circuit Protection

The TWT is passively protected against TWT short circuit by the necessary component ratings/tolerances.

Auxiliary Supply Current Limitation

The auxiliary supply is switched off as soon as the auxiliary supply current reaches approximately 700mA. Since the start up circuit is not activated, the EPC internal supply voltages will disappear, leading to switch off of the EPC.

The EPC/TWT protection logic flow is summarised below.

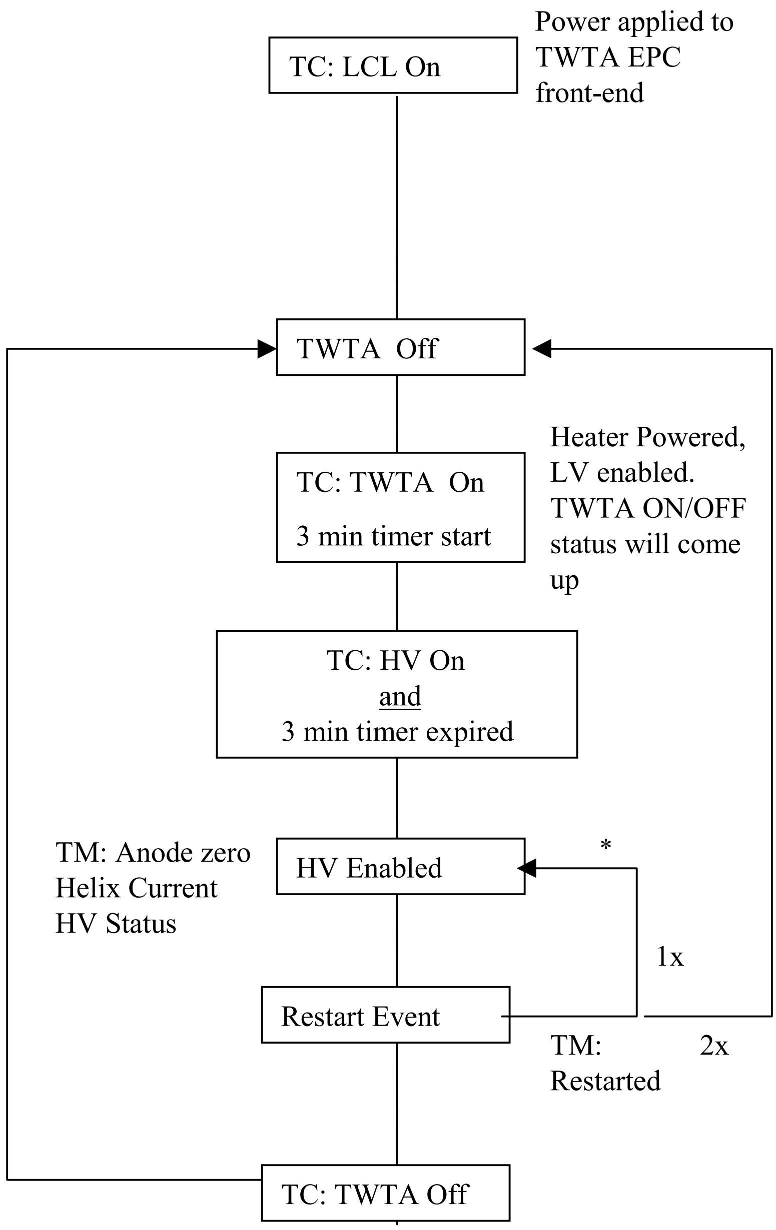


Figure 5-70: EPC Block Diagram

* Restart timer TM shows active for duration of restart (3 minutes).

5.3.3.2.2.7.3.6. EPC Control and Telemetry

This circuit performs the following functions:

- Converter Synchronisation
- Telecommand processing

- EPC Switch-On and Off operations
- Protection management
- Auto-Restart Management
- Clocks and Timer Generation (pre-heating, auto-start)

The EPC contains four telecommand lines providing TWTA ON/OFF and high voltage voltage ON/OFF:

The EPC contains two status and two analogue telemetry outputs:

- TWTA On/Off Status
- TWTA HT On/Off Status
- Helix Current
- Anode Voltage

One telemetry point provides the internal EPC temperature close to the hybrid power circuits.

5.3.3.2.2.7.4. Interfaces

The EPC has no RF inputs, or outputs, and has only one connector for TM/TC, and power inputs. The High Voltage cable is a braided multi-core cable which is permanently wired between the EPC and the TWT. The EPC does not provide redundant command inputs.

The RF input from the 3dB hybrid to the TWT is via a female SMA connector. The RF output from the TWT is via a WR-112 waveguide flange which will be fixed to the appropriate WIU input flange using 8 bolts.

The EPC is connected to the SC wall using 6 bolts, and the TWT is connected to the SC wall using 12 bolts.

The TWT must be kept within an operating range of –35 to 85 Celcius, to achieve this, the TWT is painted black, and both the TWT, and EPC are designed for conduction cooling via the baseplate.

5.3.3.2.2.7.5. Performance

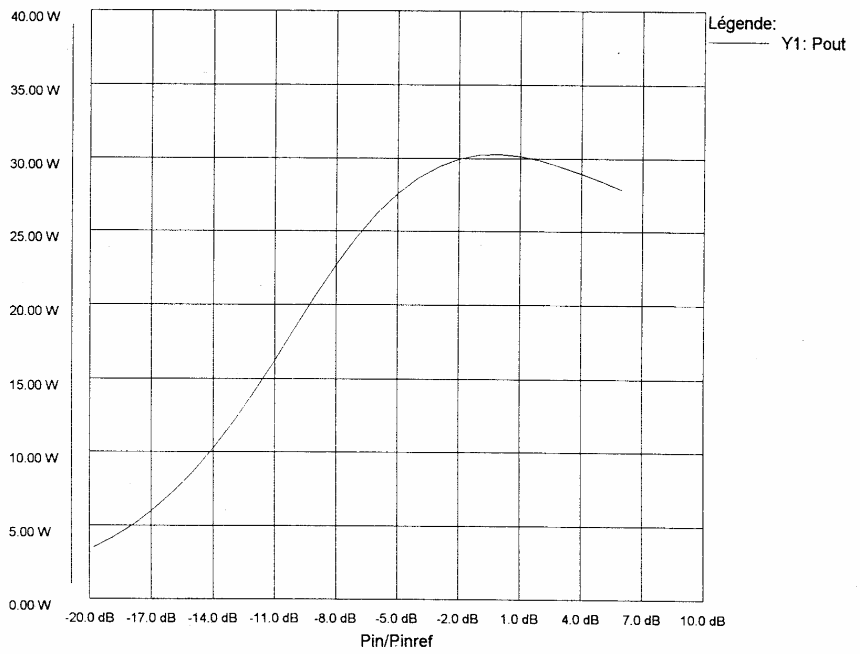
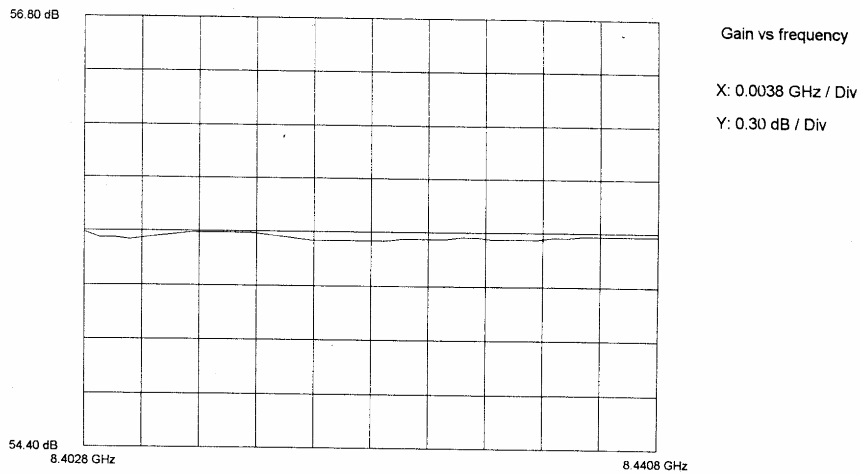


Figure 5-71: Typical Gain (Pinref –10.93 dBm)

Pin ref : -10.8 dB
Current Pin / Pin ref : 0 dB



DELTA GAIN [0.00 dB .. 0.20 dB]: 0.04 dB
MEAN GAIN : 55.57 dB
Slope / MHz [0.000 dB/MHz .. 0.010 dB/MHz]: 0.030 dB/MHz

Figure 5-72: Typical Frequency Response

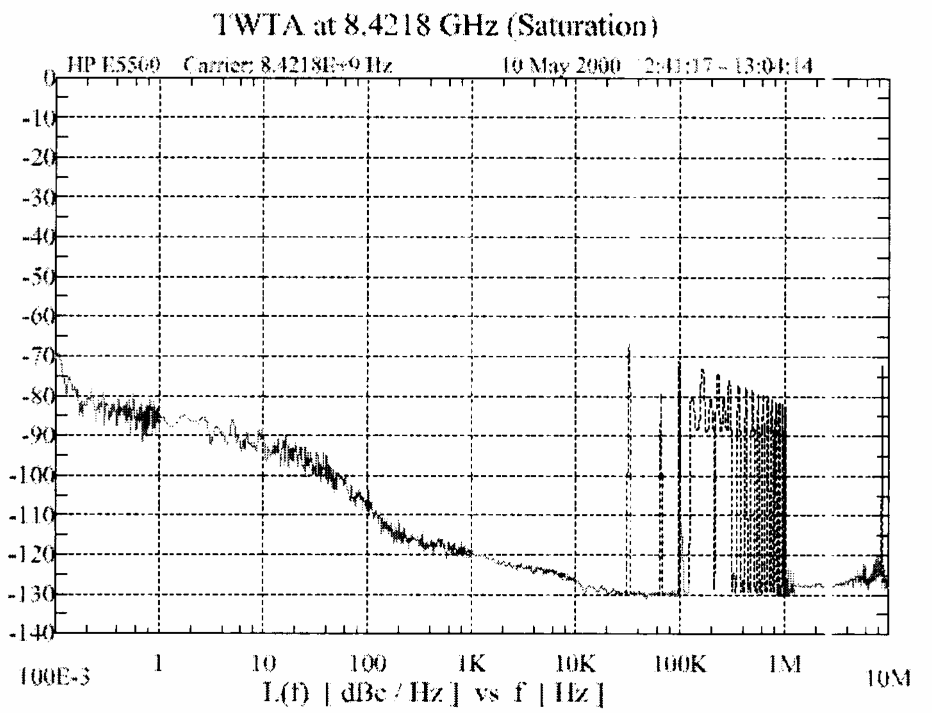


Figure 5-73: TWTA Spurious (RSI Tests)

Parameter		Value
Electrical consumption at	Saturation	57 W max
	Dissipation	28 W max
Approximate Dimensions		360 x 83 x 54 mm
Approximate Mass		750 g

Table 5-25: Typical TWT performance

Parameter	Value
Max power dissipation	7.5 W
Approximate Dimensions	250 x 84 x 105 mm
Approximate Mass	1400 g

Table 5-26: Typical EPC Performance

5.3.3.2.2.8. Waveguide Interface Unit (WIU)

The Waveguide Interface Unit (WIU) is designed to switch receive signals from either of the HGA or MGA-X antennae to either of two transponders and transmit signals from either TWTA to the two antennae. A block diagram of the WIU is shown below:

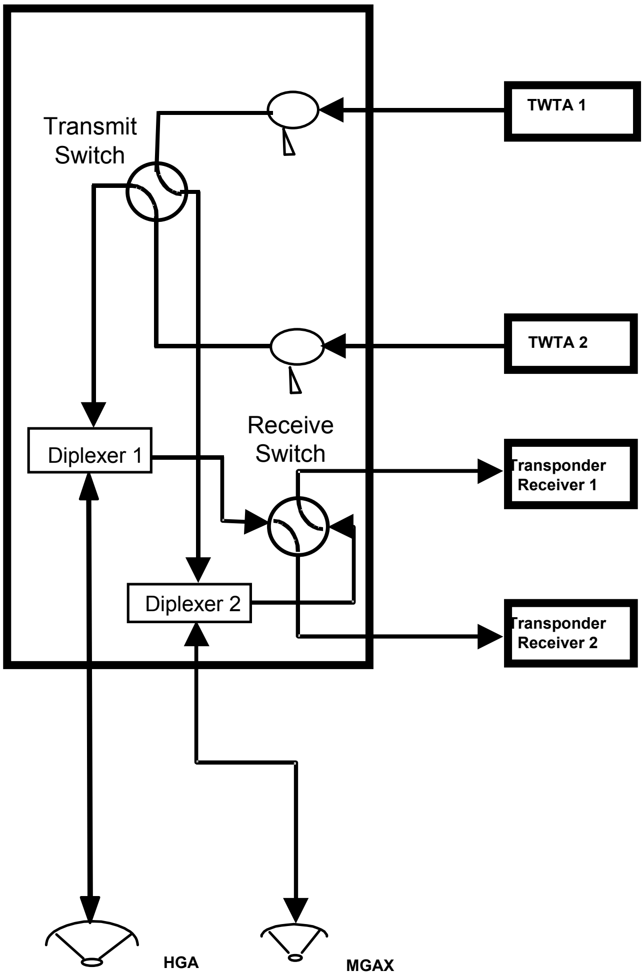


Figure 5-74 : Waveguide Interface Unit (WIU) Block Diagram

5.3.3.2.2.8.1. Function

The unit operates at X Band over the frequency range 7.1 – 8.5 GHz and has been designed to perform the following specific functions :-

- Transfer the X-Band uplink signals received by two X-band Antennas to two X-Band Telecommand/Ranging Receivers, without any receive signal path combining.
- Transfer the X-Band transmit outputs from two Travelling Wave Tube Amplifiers (TWTA) to the two X-Band Antennas without transmit signal path combining.

- Permit simultaneous operation of the receiver and transmitter equipment functions without mutual signal interference, degradation of performance or damage.
- By external command signals, it is possible to interchange the two antenna signal path routes to the two receivers, without affecting the transmit signal path routes.

By external command signals, it is possible to interchange the two antenna signal path routes to the two transmitters, without affecting the receive path signal routes.

5.3.3.2.2.8.2. Physical Configuration

The WIU consists of the following major components:

- Two high power isolators.
- Two waveguide transfer switches.
- Two Waveguide Diplexers.
- Various lengths of interconnecting waveguide.

All of the parts are made from aluminium, and the approximate mass is 3.9 kg. Flexible sections of waveguide are included in the WIU to make connection to the TWTAs easier if there are slight missalignment errors.

The following diagram shows the physical layout of the WIU.

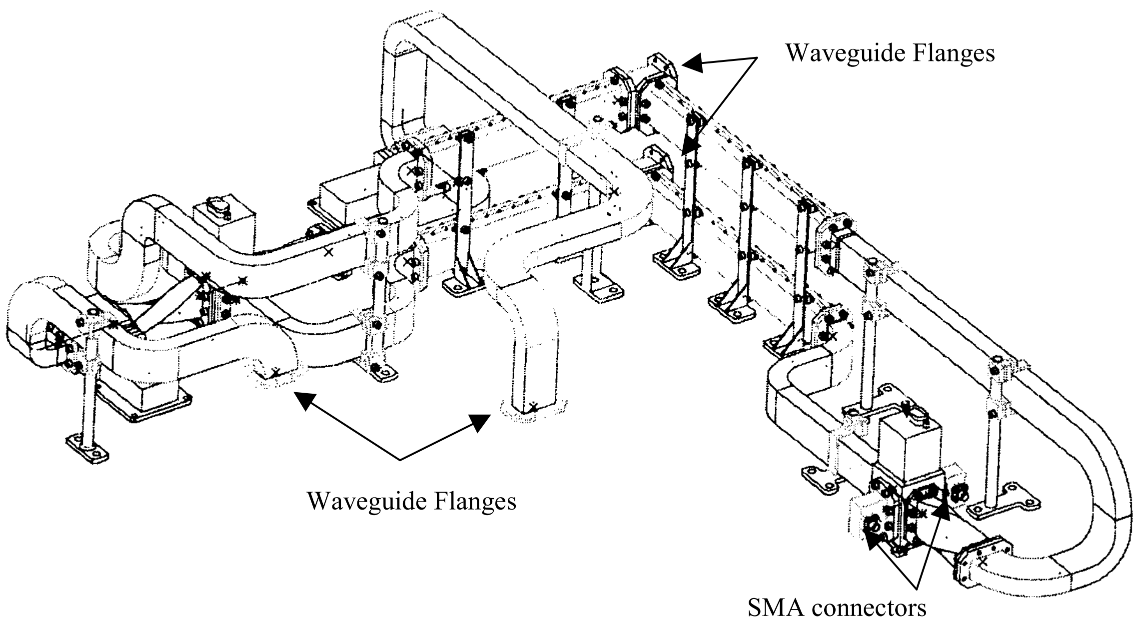


Figure 5-75: WIU Isometric Drawing

5.3.3.2.2.8.3. Interfaces

The WIU is connected to the TWTAs, and Antennas via type WR-112 waveguides. The WIU will be directly connected to the TWTAs via the waveguide flanges shown in the centre of Figure 5-75, intermediate waveguides will be used to connect the WIU to the antennas. The four waveguide flanges are rectangular in shape, and terminate in flanges approximately 35mm x 51mm in size. These flanges are attached to the intermediate waveguide sections, or TWTA flanges using 8 bolts each.

Two female SMA connectors are used to connect the WIU with the transponders using coaxial cable.

The SMA connectors, and waveguide flanges are highlighted in Figure 5-75.

The WIU is painted black for thermal reasons, and is attached the the SC panel using 42 M3 screws.

5.3.3.2.2.8.4. Performance Data

Detailed performance data can be found in RO-AEO-DD-3002, and a summary is shown below.

Parameter	PFM Value
Insertion Loss	0.44 dB
Input Return Loss	28.9 dB
Output Return Loss	32.4 dB
Isolation Tx path	112 dB
Rejection 6.62 – 6.93 GHz	33.6 dB
Approximate Passband	7000 to 7400 MHz

Table 5-27: Worst case Rx Path Performances

Parameter	PFM Value
Insertion Loss	0.64 dB
Input Return Loss	26.8 dB
Output Return Loss	25.8 dB
Isolation Rx path	111 dB
Rejection 2nd Harmonic	70 dB
Rejection 3rd Harmonic	14.7 dB
Approximate Passband	8100 to 8700 MHz

Table 5-28: Worst case Tx Path Performances

Corona effects

The Rx path is a low power path and so not susceptible to corona effects. For the Tx path a high vacuum level will be achieved inside the unit some hours after launching. The unit is foreseen to be powered up at least one day after launching, therefore no corona risk exists under normal unit operation.

5.3.3.2.2.8.5. Operational Modes

The High Power Isolators protect the TWTAs, should the antennae be switched between the MGA and HGA without switching off the TWTA.

The X-Band RF signals from each of the TWTAs are connected to a high power isolator which ensures a good impedance match for the TWTA output, preventing damage. The transmit signal is then applied to the transmit path waveguide switch which allows the signal to be routed to either of the transmit diplexer filters and subsequently routed to either the High Gain Antenna (HGA) or Medium Gain

Antenna (MGA-X). The purpose of the diplexer filter is to allow both the transmit and receive signals to share the same antenna without mutual signal interference. The Input / Output of each diplexer is connected to one antenna.

Uplink signals received from each antenna are applied to the receive filters of the diplexers which in turn are connected to the receive path waveguide switch. The receive path waveguide switch routes the signal from either antenna to either of the transponder receivers.

5.3.3.2.2.9. Radio Frequency Distribution Unit (RFDU)

The Radio Frequency Distribution Unit (RFDU) forms part of the Rosetta Platform TT&C subsystem and is designed to route Radio Frequency (RF) signals between the main and redundant S-Band transponders and the four S-Band antennas. The RFDU incorporates two diplexer filters in order to allow simultaneous S-Band transmit and receive capability without mutual interference.

The RFDU is a passive microwave equipment consisting the following major components:

- Two diplexers.
- Five coaxial transfer switches.

Figure 5-76 shows a block diagram of the RFDU, Figure 5-77 shows the actual structure of the RFDU.

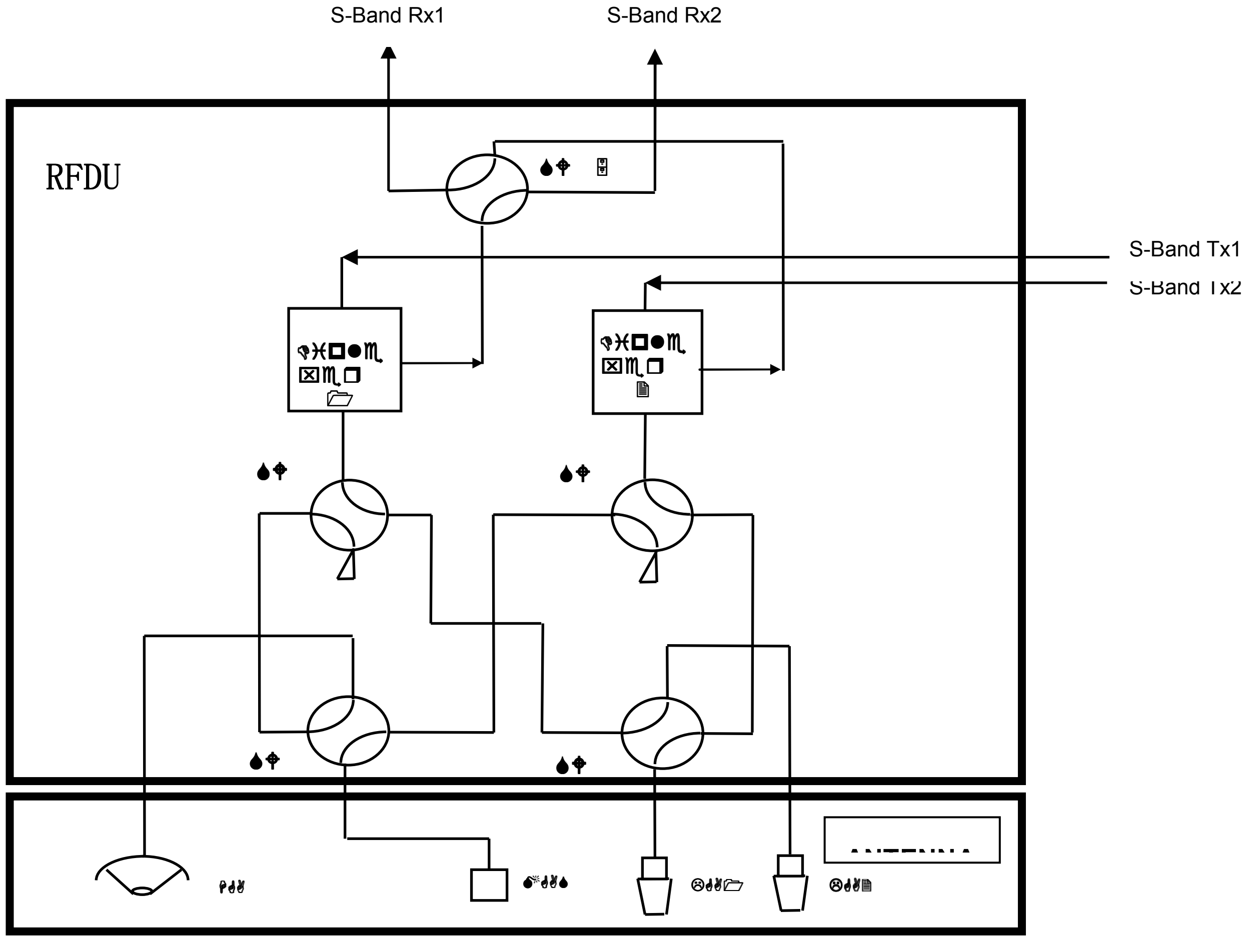


Figure 5-76: RFDU Block Diagram

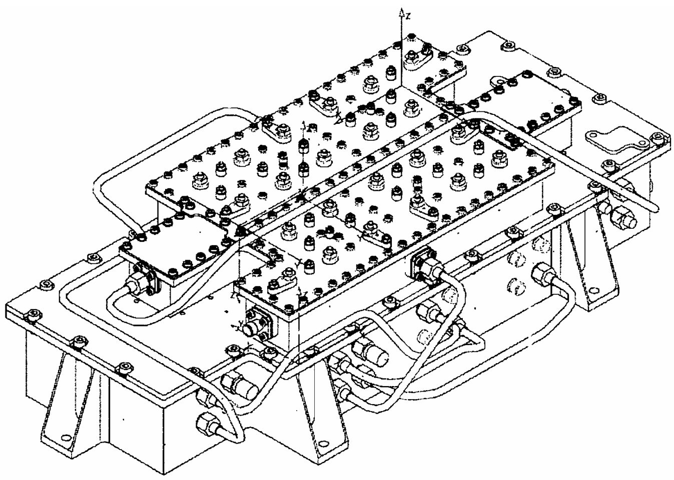


Figure 5-77: RFDU Isometric Drawing

The five switches route the RF signal from the transponders to the antennas and from the antennas to the transponders. Intermediate switches are terminated with a matched 50 Ω termination to absorb any reflected signal.
The Diplexers allow the transponders to transmit and receive simultaneously using the same antenna without causing any interference. The diplexer also serves as a filter, rejecting unwanted frequencies.

5.3.3.2.2.9.1. Interfaces

The RFDU is connected to the antennas and transponders via coaxial cable. The outputs from the RFDU terminate in SMA connectors.

The RFDU will be mounted on the +Y SC panel with 7 screws, and is painted black for thermal reasons.

5.3.3.2.2.9.2. Performance Data

The performance summary is shown below.

Parameter	Value (PFM)
I/O Return Loss	>20 dB
Tx Path Insertion Loss	<1.1 dB
Rx Path Insertion Loss	<1.87 dB
Rx Rejection Frequency 500 – 1900 MHz 1900 – 1950 MHz 2200 MHz 2230 – 2290 MHz: 2291.66 – 2299.814 MMHz 4593.7038 MHz 6890.5557 MHz 8421.7899 MHz 2300 – 16000 MHz	 > 70 dB > 60 dB > 58 dB > 70 dB > 80 dB > 65 dB > 65 dB > 65 dB > 38.7 dB
Tx Rejection Frequency 2100 – 2130 MHz 2110.243 – 2117.746 MHz	 > 70 dB > 80 dB
Switch DC power consumption	2.18 W
Approximate Rx Passband	2075 to 2145 MHz
Approximate Tx Passband	2260 to 2355 MHz

Table 5-29: RFDU Performance Data

5.3.3.2.2.10. X-Band 3dB Hybrid

The X-Band 3dB hybrid which is being supplied by Alcatel Espacio is a four port hybrid that combines the X-Band signals from each transponder transmitter and presents them to the two Travelling Wave Tube Amplifiers, via an attenuator. The hybrid provides a high degree of isolation between the two transponder outputs. Connections are made to the hybrid via coaxial cable with SMA connectors.

5.3.3.2.2.11. Waveguide

The interconnection at X-Band between the Waveguide Interface Unit, the TWTAs and Antennas is achieved using waveguide type WR112 supplied to Alcatel Espacio. The waveguide runs to the antennas are connected to the WIU via a waveguide flange which passes through a cutout in the +X spacecraft wall. Once the waveguide has exited the spacecraft it is routed up and across the wall to the MGA-X and down along the +X wall to the High Gain Antenna (HGA). At the other end of the waveguide run there is another waveguide flange providing the interface to the antennas.

The waveguides can be seen in Figure 5-78.

The waveguides have flexible sections in them to allow for thermal expansion, and they will be attached to the SC via brackets which will be attached to the walls with 2 bolts. These brackets will have a maximum distance between them in the range 261mm to 408mm, see [RO-MMB-TN-3153]. The waveguide which feeds the MGAX antenna will be held 39mm above the SC wall, and the waveguide which feeds the HGA antenna will be held 29mm above the SC wall. The waverguides will be under the MLI blankets which cover the external surface of the spacecraft.

For test, waveguide test couplers will be fitted within the waveguide runs to the antennas, and will be removed for flight. The test couplers will replace short sections of waveguide which feed the HGA, and MGA-X antennae, these waveguide sections are designated W005, and W006 as described in RO-AET-TN-1017. The test coupler has a waveguide input, and output, and a corresponding SMA output and input which are used to connect it to the test equipment.

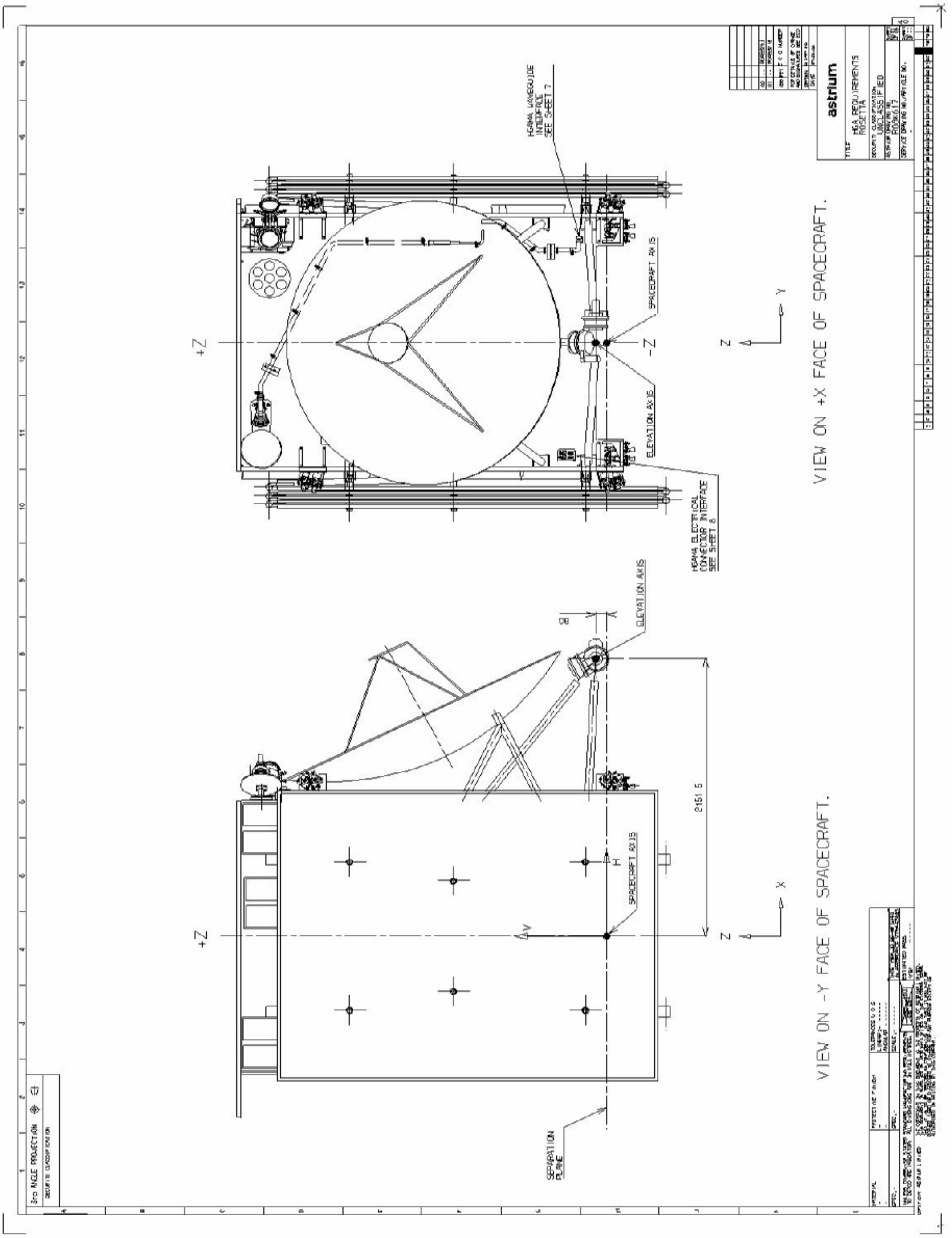


Figure 5-78: Waveguide route to MGA-X and HGA

5.3.3.2.2.12. Coax

The interconnection at S-Band between the various elements of the TTC sub-system is via coaxial cable. A trade off was performed between insertion loss and mass resulting in Gore G6 Type 42 (or equivalent) being selected. This type of coax is constructed using a large centre conductor surrounded by a PTFE dielectric core which is further surrounded by two levels of screening, a helically wound silver plated foil followed by a braided round wire providing a mechanical shield. The coaxial cable is routed around the inside of the spacecraft to and from the RFDU until finally exiting to the four external antennas, High Gain Antenna (HGA), Medium Gain Antenna (MGA-S) and two Low Gain Antennas (LGAs).

The same type of coaxial cable is also used to provide the interconnections between the transponder and Hybrid, Hybrid and attenuator, attenuator and TWTA and the WIU and transponder at X-Band.

The coax cables will be held to the spacecraft using tie downs at regular intervals of approximately 150mm.

No specific test couplers are provided at S-Band. Test access is achieved by connection to unit/antenna connectors or coax.

5.3.3.2.3. SUBSYSTEM BUDGETS

5.3.3.2.3.1. Mass

Mass budget information can be found in RO-MMB-TN-3153.

5.3.3.2.3.2. Power

Power budget information can be found in RO-MMB-RP-3106.

5.3.3.3. Telemetry and Telecommands

5.3.3.3.1. Telecommands

See Annex 2, sections 8.7 … 8.12.

5.3.3.3.2. Telemetry

The following tables list the telemetry applicable to the TT&C units.

Telemetry Name	Telemetry Label	Type	Comments
NTTDWI01	SWITCH 6 TLM	RSS	
NTTDWI02	SWITCH 7 TLM	RSS	
NTTDWI03	SWITCH 6 TLM RED	RSS	
NTTDWI04	SWITCH 7 TLM RED	RSS	

Table 5-35: WIU Telemetry

Telemetry Name	Telemetry Label	Type	Comments
NTTDRF01	SWITCH 1 TLM	RSS	
NTTDRF02	SWITCH 2 TLM	RSS	
NTTDRF03	SWITCH 3 TLM	RSS	
NTTDRF04	SWITCH 4 TLM	RSS	
NTTDRF05	SWITCH 5 TLM	RSS	
NTTDRF11	SWITCH 1 TLM RED	RSS	
NTTDRF12	SWITCH 2 TLM RED	RSS	
NTTDRF13	SWITCH 3 TLM RED	RSS	
NTTDRF14	SWITCH 4 TLM RED	RSS	
NTTDRF15	SWITCH 5 TLM RED	RSS	

Table 5-36: RFDU Telemetry

Telemetry Name	Telemetry Label	Type	Comments
NTTAUS10	USO DC CURRENT A	ANA	
NTTAUS20	USO DC VOLTAGE A	ANA	
NTTAUS30	USO OVEN TEMP A	ANA	

Telemetry Name	Telemetry Label	Type	Comments
NTTAUS40	USO OVEN TEMP B	ANA	
NTTAUS50	USO POWER MON 1A	ANA	
NTTAUS60	USO POWER MON 2A	ANA	
NTTAUS70	USO UNIT TEMP	ANA	
NTTAUS80	LOCK STATUS A	ANA	
NTTAUS90	LOCK STATUS B	ANA	
NTTDUSR3	USO ON/OFF ST A	DIG	
NTTDUSR1	USO RF SIGNAL MUTE ST	DIG	
NTTDUSR2	USO OVEN TEMP SHIFT ST		

Table 5-37: USO Telemetry

Telemetry Name	Telemetry Label	Type	Comments
NTTAT110	TWTA 1 EPC TEMP	ANA	
NTTAT120	TWTA 1 TLM A0	ANA	
NTTAT130	TWTA 1 TLM 1H	ANA	
NTTAT210	TWTA 2 EPC TEMP	ANA	
NTTAT220	TWTA 2 TLM A0	ANA	
NTTAT230	TWTA-2 TLM 1H	ANA	
NTTD0313	TWTA-1 High Volt Status	RSS	
NTTD0314	TWTA-1 RST Timer Status	RSS	
NTTD0315	TWTA-1 ON/OFF Status	RSS	
NTTD0413	TWTA-2 High Volt Status	RSS	
NTTD0414	TWTA-2 RST Timer Status	RSS	
NTTD0415	TWTA-2 ON/OFF Status	RSS	

Table 5-38: TWTA Telemetry

Telemetry Name	Telemetry Label	Type	Comments
NTTA1001	Word 00 TMGA TRSP 1		SERIAL
NTTA1002	Word 01 TMGA TRSP 1		SERIAL
NTTA1003	Word 02 TMGA TRSP 1		SERIAL
NTTA1004	Word 03 TMGA TRSP 1		SERIAL
NTTA1005	Word 04 TMGA TRSP 1		SERIAL
NTTA1006	Word 05 TMGA TRSP 1		SERIAL
NTTA2001	Word 00 TMGA TRSP 2		SERIAL
NTTA2002	Word 01 TMGA TRSP 2		SERIAL
NTTA2003	Word 02 TMGA TRSP 2		SERIAL

Telemetry Name	Telemetry Label	Type	Comments
NTTA2004	Word 03 TMGA TRSP 2		SERIAL
NTTA2005	Word 04 TMGA TRSP 2		SERIAL
NTTA2006	Word 05 TMGA TRSP 2		SERIAL
NTTAX100	TRSP-1 RX CV VOLT		ANALOG
NTTAX110	TRSP-1 RX DC CURRENT		ANALOG
NTTAX120	TRSP-1 RX S-BD TEMP		ANALOG
NTTAX130	TRSP-1 S-RF OUTPWR		ANALOG
NTTAX140	TRSP-1 S-TX DC CURR		ANALOG
NTTAX150	TRSP-1 RF S-BD TEMP		ANALOG
NTTAX160	TRSP-1 S-TX CV VOLT		ANALOG
NTTAX170	TRSP-1 X-RF OUTPWR		ANALOG
NTTAX180	TRSP-1 X-TX DC CURR		ANALOG
NTTAX190	TRSP-1 RF X-BD TEMP		ANALOG
NTTAX1A0	TRSP-1 X-TX CV VOLT		ANALOG
NTTAX200	TRSP-2 RX CV VOLT		ANALOG
NTTAX210	TRSP-2 RX DC CURR		ANALOG
NTTAX220	TRSP-2 RX S-BD TEMP		ANALOG
NTTAX230	TRSP-2 S-RF OUTPWR		ANALOG
NTTAX240	TRSP-2 S-TX DC CURR		ANALOG
NTTAX250	TRSP-2 RF S-BD TEMP		ANALOG
NTTAX260	TRSP-2 S-TX CV VOLT		ANALOG
NTTAX270	TRSP-2 X-RF OUTPWR		ANALOG
NTTAX280	TRSP-2 X-TX DC CURR		ANALOG
NTTAX290	TRSP-2 RF X-BD TEMP		ANALOG
NTTAX2A0	TRSP-2 X-TX CV VOLT		ANALOG
NDMWBT64	Fine OBT of TRSP1 acquisitions		

Table 5-39: Transponder Telemetry

5.3.4. Harness

5.3.4.1. Design Overview

The spacecraft is split into three entities; BSM, PSM and Intra Experiment Harness. Design of the IEH is the responsibility of the experimenters, only the routing is a platform responsibility so it is not described further. The harness subsystem does not include waveguide and coax, these are provided as part of the WIU/RFDU.

The BSM and PSM harness each comprise Power/signal and pyro routes.

Pyro wiring is conventional using twin screened cabled (360° coverage). All pyro lines from the PDUs are distributed by Safe/Arm connector links located on the skin of the spacecraft. Each pyro line includes a bleed resistor between live and return. Pyro wiring is only broken at the Safe/Arm connector. Where it is necessary to connect to pyro initiators outside the spacecraft, eg experiment booms and HGA, the connectors are taken through small cut-outs finally sealed by Aluminium tape.

The power and signal wiring utilises twisted/screened wiring in accordance with the System Interface Requirement. All bundles are over-wrapped with Aluminium tape and tybases used to ground the tape at regular intervals. Where practical, the minimum separation as given in the EMC requirement will be adopted, though in many areas, for example CDMU/AIU/RTU quadrant this is impossible to achieve.

- The spacecraft is provided with a number of interface breaks at the skin for test or safety. Examples are:
  - The thruster drive lines are broken via a safety connector which also allows testing of the AIU and thrusters.
  - The SADM drive is via a skin connector.
  - The payload High Voltage circuits are protected by an HV inhibit plug.
  - The HAGMA APM drive is not via a special test skin connector as testing can be performed at the natural spacecraft/HGA interface connector on the +X wall.
  - The umbilical provides the input path for main support power (via the PCU Array regulators) and also carries test lines such as receiver lock. Other test connectors are provided where necessary.

5.3.5. Electrical Subsystem Failures

See Volume 2, Contingency Recovery Procedures.

5.3.6. Electrical Subsystem Operations Procedures and Constraints

See Volume 2 – Flight Procedures

5.4. Mechanical Subsystems

5.4.1. Thermal Subsystem

5.4.1.1. Subsystem Description

The objective of the Thermal Control subsystem is to maintain the thermal environment of the spacecraft and equipment within defined limits throughout the mission life. The two methods used in meeting this objective are:

Passive Means

- Multi Layer Insulation (MLI)
- Thermal control Paints
- Conductive interfillers
- Insulating washers
- Radiators
- Louvres

Active Means

- Heaters
- Thermistors

5.4.1.2. Unit Description

5.4.1.2.1. Multi Layer Insulation (MLI)

5.4.1.2.1.1. Unit Functions

MLI is used on the spacecraft to insulate against variations in internal temperature due to external inputs, and also loss of heat through the propulsion system, and consequently save heater power budget. Four types of MLI will be used on Rosetta. [RD-1] Gives the design and construction description.

- External MLI

- ▹ 20 layer MLI is used externally on the spacecraft everywhere except radiative areas and those which need to be free from obstructions such as thrusters, antennas, sensors etc. This MLI also aids as micro-meteoroid protection. It has a carbon loaded Kapton outer layer (i.e. black) to reduce the degradation of the electrical conductance property of the MLI.

- Internal MLI
  - ▹ 20 layer MLI will be used to cover the RCS propellant tanks to reduce heat leakage through this subsystem. It has a VDA Kapton outer layer (i.e. silver).
- RCS Pipework blankets
  - ▹ 15 layer MLI will be used to wrap the RCS pipework to reduce heat leakage through this subsystem. It has a VDA Kapton outer layer (i.e. silver).
- High temperature blankets
  - ▹ These external blankets will be used around the RCS thrusters to prevent heat influx during thruster firings. These include one layer of Titanium.

5.4.1.2.1.2. Interfaces

For ease of installation the MLI will be interleaved. This interleave will consist of a Kapton sheet bonded between the inner and outer 10 layer packs of each blanket, and the bond will be placed so that the overlay between the blankets is a minimum of 100mm, see figure below.

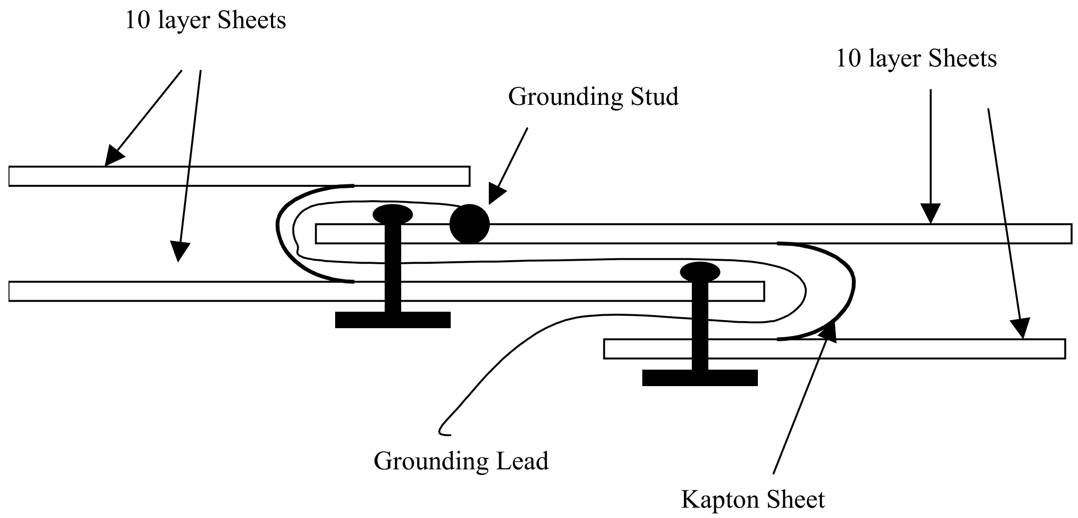


Figure 5-79: MLI - MLI interface

The MLI also provides micrometeorite protection for the +Z end of the upper propellant tank, and the –Z end of the lower propellant tank, as these are the only areas which require additional protection that is not provided by the spacecraft structure, as they protrude slightly from the outer spacecraft panels. A domed bumper will be supported over the end of the tank as shown below.

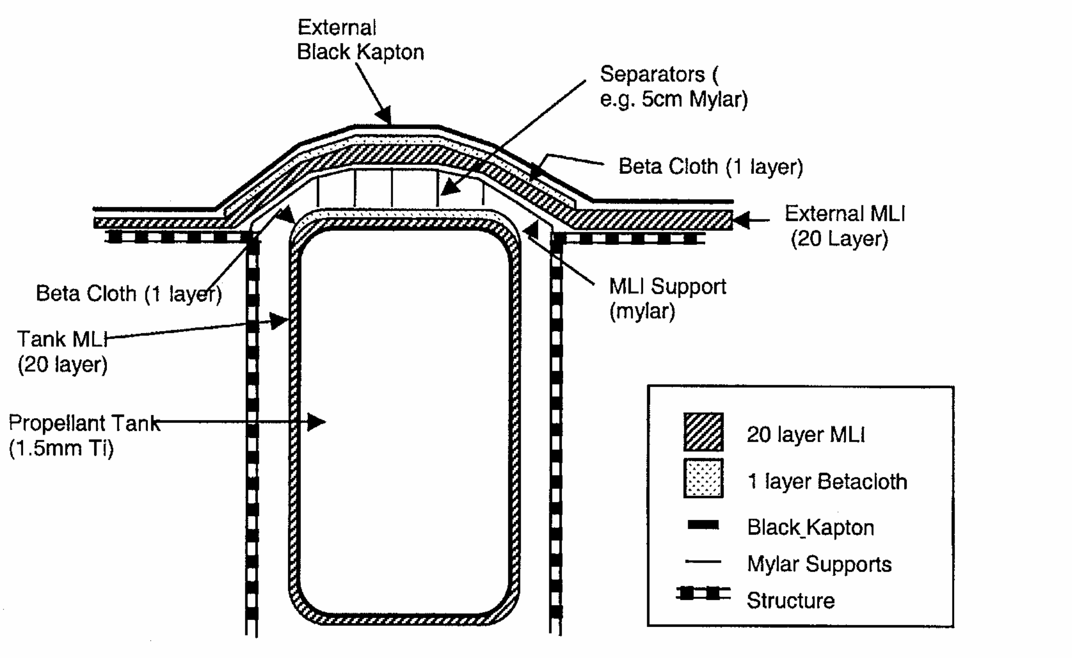


Figure 5-80: MLI – RCS Tank Interface

Note: for the -Z tank the beta cloth forms the outer layer, rather than the MLI.

The 15 layer pipe blankets will be wrapped longitudinally, rather than spirally, as shown below.

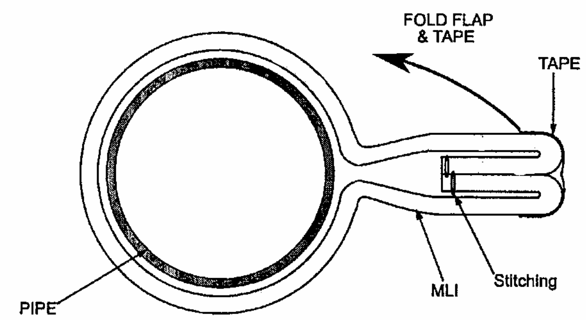


Figure 5-81: MLI – RCS Pipework interface

5.4.1.2.2. Paints

5.4.1.2.2.1. Unit Functions

The internal structure surfaces of the Bus support module will be left with an Alodine 1200 surface finish, BR127 will be used where bonding occurs. On the Payload support module the internal surfaces will be painted with black paint except under payload units, and the harness. The central cylinder will be painted externally with Alodine 1200, and internally with BR127. Other paints may be used in specific locations, e.g. white painted antennae dishes. No painting is performed by the TCS as both structure and unit are supplied with the required surfaces already painted.

The white paint used on ther radiator behind the louvers is PSG 120FD, the same paint is used on the two MGAs.

5.4.1.2.3. Conductive interfillers

5.4.1.2.3.1. Unit Functions

For unit to panel mechanical interfaces it is necessary to provide a thermal filler material to ensure adequate and predictable conductive flow. For this application Sigraflex graphite foil will be used to enhance the unit to panel conductance. The foil will be cut to appropriate gasket shapes and installed between units and substrates and or doublers and substrates.

High power dissipation units are flush-mounted to spacecraft panels to ensure a good thermal heat path from the unit to the panel. Low power or passive units may be mounted on feet to panels or may use a dry contact area, i.e. no interface filler used. This is to reduce the thermal coupling from the unit to the panel as the unit thermal control does not need to reject any heat to keep it within temperature limits. Generally, unit to panel interfaces are maximised or minimised in order to increase confidence in the thermal modelling of such interfaces.

In the HDR TMM the interface conductances between units and panels, using sigraflex interface filler, have been calculated by relating baseplate contact areas to numbers of bolts used to attach units. Generally, the more bolts used to attach a unit to a panel the better the resultant contact conductance. Figure 5-82 shows a typical relationship used to calculate unit to panel interface conductance. By creating a more predictable thermal interface conductance from units to panels the TMM modelling uncertainties are reduced thereby allowing a more thermally optimised design.

The following table shows which units use conductive interfillers.

Payload units	Avionics units	Platform units
GIADA	CDMU 1	PDU PSM
MIRO SBEU	CDMU 2	PDU BSM
MIRO EU	RTU BSM	PCU
MIRO USO	RTU PSM	TRSP 1 / 2
OSIRIS NAC CRB	SSMM	EPC 1 / 2
OSIRIS WAC CRB		TWTA 1 / 2
OSIRIS MEU	AIU	USO RSI
Rosina DFMS	WDE	SADE
Rosina RTOF	IMU 1	APME
VIRTIS OM	IMU 2	RFDU
VIRTIS Main EU	IMU 3	WIU
ESS TX RX 1	CAM/STR EU 1	
ESS TX RX 2	CAM/STR EU 2	
SSP MSS		

Table 5-40: Units Using Conductive Interfiller

5.4.1.2.3.2. Performance Data

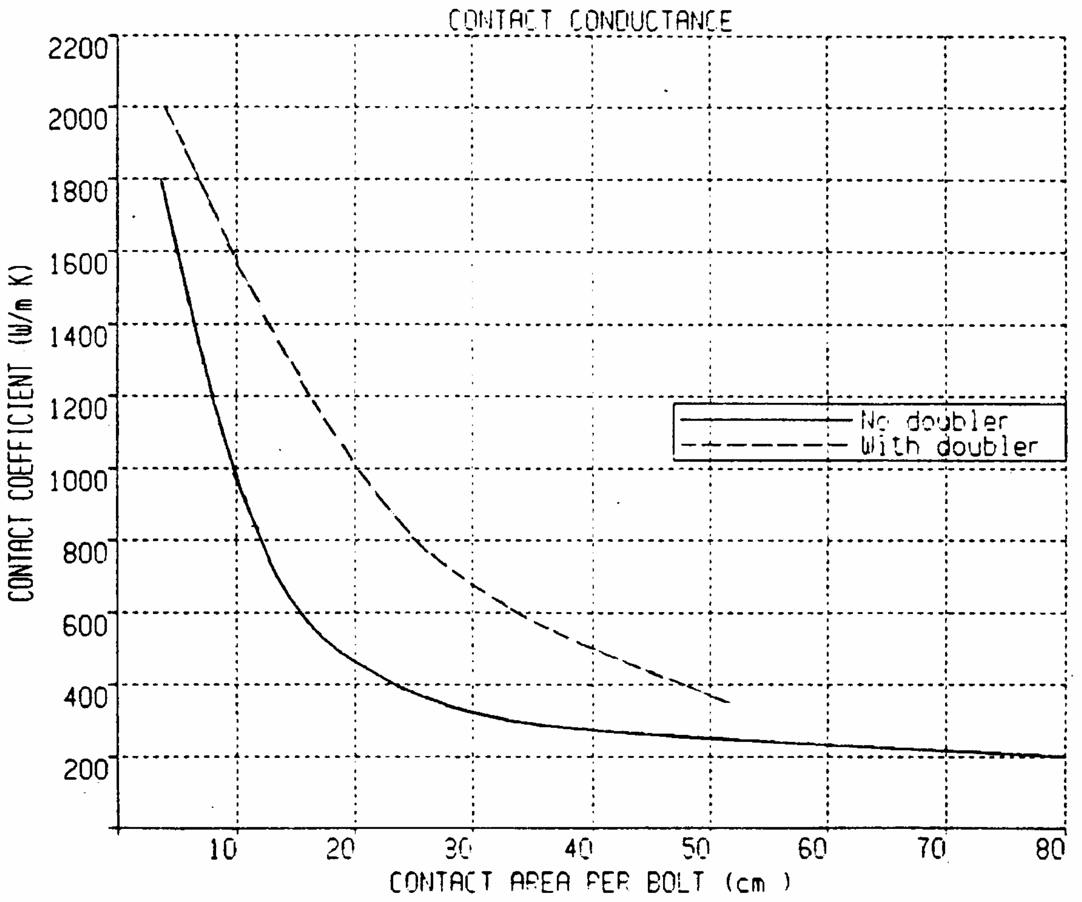


Figure 5-82: Typical 'Sigraflex' unit to panel, interface conductance data

5.4.1.2.4. Thermal Control Tapes

5.4.1.2.4.1. Unit Functions

Self adhesive tapes will be used for a variety of purposes including:

- Assembly of MLI blankets
- To provide low emissivity coatings (e.g. on RCS stand-off's)
- To provide local thermal control
- Sealing of gaps

In general the following types will be used

- Silverised Teflon

- Aluminised Kapton VDA
- Aluminium
- Kapton
- Black Kapton

5.4.1.2.5. Radiators & Louvres

5.4.1.2.5.1. Unit Functions

For external radiator surfaces experiencing significant levels of albedo and solar flux a low absorbance to emitance ratio surface finish is necessary. This is so that visible spectrum solar absorption is minimised while the IR heat rejection capability is maximised.

An area of approximately 2.38m^2 of ±Y wall louvered radiator surface is required to control the spacecraft temperatures within acceptable limits. White paint has been selected for the radiator surface. High power units are well coupled to Y walls by use of a conductive interfiller. Such units are mounted to the Y walls opposite to louver positions so that the excess heat from these units may be transferred consecutively through the Y walls and thus more easily rejected through the radiators to space.

The Louvres are mounted over white painted radiator areas on the spacecraft ±Y walls, and provide the main spacecraft heat rejection capability during hot mission phases.

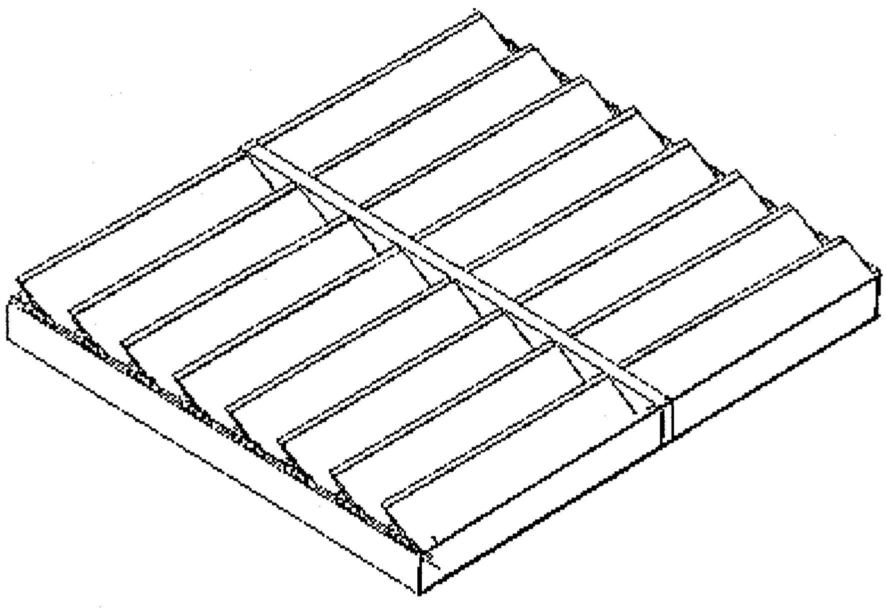


Figure 5-83: Sener Louvre

The louver design consists of a framed array (397 x 430 mm) of highly polished blades which are individually pivoted to temperature-sensitive actuators. The actuators are bimetallic coil springs enclosed within a housing that is well isolated from the external environment but which maintains good thermal contact with the mounting panel requiring thermal control. The actuators are “calibrated” to cause the associated blades to be fully open and fully closed at prescribed temperatures (15° C and 1° C ± 3° C respectively for the PCU; 10° C and -4° C ± 3° C respectively for all other units). As the temperature of the panel begins to increase, the related rise in the actuators temperature creates a thermal moment which forces the Louvres blades to open and hence lead to an increase in the radiated power to space. Similarly, as the panel temperature decreases, the actuators tend to close the blades, which now offer a high resistance to radiation losses.

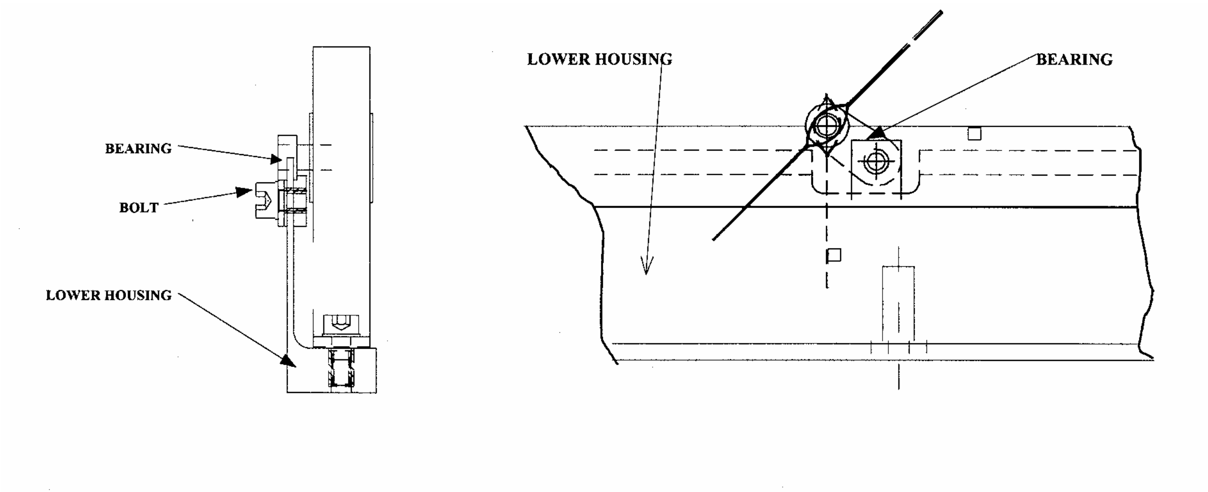


Figure 5-84: Actuator housing and Blade

The actuator has been designed to have the best thermal coupling with the spacecraft radiator. This thermal coupling is achieved both by conduction and radiation. The outer spiral end of the actuator is bolted to the aluminium actuator housing, which in turn is bolted to the s/c radiator panel and conductively coupled to it. A square plate is placed between bolt head and actuator spiral to increase contact area and hence improve thermal conduction between actuator and actuator housing. All components of the actuator (bimetal, inner ring) are inside the actuator housing, which provides an uniform thermal environment for the actuator. The actuator cover isolates the actuator housing, and hence the actuator, from the external environment.

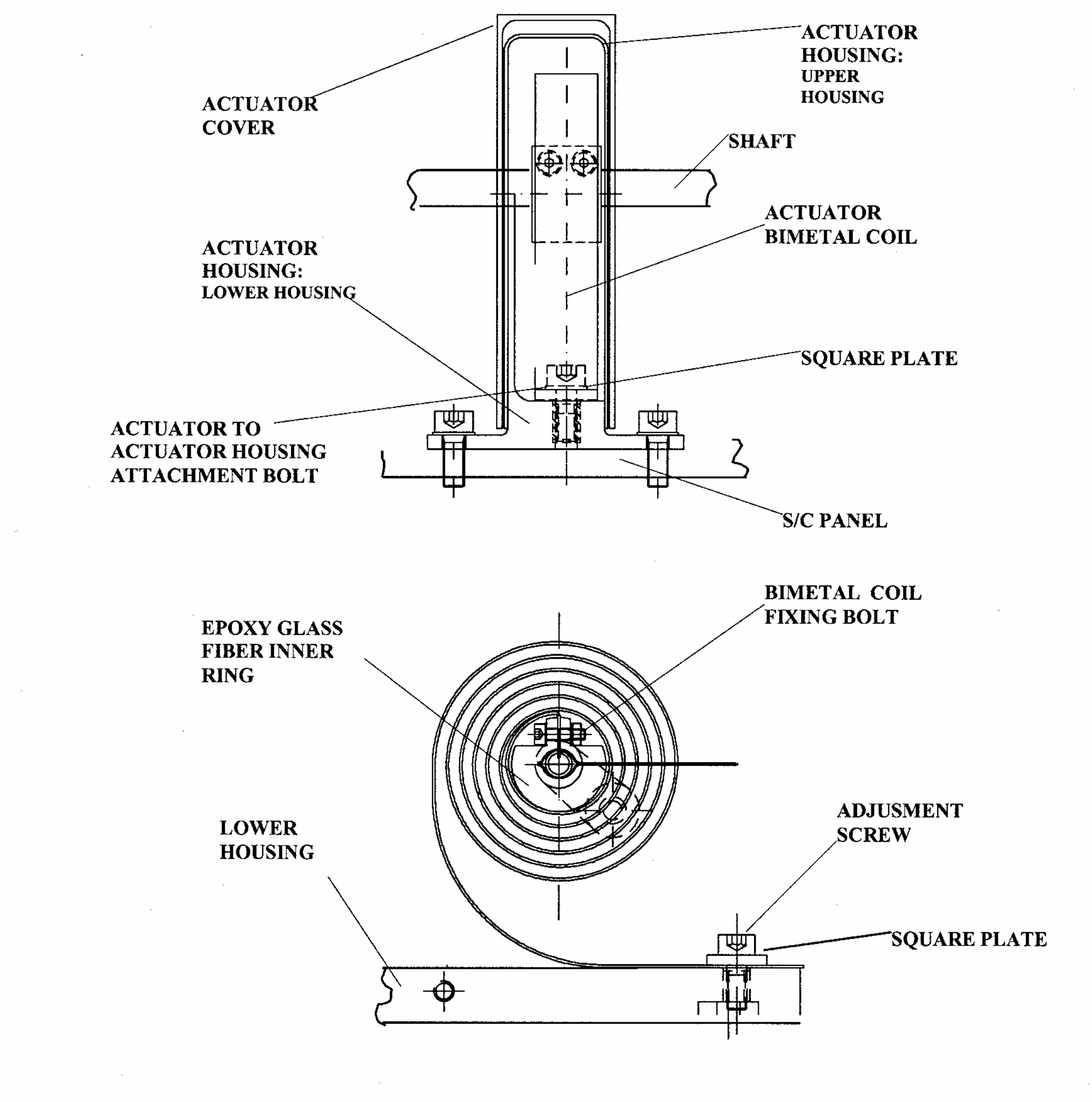


Figure 5-85: Actuator housing and Bimetallic Actuator

The inner spiral end of the bimetallic actuator coil is attached to actuator inner ring and then to the shafts of an opposing pair of blades. The actuator inner ring is made of an epoxy fibreglass that thermally decouples the actuator from the blade shafts.

A fuller design description can be found in [RO-SEN-TN-3001]

5.4.1.2.5.2. External Interfaces

The Louvres are bolted to the external area of the spacecraft, over the radiators, Figure 5-86 and Figure 5-87 show the location of the radiators with respect to the unit locations. The annotations to these figures describe which units the louvre covers, if it is not shown in the diagram.

There is no telemetry or command interface with these units.

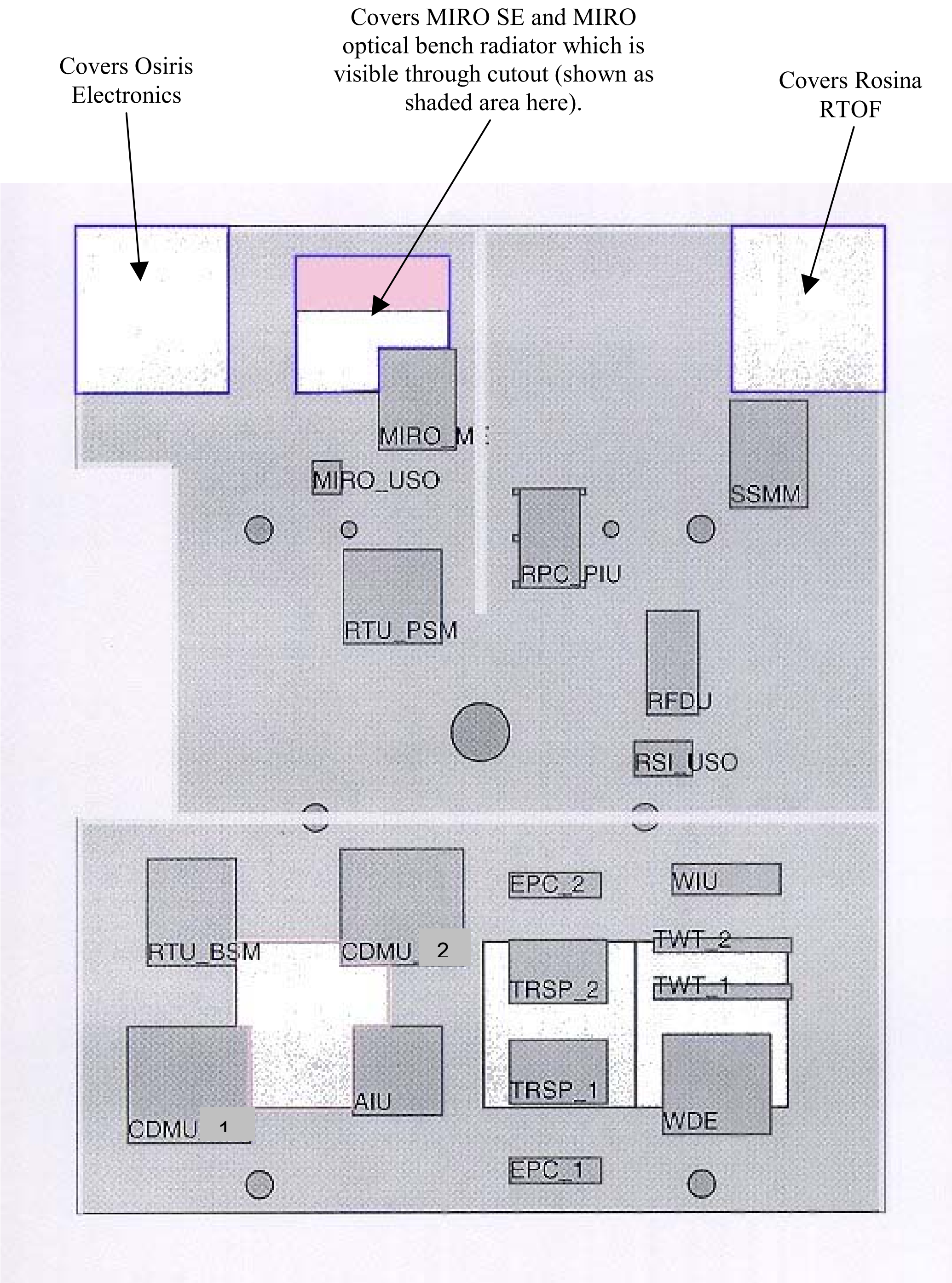


Figure 5-86: +Y Panel Louvre Positions

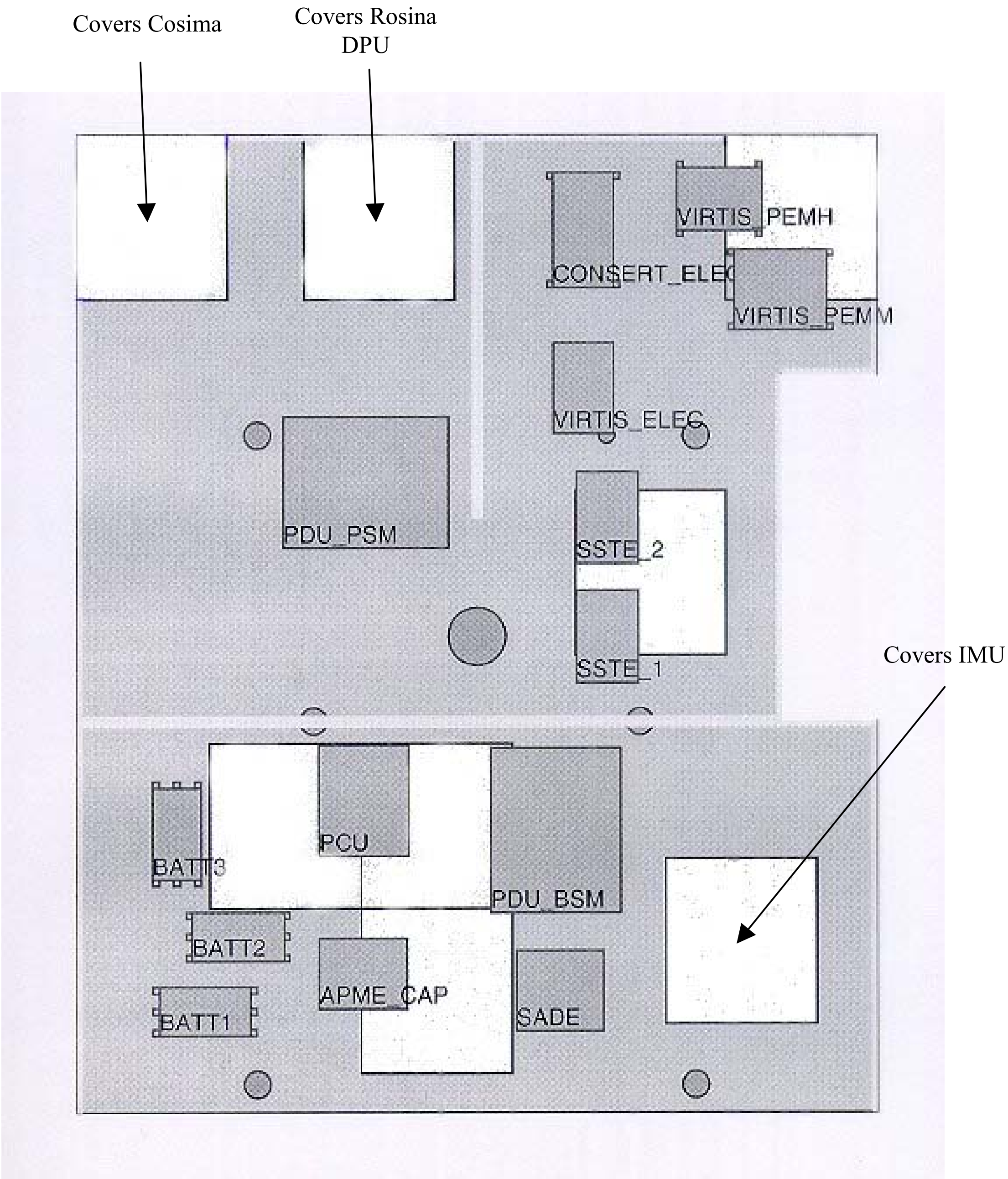


Figure 5-87: -Y Panel Louvre Positions

5.4.1.2.5.3. Performance Data

The following tables give the mechanical, physical, and thermal characteristics. [Technical Comparison between SENER and STARSYS Louvres, iss. 2]

Description	Value
Mass	0.785 Kg
C.o.M. offset from mount panel	24.8 mm
Static Height	63 mm
Footprint Area	0.1707 m^2
Effective Area	0.1531 m^2

Table 5-41: Louver Physical Characteristics

Description	Value	Required
1st Eigen frequency	220 Hz	> 140 Hz
Bimetallic actuator dimensions	0.20 x 9 x 647 mm	n.a.
Torque Margin	1.4	> 1

Table 5-42: Louver Mechanical Characteristics

Description	Value	Required
Radiator Area	0.1579 m^2	n.a.
Effective min eminence (Footprint area)	0.09	< 0.17
Effective min eminence (Effective area)	0.10	n.a.
Effective min eminence (Radiator area)	0.10	n.a.

Description	Value	Required
Effective max eminence (Footprint area) Effective max eminence (Effective area) Effective max eminence (Radiator area)	0.71 0.79 0.77	> 0.69 n.a. n.a.
Range of qualification temperatures	-47 to +53 Celsius	-47 to +53 Celsius
Rejected Power at -10 Celsius	4.2 W	n.a.
Rejected Power at +20 Celsius	50.6 W	n.a.

Table 5-43: Louver Thermal Characteristics

5.4.1.2.6. Heaters

5.4.1.2.6.1. Unit Functions

Heaters used are generally constructed of etched copper foil encapsulated between two pieces of kapton film. The proposed thermal heater concept is based upon a standard proven approach used on numerous other spacecraft including PPF and SPOT. The heater system uses two basic types of control:

- Thermistor controlled (software) heaters which are used to maintain platform, avionics and payload units within operating limits when these units are operating.

- Thermostatically controlled (hardware) heaters which are used to maintain platform, avionics and payload units within their non-operating (or switch-on) limits when these units are non-operating. These operate autonomously during satellite hibernation modes to ensure thermal control.

All software and hardware heaters circuits comprise a simple series connection, parallel connection of heaters is only allowed in certain special cases. All heater circuits have redundant circuits. All of the heaters in a circuit will be in the same locality on the spacecraft and in order to improve reliability there are no more than 4 heater elements in a circuit. The only exception to this is the RCS heating lines. Prime and redundant heater elements are on different mats, again with the exception of the RCS spiral heaters. This avoids the situation where the failure of a prime heater element can affect the redundant heater element, i.e. no failure propagation.

Where equipment requires hardware and software heating then the prime heating elements exist within the same mat and the redundant heater elements exist within a separate mat. Therefore, there are 2 heater mats per equipment whether we require hardware and software heating or hardware heating only. It is possible to use HW + SW Heaters, by including an additional FET switch into the PDU's for each heater control line. This leads to a mass saving in terms of fewer heater mats required and also because the power subsystem units become simpler. This type of Heater will be implemented on the RCS thrusters. Figure 5-90 shows the circuit diagram for this setup. Four LCLs have this configuration on Rosetta.

Software heaters were, as far as possible, not used as part of the TCS. Software heaters are designed to meet specific unit operation requirements. For example, propellant tanks use software heaters for propellant gauging and they can be used for tank temperature gradient control as well.

The sizing of the autonomous H/W heater circuits is based upon the following criteria:

- payload heaters shall be designed to maintain non-operating temperature limits at 5.25AU or switch-on limits at 3.25AU, whichever gives the greater heater power requirement,

- Platform and Avionics units which are off in hibernation have heaters designed to maintain non-operating temperature limits at 5.25AU or switch-on limits at 4.70AU, whichever is the greater,

- Platform and Avionics units which remain operating during deep space hibernation have heaters designed to maintain operating temperature limits at 5.25AU.

The heaters are mounted directly onto units as this maximises the efficiency of the heating. These heaters will be bonded onto paint-free areas on the internal or external surface of the unit.

To ensure the availability of liquid propellant at all times and also to prevent damage to the propulsion subsystem due to propellant freezing, it is necessary to provide thermal heating to the propulsion equipment, including pipes, tanks and thrusters. For the pipes, multi-element coiled wire type spiral heaters encapsulated in kapton are wound over the propellant line. Flat heater mats are used to maintain acceptable tank and thruster valve temperatures. The bi-propellant subsystem is always in an ‘operating’ condition, i.e. propellants are always required to be kept in the liquid states and not allowed to freeze. This means that a single set of temperature limits applies to the RCS over the whole of the mission. The RCS is therefore suited to hardware control of heating. All heaters will be subject to acceptance tests and will be provided with flying leads for connection of the heater harness. This connection will be via connectors mounted on local connector brackets bonded to the structure near the heaters. In addition, the connection of these circuits has been designed to minimise magnetic moments which would arise from large, inductive loops.

Double-layer heater mats and stacking of heater mats will not be used, except in the case of the thruster valve heaters, where lack of space has required the implementation of both prime and redundant elements on the same mat. Reliability considerations have been paramount in the design of the electrical resistance circuits.

5.4.1.2.6.2. External Interfaces

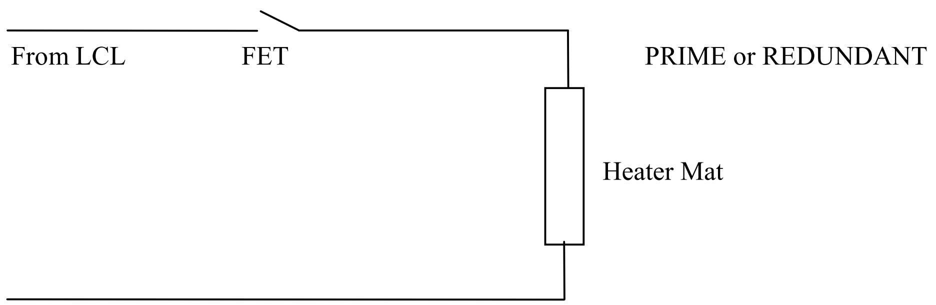


Figure 5-88: SW Heater Circuit

In the SW Heater circuit, the heater status is driven by a FET, which in turn is driven by command from the RTU. The RTU uses the temperature information from three thermistors on the unit’s TRP in order to determine the appropriate status of the FET. The same three thermistors are used for the control of both the prime, and redundant heater circuits. More information regarding the SW control of the thermistors can be found in [RO-DSS-RS-1038], and the appropriate SRD.

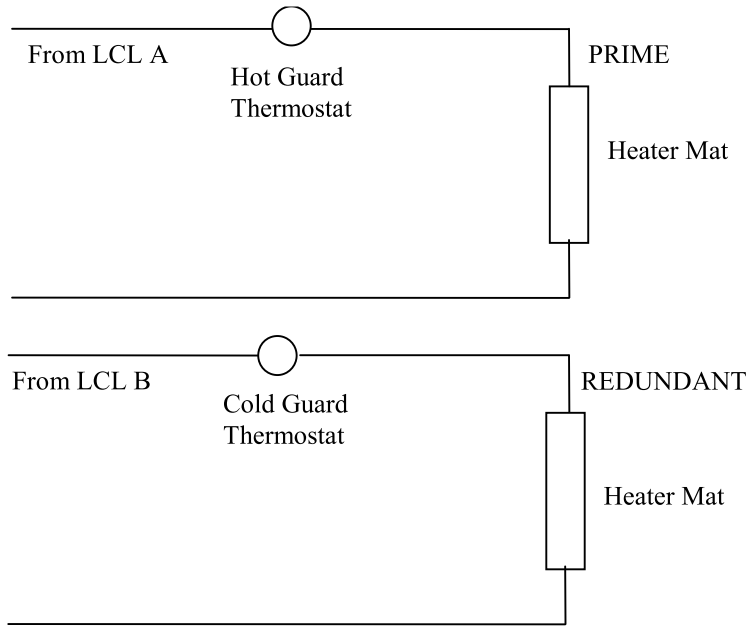


Figure 5-89: HW Heater Circuit

HW heater circuits are envisaged to support the temperature control of units in hibernation modes, prior to the unit switch on. However, since the LCLs driving the HW heaters are permanently powered during hibernation, it is only desirable to have the redundant line operating in the case of a prime line failure. Therefore, a cold guard thermostat is included in the redundant line.

Note that in the HW heater circuit, only one thermostat exists in the redundant line, as it would be considered a double failure if the thermostat failed to close as the temperature of the unit dropped.

For most unit heaters, the heater strategy will include a cold and hot guard thermostat, as shown in Figure 5-90. For these units it can be dangerous for them to become too hot, and so a hot guard thermostat will be included in the prime heater line to shut the heater off if the unit approaches the upper temperature limit. This primarily guards against an LCL failing on.

Some units will not be damaged by an over temperature, and as a result, a hot guard thermostat is not required for these units. Only the ROSINA DFMS and the RCS thruster units are in this category.

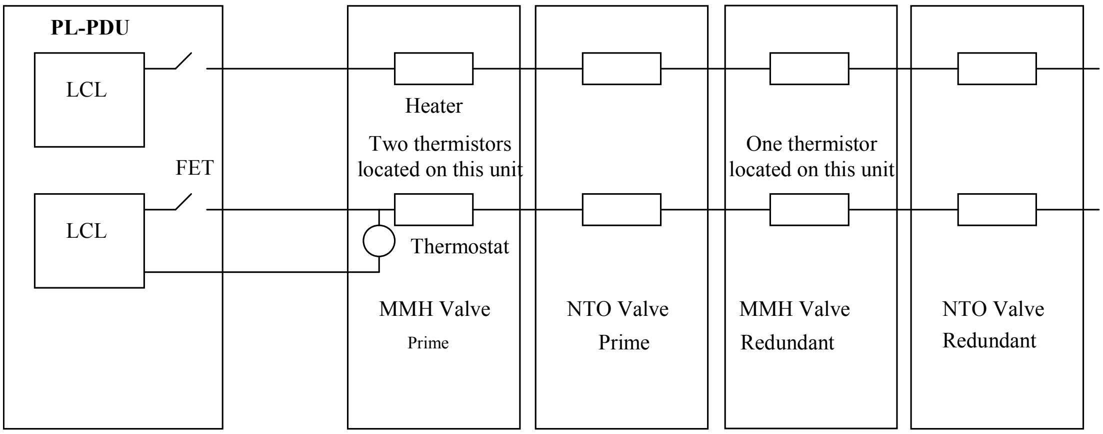


Figure 5-90: HW-SW Heater circuit

Due to the small amount of mounting area for the heaters, and the low thermal inertia of the RCS thruster valves, the HW-SW circuit shown above will be used for these units. Normally the thrusters will remain under SW control, and HW control will be used for hibernation phases. Before hibernation the prime SW FET will be closed, and the redundant FET opened. At this point, the circuit will act the same way as the cold guard system.

The SW FET is normally controlled using three thermistors, the location of which are shown in the diagram.

The Heaters are attached electrically to Latching Current Limiters (LCL). A description of the LCL can be found in the Rosetta Power User manual. Effectively each LCL can provide electrical connections for 2 or 4 Heater citcuits.

Table 5-44 gives the correlation between heater unit and the LCL it is attached to.

			LINE 1	HS	Heater No.		LINE 2	HS	Heater No.		LINE 3	HS	Heater No.		LINE 4	HS	Heater No.	
LCL #	CLASS	LOAD			Prime	Red.			Prime	Red.			Prime	Red.			Prime	Red.
PL-PDU																		
PL-5	C	HW P/L int.	SSP COMPARTMENT (NonOp)		-	-	SSP COMPARTMENT (NonOp)		-	-	-				-			
PL-7	25W	HW NonOp	MIRO SE		103	203	NC([1])		-	-	NC		-	-	MIRO ME		353	453
PL-8	25W	HW	VIRTIS PEMH([2])		104	204	NC		-	-	WAC CRB ([3])		304	404	RX TX 1 & 2([4]) ([5])		354	454
PL-9	25W	HW NonOp	NC		-([6])	-	CONSERT ELEC		155	255	OSIRIS NAC CRB		305	405	MIDAS		355	455
PL-10	25W	HW NonOp	ROSINA ELEC		106	206	COSIMA ELEC		156	256	RPC PIU		306	406	([7])			
PL-13	A	HW NonOp	ALICE		303	403	NC		-	-	-				-			
PL-17	50W	HW NonOp	SSP MSS HOUS		108	208	NC		-	-	NC		-	-	NC		-	-
PL-18	50W	HW NonOp	SSP ESS Box		109	209	NC		-	-	NC		-	-	RPC IES		359	459
PL-20	C	HW Deploymt	lower BOOM hinge heater		110	210	upper BOOM hinge heater		160	260	-				-			
PL-21	50W	HW NonOp	STR 1		111	211	STR 2		161	261	NAV CAM 1		311	411	NAV CAM 2		361	461
PL-23	25W	HW NonOp	RCS1		113	213	RCS2		162	263	RCS3		313	413	RCS4		363	463
PL-24	25W	HW NonOp	RCS5		114	214	RCS6		163	264	RCS7		314	414	RCS8		364	464
PL-25	B	HW	NC		-	-	NC		-	-	NC		-	-	NC		-	-
PL-26	B	HW	NC		-	-	NC		-	-	NC		-	-	NC		-	-

[1] 'NC' means the LCL line is connected and is theoretically available for use (although no harness exists for it)
[2] Previously Consert Elec Run-up
[3] Previously Alice Run-up
[4] Previously SSP Coax Bracket Run-up
[5] These heaters are connected in parallel. Thermostat is on the front unit in each case
[6] '-' means the LCL line is not available for heater connection
[7] LCL line not used. Harness may remain for Virtis Elec heater

			LINE 1	HS	Heater No.		LINE 2	HS	Heater No.		LINE 3	HS	Heater No.		LINE 4	HS	Heater No.	
LCL #	**CLASS**	**LOAD**			Prime	Red.			Prime	Red.			Prime	Red.			Prime	Red.
PL-27	A	HW NonOp	MIRO OPT. BENCH		117	217	NC		-	-	-				-			
PL-28	A	HW NonOp	VIRTIS PEMM		308	408	NC		-	-	-				-			
PL-34	B	HW P/L int.	ROSINA DFMS (NonOp)		-	-	NC		-	-	-				-			
PL-35	25W	HW NonOp	PROP. TANK +Z		120	220	NC		-	-	NC		-	-	NC		-	-
PL-36	25W	HW NonOp	PROP. TANK -Z		121	221	NC		-	-	NC		-	-	NC		-	-
PL-37	25W	HW NonOp	RCS9		122	222	RCS10		172	272	RCS11		322	422	RCS12		372	472
PL-39	A	HW NonOp	OSIRIS ELEC		153	253	NC		-	-	-				-			
PL-40	A	HW P/L int.	RPC IES (NonOp)		-	-	NC		-	-	-				-			
PL-41	A	HW NonOp	RPC ICA / SREM ([4])		126	226	NC		-	-	-				-			
PL-42	A	HW NonOp	ROSINA COPS		158	258	NC		-	-	-				-			
PL-43	100W	HW/SW branch	NC	1	-	-	APM	2	- (178)	- (278)	([8])				([9])			
PL-44	100W	HW/SW branch	THR HSW Module 1	5	129	229	THR HSW Module 2	6	179	279	THR HSW Module 3	7	329	429	THR HSW Module 4	8	379	479
PL-45	50W	HW/SW branch	THR HSW Module 5	9	130	230	THR HSW Module 6	10	180	280	THR HSW Module 7	11	330	430	THR HSW Module 8	12	380	480
PL-46	50W	HW/SW branch	THR HSW Module 9	13	131	231	THR HSW Module 10	14	181	281	THR HSW Module 11	15	331	431	THR HSW Module 12	16	381	481
PL-53	B	HW P/L int.	NC		-	-	NC		-	-	-				-			
PL-54	A	HW	GIADA		105	205	NC		-	-	-				-			
SS-PDU																		
SS-15	100W	SW branch	lower BOOM motor power	1	-	-	Virtis DECONT (NonOp)	2	-	-	NC	3	-	-	NC	4	-	-
SS-16	100W	SW branch	NC	5	-	-	upper Boom motor power	6	-	-	+Z TANK GAUGING	7	751	851	-Z TANK GAUGING	8	776	876
SS-17	50W	SW branch	VIRTIS CCD Heater (NonOp)	9	-	-	NC	10	-	-	([10])				([11])			

[8] LCL line not used. Harness may remain for SADM +Y heater
[9] LCL line not used. Harness may remain for SADM -Y heater

			LINE 1	HS	Heater No.		LINE 2	HS	Heater No.		LINE 3	HS	Heater No.		LINE 4	HS	Heater No.	
LCL #	CLASS	LOAD			Prime	Red.			Prime	Red.			Prime	Red.			Prime	Red.
SS-18	50W	SW branch	RW1	13	703	803	RW2	*14*	*728*	*828*	*([12])*				*([13])*			
SS-19	100W	SW branch RunUp	STR 1 ([14])	17	704	804	STR 2 ([14])	18	729	829	NAV CAM 1	19	754	854	NAV CAM 2	20	779	879
SS-20	100W	SW branch	BATT 1	21	705	805	BATT 3	22	730	830	NC	23	-	-	BATT 2	24	780	880
SS-21	50W	SW branch	NC	25	-	-	NC	26	-	-	SADM +Y Case/Shaft	27	756	856	SADM -Y Case/Shaft	28	781	881
SS-22	50W	SW branch	OSIRIS N+W CCD struc. (NonOp)	29	-	-	OSIRIS Nac+Wac struc. (NonOp)	30	-	-	NC	31	-	-	NC	32	-	-

Table 5-44: Correlation between LCL and Heater Unit

5.4.1.2.6.3. Performance Data

Heaters, Thermostats and Thermistors are listed in 5-45 .

For heaters the size (in mm), the power (in Watts at a voltage of 27.7V) and the Ohmic resistance is given.

For Thermostats the Set Points are indicated.

For Thermistors the name is recorded.

In the final column of the Table the Latched Current Limiter (LCL) is recorded. The LCL References are in a shortened form, for example "PL-13-1" means PL (PSM) PDU, LCL 13, line #1.

[10] LCL line not used. Harness may remain for NC PYRO heater
[11] LCL line not used. Harness may remain for NP PRT heaters
[12] LCL line not used. Harness may remain for RW3 heater
[13] LCL line not used. Harness may remain for RW4 heater
[14] Each line has two heaters connected in parallel

NOTES	Unit	HEATER						THERMOSTAT([1])	THERMISTOR	LCL
		No. P	No. R	Resis-tance (Ω)	Power (W, @27.7V)	DIMEN. (mm) X	Y	Set Points ° C CG , HG	Name	
	PAYLOAD									
	ALICE	1	1	280 Ω	2.74	45.7	30	-30/5,0/40	TCS001_ALICE_TRP_P TCS002_ALICE_TRP_R	PL-13-1
	CONSERT ANTENNA								TCS006_CONAN_STP TCS007_CONAN_TRP_P	
	CONSERT_ELEC	1	1	280 Ω	2.74	45.7	30	-30/5,0/40	TCS009_CONEL_TRP	PL-9-2
	COSIMA electronic_box	1	1	721 Ω	1.06	35	22.5	-30/5,0/40	TCS010_COSIM_TRP_P TCS011_COSIM_TRP_R	PL-10-2

[1] THERMOSTAT Temperature settings are given in the following order:-

HOT Guard minimum /HOT Guard maximum (HG), COLD Guard minimum / COLD Guard maximum (CG).

Each table entry indicates one Thermostat. Some are shared (eg SREM & RPC_ICA).

NOTES	Unit	HEATER						THERMOSTAT([1])	THERMISTOR	LCL
		No. P	No. R	Resis-tance (Ω)	Power (W, @27.7V)	DIMEN. (mm) X	Y	Set Points ° C CG , HG	Name	
	GIADA_CLOSED	1	1	144 Ω	5.33	76.2	25	-30/5,0/40	TCS012_GIADA_TRP_P TCS013_GIADA_TRP_R	PL-54-1
	MIDAS ebox	1	1	470 Ω	1.64	50	12	-30/5,0/40	TCS014_MIDAS_TRP_P TCS090_MIDAS_TRP_R	PL-9-4
	MIRO optical_bench	1	1	220 Ω	3.49	45	20	-30/5,0/40	TCS018_MIROB_TRP	PL-27-1
	MIRO_SE	1	1	470 Ω	1.64	50	12	-30/5,0/40	TCS019_MIRSE_TRP_P TCS091_MIRSE_TRP_R	PL-7-1
	MIRO_ME	1	1	280 Ω	2.74	45.7	30	-30/5,0/40	TCS020_MIRME_TRP_P TCS021_MIRME_TRP_R	PL-7-4
	MIRO_USO								TCS022_MIRUS_TRP_P TCS023_MIRUS_TRP_R	
	MIRO Telescope								TCS015_MIRTE_STP TCS016_MIRTE_TRP_P TCS017_MIRTE_TRP_R	
	NAC1 (internal)				3.30					
	NAC2 (internal)				1.70					
	OSIRIS_WAC optical_bench			(internal heater)	5.00					
	OSIRIS NAC								TCS024_NAC___STP_P TCS092_NAC___STP_R	
	OSIRIS_NAC_CRB	1	1	280 Ω	2.74	45.7	30	-30/5,0/40	TCS030_NACRB_TRP_P TCS031_NACRB_TRP_R	PL-9-3
	OSIRIS WAC								TCS027_WAC___STP_P TCS093_WAC___STP_R	

NOTES	Unit	HEATER						THERMOSTAT([1])	THERMISTOR	LCL
		No. P	No. R	Resis-tance (Ω)	Power (W, @27.7V)	DIMEN. (mm) X	Y	Set Points ° C CG , HG	Name	
	OSIRIS_WAC_CRB	1	1	280 Ω	2.74	45.7	30	-30/5,0/40	TCS032_WACRB_TRP_P TCS033_WACRB_TRP_R	PL-8-3
	OSIRIS_ELEC	1	1	144 Ω	5.33	76.2	25	-30/5,0/40	TCS034_OSIEL_TRP_P TCS035_OSIEL_TRP_R	PL-39-1
	ROSINA_DFMS				1.3			no CG,no HG	TCS036_DFMS__TRP_P TCS037_DFMS__TRP_R	PL-34-1
	ROSINA_COPS	1	1	125 Ω	6.14	93	27	-30/5,0/40	TCS039_COPS__TRP_P TCS040_COPS__TRP_R	PL-42-1
	ROSINA DPU	1	1	470 Ω	1.64	50	12	-30/5,0/40	TCS041_RODPU_TRP_P TCS042_RODPU_TRP_R	PL-10-1
	ROSINA_RTOF (NC)				3.79				TCS038_RTOF__TRP_P TCS094_RTOF__TRP_R	PL-53-1
	RPC_IES	1	1	280 Ω	2.74	45.7	30	-30/5,0/40	TCS053_IES___TRP_P TCS054_IES___TRP_R	PL-18-4
	RPC IES (internal)				0.47					PL-40-1
	RPC LAP1								TCS058_LAP1__STP	
	RPC LAP2								TCS096_LAP2__STP	
	RPC MAG IB								TCS062_MAGIB_STP	
	RPC MIP								TCS059_MIP___STP	
	RPC_PIU cover	1	1	470 Ω	1.64	50	12	-30/5,0/40	TCS051_RPCEL_TRP_P TCS052_RPCEL_TRP_R	PL-10-3
	RSI_USO cover									
4	RPC_ICA	1	1	220 Ω	3.49	45	20	-30/5,0/40	TCS055_ICA___STP TCS056_ICA___TRP_P TCS057_ICA___TRP_R	PL-41-1

NOTES	Unit	HEATER						THERMOSTAT([1])	THERMISTOR	LCL
		No. P	No. R	Resis-tance (Ω)	Power (W, @27.7V)	DIMEN. (mm) X	Y	Set Points ° C CG , HG	Name	
4	SREM	1	1	220 Ω	3.49	45	20	As for ICA	TCS064_SREM__STP TCS065_SREM__TRP_P	As for ICA
	SSP ANT A								TCS069_ESSAA_STP TCS070_ESSAA_TRP_P TCS071_ESSAA_TRP_R	
	SSP ANT B								TCS072_ESSAB_STP TCS073_ESSAB_TRP_P TCS074_ESSAB_TRP_R	
	SSP Compartment				12.8					PL-5-1 PL-5-2
	SSP_ESS Box	1	1	470 Ω	1.63	50	12	-30/5,0/40	TCS075_ESSEL_TRP	PL18-1
	SSPNUT PYPZ								TCS079_NPYPZ_TRP	
	SSPNUT MYPZ								TCS080_NMYPZ_TRP	
	SSPNUT PYMZ								TCS081_NPYMZ_TRP	
	SSPNUT MYMZ								TCS082_NMYMZ_TRP	
3	SSP_RX/TX_1 Box	1	1	280 Ω	2.74	45.7	30	-30/5,0/40	TCS067_ESSRA_TRP	PL8-4
3	SSP_RX/TX_2 Box	1	1	280 Ω	2.74	45.7	30	As for RX/TX1	TCS068_ESSRB_TRP	ditto
	SSP Switchbox TX								TCS076_ESSSW_TRP	
5	SSP_MSS Housing	1	1	144 Ω	5.33	76.2	25	-40/-5,0/40	TCS077_MSS___TRP TCS078_MSS___STP	PL17-1
	VIRTIS CCD				0.77					SS-17-1
	VIRTIS DECONT									SS-15-2

NOTES	Unit	HEATER						THERMOSTAT([1])	THERMISTOR	LCL
		No. P	No. R	Resis-tance (Ω)	Power (W, @27.7V)	DIMEN. (mm) X	Y	Set Points ° C CG , HG	Name	
	VIRTIS_ELEC								TCS045_VIREL_TRP_P TCS046_VIREL_TRP_R	
	VIRTIS OPTICS PALLET								TCS043_VIRTI_TRP_P TCS044_VIRTI_TRP_R	
	VIRTIS_PEMH	1	1	220 Ω	3.49	45	20	-30/5,0/40	TCS047_VIRPH_TRP_P TCS048_VIRPH_TRP_R	PL8-1
	VIRTIS_PEMM	1	1	220 Ω	3.49	45	20	-30/5,0/40	TCS049_VIRPM_TRP_P TCS050_VIRPM_TRP_R	PL28-1
POWER										
	PDU -BSM								TCS100_PDUSS_TRP	
	PDU -PSM								TCS101_PDUPL_TRP	
	PCU								TCS102_PCU___TRP	
	BATTERY1 TCS (SW controlled heater) DISCHARGE	1	1	125 + 125 Ω 2∗220 Ω	3.07	45 45	20 20	-12/0, no HG	TCS103_BATT1_H705_1 TCS104_BATT1_H705_2 TCS105_BATT1_H705_3	SS-20-1
	BATTERY2 TCS (SW controlled heater) DISCHARGE	1	1	125 + 125 Ω 2∗220 Ω	3.07	45 45	20 20	-12/0, no HG	TCS106_BATT2_H780_1 TCS107_BATT2_H780_2 TCS108_BATT2_H780_3	SS-20-4
	BATTERY3 TCS (SW controlled heater) DISCHARGE	1	1	125 + 125 Ω 2∗220 Ω	3.07	45 45	20 20	-12/0, no HG	TCS109_BATT3_H730_1 TCS110_BATT3_H730_2 TCS111_BATT3_H730_3	SS-20-2

NOTES	Unit	HEATER						THERMOSTAT([1])	THERMISTOR	LCL
		No. P	No. R	Resis-tance (Ω)	Power (W, @27.7V)	DIMEN. (mm) X	Y	Set Points ° C CG , HG	Name	
	ANTENNAE									
	MGA-S								TCS120_MGAS__STP TCS121_MGAS__TRP_P TCS122_MGAS__TRP_R	
	MGA-X								TCS123_MGAX__STP TCS124_MGAX__TRP_P TCS125_MGAX__TRP_R	
	LGA +Z								TCS126_LGAPZ_STP TCS127_LGAPZ_TRP_P TCS128_LGAPZ_TRP_R	
	LGA -Z								TCS129_LGAMZ_STP TCS130_LGAMZ_TRP_P TCS131_LGAMZ_TRP_R	
	MECHANISMS									
	PZ Boom								TCS140_BOOPZ_STP	
	MZ Boom								TCS141_BOOMZ_STP	
	HGA APM (HW/SW controlled heater)				8.05			-50/-15, no HG	TCS142_APM___H178_1 TCS143_APM___H178_2 TCS144_APM___H178_3 TCS145_HGAMA_STP_1 TCS146_HGAMA_STP_2 TCS147_HGAMA_STP_3	PL-43-2
	HGA APME								TCS151_APME__TRP_1 TCS152_APME__TRP_2 TCS153_APME__TRP_3 TCS154_APME__TRP_4	

NOTES	Unit	HEATER						THERMOSTAT([1])	THERMISTOR	LCL
		No. P	No. R	Resis-tance (Ω)	Power (W, @27.7V)	DIMEN. (mm) X	Y	Set Points ° C CG , HG	Name	
	SADE								TCS161_SADE__TRP	
	SADM PY (SW controlled heater)			2 x 102 Ω in series	3.76				TCS155_SADPY_H756_1 TCS156_SADPY_H756_2 TCS157_SADPY_H756_3	SS-21-3
	SADM MY (SW controlled heater)			2 x 102 Ω in series	3.76				TCS158_SADMY_H781_1 TCS159_SADMY_H781_2 TCS160_SADMY_H781_3	SS-21-4
** This is one of the HGA skin connectors (+X panel)*										
	RCS									
	PZ PROP TANK TCS	4	4	2 x 6.1 Ω	3.8 W on each heater			0/20,20/40	TCS200_MMH___H701_1 TCS201_MMH___H701_2 TCS202_MMH___H701_3	PL-35-1
	Upper Gauging Lower Gauging	12	12	2 x 5.2 Ω	2 W on each heater				TCS203_MMHHI_GAU TCS204_MMHLO_GAU_P TCS205_MMHLO_GAU_R	SS-16-3
	MZ PROP TANK TCS	4	4	2 x 5.5 Ω	4.2 W on each heater			0/20,20/40	TCS206_NTO___H726_1 TCS207_NTO___H726_2 TCS208_NTO___H726_3	PL-36-1
	MZ PROP TANK Upper Gauging Lower Gauging	12	12	2 x 5.2 Ω	2 W on each heater				TCS209_NTOHI_GAU TCS210_NTOLO_GAU_P TCS211_NTOLO_GAU_R	SS-16-4
1	CYLINDER WALL – PSM								TCS276_CYPSM_GAU	

NOTES	Unit	HEATER						THERMOSTAT([1])	THERMISTOR	LCL
		No. P	No. R	Resis-tance (Ω)	Power (W, @27.7V)	DIMEN. (mm) X	Y	Set Points ° C CG , HG	Name	
1	CYLINDER WALL – BSM								TCS277_CYBSM_GAU	
	NC PYRO 3								TCS270_PVC03_TRP	
	NC PYRO 4								TCS271_PVC04_TRP	
	NC PYRO 7								TCS272_PVC07_TRP	
	NC PYRO 8								TCS273_PVC08_TRP	
	NC PYRO 9								TCS274_PVC09_TRP	
	NC PYRO 10								TCS275_PVC10_TRP	
	PRESS_TANK_PY								TCS212_HEPY__TRP	
	PRESS_TANK_MY								TCS213_HEMY__TRP	
	PR1								TCS266_PR1___TRP_P TCS267_PR1___TRP_R	
	PR2								TCS268_PR2___TRP_P TCS269_PR2___TRP_R	
6	RCS Line 1	13	13	386.4 Ω	1.99			0/5, 40/45	TCS254_RCS01_TRP	PL-23-1
6	RCS Line 2	19	19	374.1 Ω	2.05			0/5, 40/45	TCS255_RCS02_TRP	PL-23-2
6	RCS Line 3	22	22	425.8 Ω	1.8			0/5, 40/45	TCS256_RCS03_TRP	PL-23-3
6a	RCS Line 4	35	35	117.5 Ω	6.53			0/5, 40/45	TCS257_RCS04_TRP	PL-23-4
6b	RCS Line 5	38	38	131.1 Ω	5.85			0/5, 40/45	TCS258_RCS05_TRP	PL-24-1
6	RCS Line 6	17	17	452.2 Ω	1.7			0/5, 40/45	TCS259_RCS06_TRP	PL-24-2

NOTES	Unit	HEATER						THERMOSTAT([1])	THERMISTOR	LCL
		No. P	No. R	Resis-tance (Ω)	Power (W, @27.7V)	DIMEN. (mm) X	Y	Set Points ° C CG , HG	Name	
6	RCS Line 7	7	7	692 Ω	1.11			0/5, 40/45	TCS260_RCS07_TRP	PL-24-3
6	RCS Line 8	13	13	388.7 Ω	1.97			0/5, 40/45	TCS261_RCS08_TRP	PL-24-4
6	RCS Line 9	4	4	1080 Ω	0.71			0/5, 40/45	TCS262_RCS09_TRP	PL-37-1
6	RCS Line 10	3	3	1900 Ω	0.4			0/5, 40/45	TCS263_RCS10_TRP	PL-37-2
6	RCS Line 11	5	5	790 Ω	0.97			0/5, 40/45	TCS264_RCS11_TRP	PL-37-3
6	RCS Line 12	5	5	835 Ω	0.92			0/5, 40/45	TCS265_RCS12_TRP	PL-37-4
	THR1 (HW/SW controlled heater)	2	2	960 Ω	2.6	65	15	0/40	TCS214_THR01_H129_1 TCS215_THR01_H129_2 TCS216_THR01_H129_3	PL-44-1
	THR2 (HW/SW controlled heater)	2	2	960 Ω	2.9	65	15	0/40	TCS217_THR02_H179_1 TCS218_THR02_H179_2 TCS219_THR02_H179_3	PL-44-2
	THR3 (HW/SW controlled heater)	2	2	960 Ω	2.6	65	15	0/40	TCS220_THR03_H329_1 TCS221_THR03_H329_2 TCS222_THR03_H329_3	PL-44-3
	THR4 (HW/SW controlled heater)	2	2	960 Ω	2.9	65	15	0/40	TCS223_THR04_H379_1 TCS224_THR04_H379_2 TCS225_THR04_H379_3	PL-44-4
	THR5 (HW/SW controlled heater)	2	2	960 Ω	2.6	65	15	0/40	TCS226_THR05_H130_1 TCS227_THR05_H130_2 TCS228_THR05_H130_3	PL-45-1

NOTES	Unit	HEATER						THERMOSTAT([1])	THERMISTOR	LCL
		No. P	No. R	Resis-tance (Ω)	Power (W, @27.7V)	DIMEN. (mm) X	Y	Set Points ° C CG , HG	Name	
	THR6 (HW/SW controlled heater)	2	2	960 Ω	2.9	65	15	0/40	TCS229_THR06_H180_1 TCS230_THR06_H180_2 TCS231_THR06_H180_3	PL-45-2
	THR7 (HW/SW controlled heater)	2	2	960 Ω	2.6	65	15	0/40	TCS232_THR07_H330_1 TCS233_THR07_H330_2 TCS234_THR07_H330_3	PL-45-3
	THR8 (HW/SW controlled heater)	2	2	960 Ω	2.9	65	15	0/40	TCS235_THR08_H380_1 TCS236_THR08_H380_2 TCS237_THR08_H380_3	PL-45-4
	THR9 (HW/SW controlled heater)	2	2	960 Ω	2.9	65	15	0/40	TCS238_THR09_H131_1 TCS239_THR09_H131_2 TCS240_THR09_H131_3	PL-46-1
	THR10 (HW/SW controlled heater)	2	2	960 Ω	2.9	65	15	0/40	TCS241_THR10_H181_1 TCS242_THR10_H181_2 TCS243_THR10_H181_3	PL-46-2
	THR11 (HW/SW controlled heater)	2	2	960 Ω	2.9	65	15	0/40	TCS244_THR11_H331_1 TCS245_THR11_H331_2 TCS246_THR11_H331_3	PL-46-3
	THR12 (HW/SW controlled heater)	2	2	960 Ω	2.9	65	15	0/40	TCS247_THR12_H381_1 TCS248_THR12_H381_2 TCS249_THR12_H381_3	PL-46-4
	20cm Downstream of PY He								TCS250_HEPYD_TRP	
	20cm Downstream of MY He								TCS251_HEMYD_TRP	
	20cm Downstream of PR1								TCS252_PR1D__TRP	
	20cm Downstream or PR2								TCS253_PR2D__TRP	

TELEMETRY, TRACKING & CONTROL

NOTES	Unit	HEATER						THERMOSTAT([1])	THERMISTOR	LCL
		No. P	No. R	Resis-tance (Ω)	Power (W, @27.7V)	DIMEN. (mm) X	Y	Set Points ° C CG , HG	Name	
	EPC 1								TCS283_EPC1__TRP	
	EPC 2								TCS284_EPC2__TRP	
	RFDU								TCS287_RFDU__TRP	
	TRSP 1								TCS285_TRSP1_TRP	
	TRSP 2								TCS286_TRSP2_TRP	
	TWT 1								TCS281_TWT1__TRP	
	TWT 2								TCS282_TWT2__TRP	
	USO								TCS288_USO___TRP	
	WIU								TCS280_WIU___TRP	
	DATA MANAGEMENT SYSTEM									
	CDMU1								TCS300_CDMU1_TRP	
	CDMU2								TCS301_CDMU2_TRP	
	RTU -BSM								TCS302_RTUSS_TRP	
	RTU -PSM								TCS303_RTUPL_TRP	
	SSMM								TCS304_SSMM__TRP	
	AIU								TCS320_AIU___TRP	
	IMU1								TCS334_IMU1__TRP	
	IMU2								TCS335_IMU2__TRP	
	IMU3								TCS336_IMU3__TRP	
	Reaction_Wheel_1 (SW controlled heater)			280 Ω	2.74	45.7	30		TCS321_RW1___H703_1 TCS322_RW1___H703_2 TCS323_RW1___H703_3	SS-18-1

NOTES	Unit	HEATER						THERMOSTAT([1])	THERMISTOR	LCL
		No. P	No. R	Resis-tance (Ω)	Power (W, @27.7V)	DIMEN. (mm) X	Y	Set Points ° C CG , HG	Name	
	Reaction_Wheel_2 (SW controlled heater)			280 Ω	2.74	45.7	30		TCS324_RW2___H728_1 TCS325_RW2___H728_2 TCS326_RW2___H728_3	SS-18-2
	Reaction_Wheel_3								TCS327_RW3___H753_1 TCS328_RW3___H753_2 TCS329_RW3___H753_3	
	Reaction_Wheel_4								TCS330_RW4___H778_1 TCS331_RW4___H778_2 TCS332_RW4___H778_3	
	SAS PZ								TCS337_SASPX_STP TCS338_SASPX_TRP	
	SAS MZ								TCS339_SASMX_STP TCS340_SASMX_TRP	
	WDE cover								TCS333_WDE___TRP	
	SSTE1			176 Ω	8.72				TCS349_SSTE1_TRP	
	SSTE2			176 Ω	8.72				TCS350_SSTE2_TRP	
	STR_1_PY Hibernation (Run-up, SW controlled heater)	1 2	1 2	220 Ω 176 Ω	3.49 8.72	45 60	20 30	-40/-5,0/40	TCS341_STR1__STP TCS342_STR1__H704_1 TCS343_STR1__H704_2 TCS344_STR1__H704_3	PL-21-1 SS-19-1
	STR_2_MY Hibernation (Run-up, SW controlled heater)	1 2	1 2	220 Ω 176 Ω	3.49 8.72	45 60	20 30	-40/-5,0/40	TCS345_STR2__STP TCS346_STR2__H729_1 TCS347_STR2__H729_2 TCS348_STR2__H729_3	PL-21-2 SS-19-2

NOTES	Unit	HEATER						THERMOSTAT([1])	THERMISTOR	LCL
		No. P	No. R	Resis-tance (Ω)	Power (W, @27.7V)	DIMEN. (mm) X	Y	Set Points ° C CG , HG	Name	
	NAVCAM_1 Hibernation (Run-up, SW controlled heater)	1 1	1 1	721 Ω 144 Ω	1.06 5.33	35 76.2	22.5 25	-40/-5,0/40	TCS351_NAV1__STP TCS352_NAV1__H754_1 TCS353_NAV1__H754_2 TCS354_NAV1__H754_3	PL-21-3 SS-19-3
	NAVCAM_2 Hibernation (Run-up, SW controlled heater)	1 1	1 1	721 Ω 144 Ω	1.06 5.33	35 76.2	22.5 25	-40/-5,0/40	TCS355_NAV2__STP TCS356_NAV2__H779_1 TCS357_NAV2__H779_2 TCS358_NAV2__H779_3	PL-21-4 SS-19-4

Table 5-45: Heater Description

Run-Up Heaters:	Power (W)
STR_1	8.2
STR_2	8.2
NAVCAM_1	5.16
NAVCAM_2	5.16
Reaction_Wheel_1 B	2.65
Reaction_Wheel_3 B	2.65
SADM +Y	4.1
SADM –Y	4.1

Table 5-46: Run-up Heaters Description

5.4.1.2.7. Thermistors and Thermostats

5.4.1.2.7.1. Unit Functions

Thermistors are used for monitoring the performance of the TCS and as input information to control the software heaters. The design includes 3 control thermistors sited next to each other and using the middle temperature reading to control the heater switching. This method is used in order to maximise the reliability of thermistor controlling temperature and to ensure that no single thermistor failure affects heater switching accuracy. The upper switch off temperature for the thermistors shall nominally be 20°C higher than the switch on temperature. This ensures little thermal cycling and therefore no problems with reliability of software heater circuit elements over the 10.5 year mission. The thermistor limit set points may, of course, be updated to whatever is required as they are software controlled and therefore may be updated from the ground as required. Predicted thresholds are given in Table 5-47.

There is also a requirement to monitor the temperature at each unit's temperature reference point (TRP) and at the System Interface Temperature Points (STP), so at least one thermistor will be used at these points.

Yellowspring thermistors have been baselined for use throughout the thermal subsystem.

For spacecraft hibernation modes, it is necessary that the heater circuits operate without any external support. Prime heater lines will be on permanently and redundant heaters will be thermostatically controlled. These thermostats, as with the thermistors, are locally bonded at pre-defined controlling points. The use of thermostatically controlled heater circuits on Rosetta will be maximised in order to help produce a simple, autonomous TCS design.

Thermostat switching ranges are set to produce little or no cycling of the hardware heaters. This produces a stable temperature platform and also improves the reliability of the hardware heater circuits. The hardware heater power budget will be able to power all hardware heaters simultaneously as the Rosetta spacecraft does not rely on battery power after LEOP.

The thermostats selected for use in the Rosetta TCS are COMEPA Type 47.

5.4.1.2.7.2. Interfaces

The thermostat devices have no telemetry or telecommand interfaces, and draw no power.

Thermistor interfaces have no telecommand interfaces, but are attached to the remote terminal unit (RTU) as described in [RO-DSS-IF-1002]. The RTU will provide the power required by the thermistors and process the analogic data returned by them into such a form that it can be telemetered to the ground.

5.4.1.2.7.3. Performance Data

Description	TRP Node	Upper NOP(°C)	Upper OP(°C)	Lower OP(°C)	Lower NOP (°C)	Lower SW ON(°C)	Upper SW ON(°C)	Hot Uncert. (°C)	Cold Uncert. (°C)
Payload									
ALICE	50001	60	50	-20	-30	-20	50	2.0	2.0
CONSERT_antenna	50042	100	100	-80	-180	-80	100	2.0	4.0
CONSERT_electronics	50060	60	50	-20	-30	-20	50	5.3	2.0
COSIMA	50092	30	30	-40	-40	-40	20	3.0	3.0
COSIMA_electronics	50085	60	50	-20	-30	-30	40	2.0	2.0
GIADA	50122	60	50	-20	-30	-30	50	2.0	4.8
MIDAS	50200	60	55	-20	-30	-30	50	2.0	2.0
MIRO_primary_reflector	50220	125	125	-180	-180	-180 (2)	125 (2)	2.0	2.0
MIRO_secondary_reflector	50221	125	125	-180	-180	-180 (2)	125 (2)	2.0	2.0
MIRO primary reflector support	50222	125	125	-180	-180	-180 (2)	125 (2)	2.0	2.0
MIRO_optical_bench	50241	60	40	-20	-30	-30	40	2.0	2.0
MIRO_sensor_electronics	50250	60	55	-20	-30	-30	50	2.8	2.0
MIRO_electronics	50260	60	55	-20	-30	-30	50	4.3	2.0
MIRO_USO	50270	60	55	-20	-30	-30	50	2.0	2.0
OSIRIS_NAC_structure	50280	90	90	-90	-90	-90 (2)	90 (2)	13.0	2.9
OSIRIS_NAC_PPE	50281	60	60	-30	-50	-30 (2)	60 (2)	13.0	2.9
OSIRIS_NAC_FDM	50283	60	60	-45	-45	-45 (2)	60 (2)	13.0	2.9
OSIRIS_WAC	50300	50	17	7	-40	-40	10	2.0	4.1
OSIRIS_NAC_CRB	50320	60	50	-20	-30	-30	50	2.1	2.1
OSIRIS_WAC_CRB	50340	60	50	-20	-30	-30	50	2.0	2.0
OSIRIS_electronics	50360	60	50	-20	-30	-30	50	2.0	2.0
SSP_compartment	50400	60	50	-40	-55	-40	50	3.0	3.0
SSP_batterystack	50408	60	60	0	-55	-40	50	3.0	3.0
SSP_ejectblock	50471	120	100	-150	-170	-150	100	5.0	5.0
SSP_ESS	50480	60	50	-20	-30	-30	50	2.1	2.0
SSP_RXTX1	50485	60	50	-20	-30	-20	50	2.0	2.0
SSP_RXTX2	50486	60	50	-20	-30	-20	50	2.1	2.0
SSP_coax_relays	50492	60	50	-20	-30	-20	50	2.0	2.0
SSP_MSS	50500	60	50	-30	-40	-30	50	2.0	2.0
SSP_antenna1	50495	130	120	-110	-120	-120	110	4.7	4.0

Description	TRP Node	Upper NOP(°C)	Upper OP(°C)	Lower OP(°C)	Lower NOP (°C)	Lower SW ON(°C)	Upper SW ON(°C)	Hot Uncert. (°C)	Cold Uncert. (°C)
SSP_antenna2	50497	130	120	-110	-120	-120	110	4.7	4.0
ROSINA_DFMS_baseplate	50520	60	50	-30	-50	-40	50	2.0	2.0
ROSINA_DFMS_detector	50523	60	30	-70	-80	-40	30	2.0	2.0
ROSINA_COPS	50546	60	60	-20	-30	-30	50	2.0	4.8
ROSINA_RTOF_box	50561	60	50	-30	-40	-40	50	5.9	7.8
ROSINA_DPU	50580	60	50	-20	-30	-30	50	3.1	2.0
RPC_PIU	50740	60	55	-20	-30	-30	50	6.6	2.0
RPC_ICA	50605	60	55	-30	-45	-30	50	10.6	2.0
RPC_IES	50620	60	50	-20	-30	-20	50	8.2	8.3
RPC_LAP1	50640	250	250	-150	-150	-170	250	91.0	3.0
RPC_LAP2	50660	250	250	-150	-150	-170	250	91.0	3.0
RPC_MAG_OB	50704	150	120	-160	-180	-150	100	13.0	3.0
RPC_MAG_IB	50684	150	120	-160	-180	-150	100	13.0	3.0
RPC_MIP	50721	100	100	-130	-160	-160	100	16.0	10.0
SREM	50860	65	55	-20	-30	-20 (2)	55 (2)	6.8	2.0
VIRTIS_Sensor	50780	60	50	-30	-40	-40	40	2.0	4.6
VIRTIS_electronics	50800	60	50/40 (3)	-20	-30	-30	40	7.6	2.0
VIRTIS_PEMM	50820	60	50	-20	-30	-30	40	7.3	2.0
VIRTIS_PEMH	50840	60	50	-20	-30	-30	40	4.5	2.0
Propulsion									
TANK_Propellant_MZ	80000	45	45	0	0	n/a	n/a	4.5	3.6
	80001	45	45	0	0	n/a	n/a	5.2	2.0
TANK_Propellant_PZ	80004	45	45	0	0	n/a	n/a	5.3	4.4
	80005	45	45	0	0	n/a	n/a	2.0	2.0
TANK_Pressurant_MY	83000	45	45	-40	-40	n/a	n/a	3.1	2.0
TANK_Pressurant_PY	83001	45	45	-40	-40	n/a	n/a	4.7	4.6
RCS_Thruster_Lines		50	50	2	2			1.4	4.6
RCS_Sidebranch_Lines		75	75	-5	-5			1.4	4.6
Pyro_valves_T1_T3			50	-50				1.4	2.8
Pyro_valves_T2_T4			50	-10				1.4	2.8
PRT_LP			40	0				1.4	2.8

Description	TRP Node	Upper NOP(°C)	Upper OP(°C)	Lower OP(°C)	Lower NOP (°C)	Lower SW ON(°C)	Upper SW ON(°C)	Hot Uncert. (°C)	Cold Uncert. (°C)
PRT_HP			40	-60				1.4	2.8
He_Regulator		65	40	-20	-50			1.4	2.8
F&D_Valves		30	30	0	0			1.4	2.8
Electrical									
PDU_BSM	52000	65	60	-25	-35	-25 (2)	60 (2)	6.1	2.0
PDU_PSM	52010	65	60	-25	-35	-25 (2)	60 (2)	6.3	2.0
PCU	52029	65	60	-25	-35	-25 (2)	60 (2)	4.0	5.6
BATT_1	52050	55	45	-12	-12	-12 (2)	45 (2)	4.7	2.5
BATT_2	52060	55	45	-12	-12	-12 (2)	45 (2)	3.4	4.6
BATT_3	52070	55	45	-12	-12	-12 (2)	45 (2)	2.0	5.6
SADE	52099	65	60	-25	-25	-25 (2)	60 (2)	3.7	2.0
Mechanisms									
SADM_PY	52127	70	60	-30	-40	-30 (2)	60 (2)	5.1	2.0
SADM_MY	52107	70	60	-30	-40	-30 (2)	60 (2)	12.1	2.9
HGA EDU Housing(1)	52261	100	100	-70	-70	-70 (2)	100 (2)	2.2	2.0
HGA ADU Housing(1)	52264	100	100	-70	-70	-70 (2)	100 (2)	6.3	2.0
MGU pz	86192	75	75	-55	-55	n/a	n/a	2.0	2.6
MGU mz	86292	75	75	-55	-55	n/a	n/a	3.0	3.0
TT&C									
RSI_USO	50761	70	50	-20	-40	-30	50	2.0	6.6
TWT_1	52400	75	75	-25	-30	-25 (2)	75 (2)	11.3	4.6
TWT_2	52410	75	75	-25	-30	-25 (2)	75 (2)	2.0	4.8
EPC_1	52421	70	60	-25	-30	-25 (2)	60 (2)	5.7	3.0
EPC_2	52431	70	60	-25	-30	-25 (2)	60 (2)	3.2	6.3
WIU	52449	80	70	-40	-50	-40 (2)	70 (2)	2.6	2.0
TRSP_1	52459	70	60	-25	-35	-25 (2)	60 (2)	2.0	2.0
TRSP_2	52469	70	60	-25	-35	-25 (2)	60 (2)	5.7	2.0
RFDU	52470	80	70	-35	-50	-35 (2)	70 (2)	2.0	2.8
APME	52480	60	60	-30	-40	-30 (2)	60 (2)	2.0	3.6
Avionics-DMS									
CDMU_1	54490	65	60	-25	-35	-35	60 (2)	2.0	3.7

Description	TRP Node	Upper NOP(°C)	Upper OP(°C)	Lower OP(°C)	Lower NOP (°C)	Lower SW ON(°C)	Upper SW ON(°C)	Hot Uncert. (°C)	Cold Uncert. (°C)
CDMU_2	54500	65	60	-25	-35	-35	60 (2)	2.0	3.9
RTU_BSM	52500	65	60	-25	-35	-35	60 (2)	4.0	2.0
RTU_PSM	52510	65	60	-25	-35	-35	60 (2)	4.6	2.0
SSMM	52580	65	60	-25	-35	-35	60 (2)	2.0	3.5
Avionics-AOCMS									
AIU	54300	65	60	-25	-25	-25	60 (2)	4.7	2.0
RW_1	54321	60	50	-5	-25	-15	50 (2)	3.1	3.5
RW_2	54331	60	50	-5	-25	-15	50 (2)	4.4	2.0
RW_3	54341	60	50	-5	-25	-15	50 (2)	4.5	2.0
RW_4	54351	60	50	-5	-25	-15	50 (2)	2.0	6.4
WDE	54369	60	50	-20	-25	-25	50 (2)	2.6	4.7
IMU_1	54370	65	55	-20	-30	-25	55 (2)	2.5	4.7
IMU_2	54380	65	55	-20	-30	-25	55 (2)	2.0	4.9
IMU_3	54390	65	55	-20	-30	-25	55 (2)	4.9	5.0
SAS_PZ	54561	110	110	-135	-135	n/a	n/a	2.0	5.0
SAS_MX	54581	110	110	-135	-135	n/a	n/a	5.3	2.8
SST_1	54404	45	40	-15	-40	-25	40 (2)	6.1	5.7
SST_2	54424	45	40	-15	-40	-25	40 (2)	6.6	2.0
SSTE_1	54440	60	50	-25	-45	-40 (2)	50 (2)	2.0	2.0
SSTE_2	54450	60	50	-25	-45	-40 (2)	50 (2)	2.0	3.2
Avionics-NAVCAM									
NAVCAM_1	54515	45	40	-15	-35	-25	40	2.0	4.4
NAVCAM_2	54535	45	40	-15	-35	-25	40	2.0	2.0
Antenna									
LGA_PZ	52560	130	130	-135	-135	-135 (2)	130 (2)	2.0	13.3
LGA_MZ	52570	130	130	-135	-135	-135 (2)	130 (2)	8.6	2.0
MGA_X	52540	90	90	-125	-125	-125 (2)	90 (2)	14.5	3.7
MGA_S	52550	110	110	-128	-128	-128 (2)	110 (2)	2.0	2.0
RCS									
Thruster 1A Valve	90112	60	60	-5	-5	n/a	n/a	3.0	3.0
Thruster 1B Valve	90122	60	60	-5	-5	n/a	n/a	3.0	3.0
Thruster 2A Valve	90212	60	60	-5	-5	n/a	n/a	6.1	3.0

Description	TRP Node	Upper NOP(°C)	Upper OP(°C)	Lower OP(°C)	Lower NOP (°C)	Lower SW ON(°C)	Upper SW ON(°C)	Hot Uncert. (°C)	Cold Uncert. (°C)
Thruster 2B Valve	90222	60	60	-5	-5	n/a	n/a	5.7	3.0
Thruster 3A Valve	90312	60	60	-5	-5	n/a	n/a	3.0	4.8
Thruster 3B Valve	90322	60	60	-5	-5	n/a	n/a	3.0	3.8
Thruster 4A Valve	90412	60	60	-5	-5	n/a	n/a	3.0	3.0
Thruster 4B Valve	90422	60	60	-5	-5	n/a	n/a	3.0	3.0
Thruster 5A Valve	90512	60	60	-5	-5	n/a	n/a	3.0	3.1
Thruster 5B Valve	90522	60	60	-5	-5	n/a	n/a	3.0	3.0
Thruster 6A Valve	90612	60	60	-5	-5	n/a	n/a	3.0	3.0
Thruster 6B Valve	90622	60	60	-5	-5	n/a	n/a	3.0	3.0
Thruster 7A Valve	90712	60	60	-5	-5	n/a	n/a	3.0	3.9
Thruster 7B Valve	90722	60	60	-5	-5	n/a	n/a	3.0	3.0
Thruster 8A Valve	90812	60	60	-5	-5	n/a	n/a	3.0	3.0
Thruster 8B Valve	90822	60	60	-5	-5	n/a	n/a	3.0	3.0
Thruster 9A Valve	90912	60	60	-5	-5	n/a	n/a	3.0	7.8
Thruster 9B Valve	90922	60	60	-5	-5	n/a	n/a	3.0	7.7
Thruster 10A Valve	91012	60	60	-5	-5	n/a	n/a	3.2	3.0
Thruster 10B Valve	91022	60	60	-5	-5	n/a	n/a	3.0	3.0
Thruster 11A Valve	91112	60	60	-5	-5	n/a	n/a	3.5	4.1
Thruster 11B Valve	91122	60	60	-5	-5	n/a	n/a	3.2	4.1
Thruster 12A Valve	91212	60	60	-5	-5	n/a	n/a	3.0	3.0
Thruster 12B Valve	91222	60	60	-5	-5	n/a	n/a	3.0	3.0

Table 5-47: Temperature Limits for SC Equipments

NOTE 1 : From RO-HTS-AN-0004 , Issue 3, Nov 2000, HGAMA Thermal Design and Analysis Report

NOTE 2 : Switch On limit has not been defined, operational limit has been assumed

NOTE 3 : 50°C Upper operational limit is that at 1.06AU with comet 40°CUpper operational limit is that at 1.4AU with comet (case 7-10)

The thermostats will be located near the TRP of the unit which requires heater control. Table 5-49 shows the correlation between the unit’s TRP and the thermostat set point value which will be used at that location.

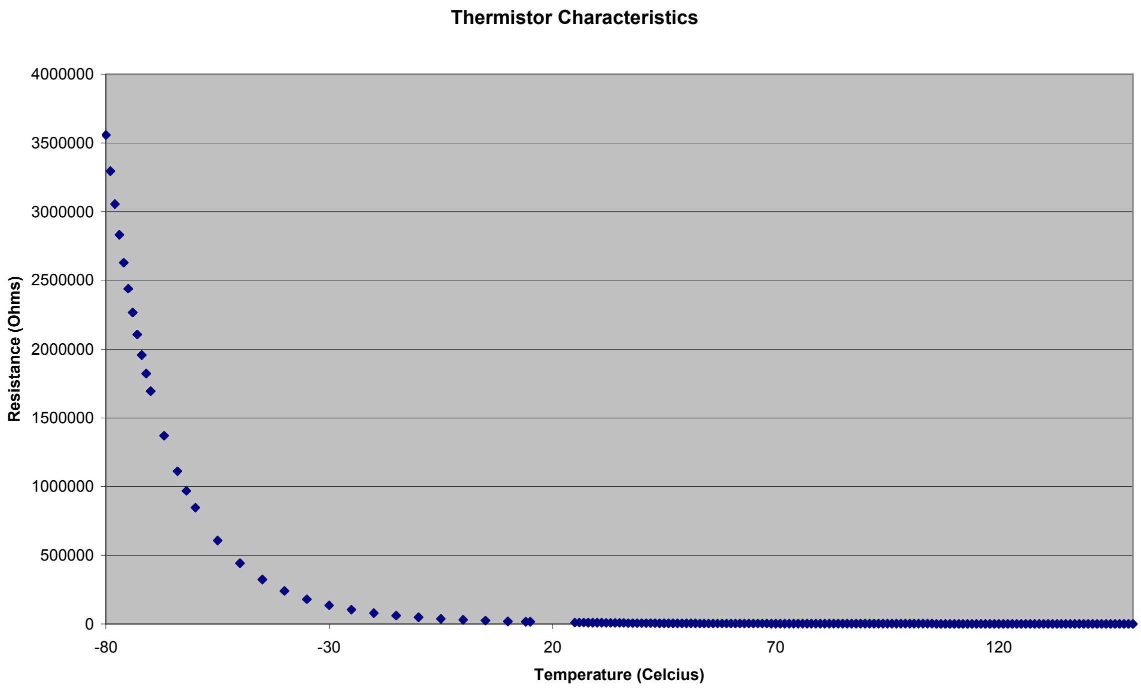


Figure 5-91: Thermistor Characteristic

The above graph shows the resistance of the Yellowspring thermistor as it varies with temperature. Data taken from [http://misspiggy.gsfc.nasa.gov/ctre/parts/specs/thermistor/p18.pdf]. The thermistor type is YSI 311-P18-07T76R.

5.4.1.3. Subsystem Operations Modes

The following table gives the TCS configuration for each system mode.

Mission Phase	System Mode
Launch	Launch Mode
Commissioning	Activation Mode
Earth to Mars Cruise	Near Sun Hibernation Mode
Mars Gravity Assist	Active Cruise Mode
Mars to Earth Cruise (C#2)	Active Cruise Mode
Firs Earth Gravity Assist	Active Cruise Mode
Earth to Asteroid Cruise (C#3)	Near Sun Hibernation Mode
Ottawara fly-by	Active Cruise Mode/ Asteroid Flyby Mode
Ottawara to Earth Cruise	Near Sun Hibernation Mode
Second Earth Gravity Assist	Active Cruise Mode
Earth to Asteroid Cruise	Near Sun Hibernation Mode
Siwa fly-by	Active Cruise Mode/ Asteroid Flyby Mode
Siwa to RVM-1 Cruise (C#6)	Near Sun Hibernation Mode
Deep Space Manoeuvre	Active Cruise Mode
RVM-1 to RDVM Cruise (C#7)	Deep Space Hibernation Mode
Comet Orbit Matching Manoeuvre	Active Cruise Mode
Near Comet Drift	Near Comet Mode
Far Approach Trajectory	Near Comet Mode
Close Approach Trajectory	Near Comet Mode
Transition to Global Mapping	Near Comet Mode
Global Mapping	Near Comet Mode
Close Observation	Near Comet Mode
SSP Delivery,	Near Comet Mode
SSP Data Relay	Near Comet Mode
Extended Monitoring (to Perihelion)	Near Comet Mode
End of Mission (Design Life of 11 years)	

Table 5-48: TCS Modes

Launch Mode

A number of units may require heating immediately after the launcher fairing is jettisoned. Consequently this heater configuration will be commanded by ground before the launch, and will remain the same throughout the launch, a period of approximately one hour. The heater status will be ‘ON’ only if the appropriate thermostats/ thermistor controlled switches are closed.

Towards the end of the launch phase, and the start of the Activation phase, the SC and third stage of the launch vehicle will be spun up to a rate of 1 rpm. In this configuration, the incident solar flux will illuminate the SC faces sequentially, helping to maintain a good thermal configuration.

Activation Mode

During this phase of the mission, the TCS configuration will change depending upon the in orbit test plan.

Near Sun Hibernation Mode

In this mode, the SC is 3 axis stabilised with the +X face pointing towards the sun. Nearly all non ADCS SC units are switched to a dormant state.

Active Cruise Mode

With respect to the TCS, this phase is the same as Near Sun Hibernation mode.

Asteroid Flyby Mode

TCS configuration will be similar to Near Sun Hibernation mode.

Deep Space Hibernation Mode

When the spacecraft reaches 4.7AU from the sun it enters a deep space hibernation mode. For this, all but the essential equipment are turned off, hence the minimum total dissipation occurs, and so all hardware heaters will be required. The aphelion point of the Rosetta mission occurs at the maximum sun distance of 5.25AU, where the value of the incident solar flux on the spacecraft is only around 4% of the value at 1.0AU. The TCS design is optimised to give the minimum allowed equipment temperatures so as to minimise the required heater power.

Near Comet Mode

The comet operation phases towards the end of mission have the highest dissipation of the mission since all the payloads are operational, along with the avionics units. Additionally, at the end of life when the degradation of the thermo-optical properties of the various surfaces will be a maximum, the efficiency of the radiators (heat rejection) will be at a minimum. Coupled with a sun distance of 1.0AU (mission closest sun passage = 0.9AU) and the thermal and degradation effects of the near comet environment, this is the hot design case, from which the sizes of the radiators are determined. Thus, all hardware heater will be off.

Safe Mode

This mode is foreseen to reconfigure the S/C. All P/L will be switched off, but the essential S/C equipment will be still operating. This will require a heater setting which is similar to the ACM without any P/L operating.

Survival Mode

The survival mode is a back up mode for the safe mode in case of power shortage. In this case only the real essential equipment for S/C reconfiguration is operating. This require a different heater setting (some more heater power) from the safe mode in order to keep all units within limits.

SKM/SHM Mode
This modes are backup modes for DSHM and will have a similar heater setting as the NSHM.

5.4.1.4. Subsystem Telemetry and Telecommand Data Summary

5.4.1.5. Telecommand Summary

The Telecommands for controlling the LCLs are described in Annex 2.

5.4.1.6. Telemetry Summary

The following table lists the TCS thermistor RSDB names together with the assigned unit.

Unit	RSDB LNAME	RSDB NAME
Alice	TCS001_ALICE_TRP_P-C29	NTSA0062
Alice	TCS002_ALICE_TRP_R-C29	NTSA0188
Consert Antenna	TCS006_CONAN_STP-C36	NTSA0259
Consert Antenna	TCS007_CONAN_TRP_P-C31	NTSA0064
Consert DPU	TCS009_CONEL_TRP-C32	NTSA0065
Cosima	TCS010_COSIM_TRP_P-C33	NTSA0066
Cosima	TCS011_COSIM_TRP_R-C33	NTSA0192
Giada	TCS012_GIADA_TRP_P-C34	NTSA0067
Giada	TCS013_GIADA_TRP_R-C34	NTSA0193
Midas	TCS014_MIDAS_TRP_P-C30	NTSA0063
Miro Telescope	TCS015_MIRTE_STP-C35	NTSA0068
Miro Telescope	TCS016_MIRTE_TRP_P-C37	NTSA0001
Miro Telescope	TCS017_MIRTE_TRP_R-C37	NTSA0127
Miro Optical bench	TCS018_MIROB_TRP-C35	NTSA0194
Miro Sensor Electronic (SE)	TCS019_MIRSE_TRP_P-C43	NTSA0256
Miro Electronic (ME)	TCS020_MIRME_TRP_P-C38	NTSA0002
Miro Electronic (ME)	TCS021_MIRME_TRP_R-C38	NTSA0128
Miro USO	TCS022_MIRUS_TRP_P-C39	NTSA0003
Miro USO	TCS023_MIRUS_TRP_R-C39	NTSA0129
Osiris NAC	TCS024_NAC__STP_P-C44	NTSA0007
Osiris WAC	TCS027_WAC__STP_P-C45	NTSA0008
Osiris NAC CRB	TCS030_NACRB_TRP_P-C46	NTSA0009
Osiris NAC CRB	TCS031_NACRB_TRP_R-C46	NTSA0135
Osiris WAC CRB	TCS032_WACRB_TRP_P-C47	NTSA0010
Osiris WAC CRB	TCS033_WACRB_TRP_R-C47	NTSA0136
Osiris Main Electronic (ME)	TCS034_OSIEL_TRP_P-C48	NTSA0011
Osiris Main Electronic (ME)	TCS035_OSIEL_TRP_R-C48	NTSA0137

Unit	RSDB LNAME	RSDB NAME
Rosina DFMS	TCS036_DFMS_TRP_P-C49	NTSA0012
Rosina DFMS	TCS037_DFMS_TRP_R-C49	NTSA0138
Rosina RTOF	TCS038_RTOF_TRP_P-C85	NTSA0083
Rosina Cops	TCS039_COPS_TRP_P-C50	NTSA0013
Rosina Cops	TCS040_COPS_TRP_R-C50	NTSA0139
Rosina DPU	TCS041_RODPU_TRP_P-C51	NTSA0014
Rosina DPU	TCS042_RODPU_TRP_R-C51	NTSA0140
Virtis Optical Module (Sensor)	TCS043_VIRTI_TRP_P-C40	NTSA0004
Virtis Optical Module (Sensor)	TCS044_VIRTI_TRP_R-C40	NTSA0130
Virtis Main Electronic (ME)	TCS045_VIREL_TRP_P-C52	NTSA0015
Virtis Main Electronic (ME)	TCS046_VIREL_TRP_R-C52	NTSA0141
Virtis PEM H	TCS047_VIRPH_TRP_P-C41	NTSA0005
Virtis PEM H	TCS048_VIRPH_TRP_R-C41	NTSA0131
Virtis PEM M	TCS049_VIRPM_TRP_P-C42	NTSA0006
Virtis PEM M	TCS050_VIRPM_TRP_R-C42	NTSA0132
RPC PIU	TCS051_RPCEL_TRP_P-C53	NTSA0016
RPC PIU	TCS052_RPCEL_TRP_R-C53	NTSA0142
RPC IES	TCS053_IES__TRP_P-C54	NTSA0017
RPC IES	TCS054_IES__TRP_R-C54	NTSA0143
RPC ICA	TCS055_ICA__STP-C86	NTSA0084
RPC ICA	TCS056_ICA__TRP_P-C55	NTSA0018
RPC ICA	TCS057_ICA__TRP_R-C55	NTSA0144
RPC LAP2	TCS096_LAP2_STP-C86	NTSA0210
RPC MIP	TCS059_MIP__STP-C56	NTSA0019
RPC MAG IB	TCS062_MAGIB_STP-C57	NTSA0020
SREM	TCS064_SREM_STP-C87	NTSA0085
SREM	TCS065_SREM_TRP_P-C59	NTSA0022
SSP RX/TX 1	TCS067_ESSRA_TRP-C58	NTSA0147
SSP RX/TX 2	TCS068_ESSRB_TRP-C60	NTSA0023
SSP Antenna 1	TCS069_ESSAA_STP-C87	NTSA0211
SSP Antenna 1	TCS070_ESSAA_TRP_P-C61	NTSA0024
SSP Antenna 1	TCS071_ESSAA_TRP_R-C61	NTSA0150
SSP Antenna 2	TCS072_ESSAB_STP-C88	NTSA0086
SSP Antenna 2	TCS073_ESSAB_TRP_P-C62	NTSA0025
SSP Antenna 2	TCS074_ESSAB_TRP_R-C62	NTSA0151
SSP ESS	TCS075_ESSEL_TRP-C63	NTSA0026
SSP Switch	TCS076_ESSSW_TRP-C63	NTSA0152
SSP MSS	TCS077_MSS__TRP-C64	NTSA0027
SSP MSS	TCS078_MSS__STP-C64	NTSA0153
SSP separation nuts (NEAs)	TCS079_NPYPZ_TRP-C65	NTSA0028
SSP separation nuts (NEAs)	TCS080_NMYPZ_TRP-C65	NTSA0154
SSP separation nuts (NEAs)	TCS081_NPYMZ_TRP-C66	NTSA0029
SSP separation nuts (NEAs)	TCS082_NMYMZ_TRP-C66	NTSA0155
Midas	TCS090_MIDAS_TRP_R-C30	NTSA0189

Unit	RSDB LNAME	RSDB NAME
Miro Sensor Electronic (SE)	TCS091_MIRSE_TRP_R-C43	NTSA0260
Osiris NAC	TCS092_NAC__STP_R-C44	NTSA0133
Osiris WAC	TCS093_WAC__STP_R-C45	NTSA0134
Rosina RTOF	TCS094_RTOF_TRP_R-C85	NTSA0209
RPC LAP1	TCS058_LAP1_STP-C58	NTSA0021
PDU-PL	TCS100_PDUSS_TRP-C91	NTSA0089
PDU-PL	TCS101_PDUPL_TRP-C91	NTSA0215
PCU	TCS102_PCU__TRP-C88	NTSA0212
Battery 1	TCS103_BAT1_H705_1_C1	NTSA0034
Battery 1	TCS104_BAT1_H705_2-C71	NTSA0069
Battery 1	TCS105_BAT1_H705_3-C1	NTSA0160
Battery 2	TCS106_BAT2_H780_1-C2	NTSA0035
Battery 2	TCS107_BAT2_H780_2-C71	NTSA0195
Battery 2	TCS108_BAT2_H780_3-C2	NTSA0161
Battery 3	TCS109_BAT3_H730_1-C3	NTSA0036
Battery 3	TCS110_BAT3_H730_2-C72	NTSA0070
Battery 3	TCS111_BAT3_H730_3-C3	NTSA0162
Battery 3	TCS120_MGAS_STP-C89	NTSA0087
MGA S	TCS121_MGAS_TRP_P-C67	NTSA0030
MGA S	TCS122_MGAS_TRP_R-C67	NTSA0156
MGA X	TCS123_MGAX_STP-C89	NTSA0213
MGA X	TCS124_MGAX_TRP_P-C68	NTSA0031
MGA X	TCS125_MGAX_TRP_R-C68	NTSA0157
LGA PZ	TCS126_LGAPZ_STP-C90	NTSA0088
LGA PZ	TCS127_LGAPZ_TRP_P-C69	NTSA0032
LGA PZ	TCS128_LGAPZ_TRP_R-C69	NTSA0158
LGA MZ	TCS129_LGAMZ_STP-C90	NTSA0214
LGA MZ	TCS130_LGAMZ_TRP_P-C70	NTSA0033
LGA MZ	TCS131_LGAMZ_TRP_R-C70	NTSA0159
Boom PZ (motor)	TCS140_BOOPZ_STP-C92	NTSA0216
Boom MZ (motor)	TCS141_BOOMZ_STP-C93	NTSA0091
APM	TCS142_APM__H178_1-C4	NTSA0037
APM	TCS143_APM__H178_2-C72	NTSA0196
APM	TCS144_APM__H178_3-C4	NTSA0163
HGA	TCS145_HGAMA_STP_1-C93	NTSA0217
HGA	TCS146_HGAMA_STP_2-C94	NTSA0092
HGA	TCS147_HGAMA_STP_3-C94	NTSA0218
APME	TCS151_APME_TRP_1-C128	NTSA0126
APME	TCS152_APME_TRP_2-C129	NTSA0253
APME	TCS153_APME_TRP_3-C128	NTSA0252
APME	TCS154_APME_TRP_4-C129	NTSA0257
SADM +Y care/shaft	TCS155_SAPY_H756_1-C5	NTSA0038
SADM +Y care/shaft	TCS156_SAPY_H756_2-C73	NTSA0071
SADM +Y care/shaft	TCS157_SAPY_H756_3-C5	NTSA0164

Unit	RSDB LNAME	RSDB NAME
SADM -Y care/shaft	TCS158_SAMY_H781_1-C6	NTSA0039
SADM -Y care/shaft	TCS159_SAMY_H781_2-C73	NTSA0197
SADM -Y care/shaft	TCS160_SAMY_H781_3-C6	NTSA0165
SADE	TCS161_SADE_TRP-C92	NTSA0090
propellant tank +Z (MMH)	TCS200_MMH__H701_1-C7	NTSA0040
propellant tank +Z (MMH)	TCS201_MMH__H701_2-C74	NTSA0072
propellant tank +Z (MMH)	TCS202_MMH__H701_3-C7	NTSA0166
propellant tank +Z (gauging)	TCS203_MMHHI_GAU-C96	NTSA0094
propellant tank +Z (gauging)	TCS204_MMHLO_GAU_P-C95	NTSA0093
propellant tank +Z (gauging)	TCS205_MMHLO_GAU_R-C95	NTSA0219
propellant tank -Z (NTO)	TCS206_NTO__H726_1-C8	NTSA0041
propellant tank -Z (NTO)	TCS207_NTO__H726_2-C74	NTSA0198
propellant tank -Z (NTO)	TCS208_NTO__H726_3-C8	NTSA0167
propellant tank -Z (gauging)	TCS209_NTOHI_GAU-C96	NTSA0220
propellant tank -Z (gauging)	TCS210_NTOLO_GAU_P-C97	NTSA0095
propellant tank -Z (gauging)	TCS211_NTOLO_GAU_R-C97	NTSA0221
pressurant tanks	TCS212_HEPY_TRP-C98	NTSA0096
pressurant tanks	TCS213_HEMY_TRP-C98	NTSA0222
THR HSW module 1	TCS214_Tr01_H129_1-C9	NTSA0042
THR HSW module 1	TCS215_Tr01_H129_2-C75	NTSA0073
THR HSW module 1	TCS216_Tr01_H129_3-C9	NTSA0168
THR HSW module 2	TCS217_Tr02_H179_1-C10	NTSA0043
THR HSW module 2	TCS218_Tr02_H179_2-C75	NTSA0199
THR HSW module 2	TCS219_Tr02_H179_3-C10	NTSA0169
THR HSW module 3	TCS220_Tr03_H329_1-C11	NTSA0044
THR HSW module 3	TCS221_Tr03_H329_2-C76	NTSA0074
THR HSW module 3	TCS222_Tr03_H329_3-C11	NTSA0170
THR HSW module 4	TCS223_Tr04_H379_1-C12	NTSA0045
THR HSW module 4	TCS224_Tr04_H379_2-C76	NTSA0200
THR HSW module 4	TCS225_Tr04_H379_3-C12	NTSA0171
THR HSW module 5	TCS226_Tr05_H130_1-C13	NTSA0046
THR HSW module 5	TCS227_Tr05_H130_2-C77	NTSA0075
THR HSW module 5	TCS228_Tr05_H130_3-C13	NTSA0172
THR HSW module 6	TCS229_Tr06_H180_1-C14	NTSA0047
THR HSW module 6	TCS230_Tr06_H180_2-C77	NTSA0201
THR HSW module 6	TCS231_Tr06_H180_3-C14	NTSA0173
THR HSW module 7	TCS232_Tr07_H330_1-C15	NTSA0048
THR HSW module 7	TCS233_Tr07_H330_2-C78	NTSA0076
THR HSW module 7	TCS234_Tr07_H330_3-C15	NTSA0174
THR HSW module 8	TCS235_Tr08_H380_1-C16	NTSA0049
THR HSW module 8	TCS236_Tr08_H380_2-C78	NTSA0202
THR HSW module 8	TCS237_Tr08_H380_3-C16	NTSA0175
THR HSW module 9	TCS238_Tr09_H131_1-C17	NTSA0050
THR HSW module 9	TCS239_Tr09_H131_2-C79	NTSA0077

Unit	RSDB LNAME	RSDB NAME
THR HSW module 9	TCS240_Tr09_H131_3-C17	NTSA0176
THR HSW module 10	TCS241_Tr10_H181_1-C18	NTSA0051
THR HSW module 10	TCS242_Tr10_H181_2-C79	NTSA0203
THR HSW module 10	TCS243_Tr10_H181_3-C18	NTSA0177
THR HSW module 11	TCS244_Tr11_H331_1-C19	NTSA0052
THR HSW module 11	TCS245_Tr11_H331_2-C80	NTSA0078
THR HSW module 11	TCS246_Tr11_H331_3-C19	NTSA0178
THR HSW module 12	TCS247_Tr12_H381_1-C20	NTSA0053
THR HSW module 12	TCS248_Tr12_H381_2-C80	NTSA0204
THR HSW module 12	TCS249_Tr12_H381_3-C20	NTSA0179
pressurant tanks	TCS250_HEPYD_TRP-C99	NTSA0097
pressurant tanks	TCS251_HEMYD_TRP-C99	NTSA0223
Pyro valves T1&T3 / T2&T4	TCS252_PR1D_TRP-C100	NTSA0098
Pyro valves T1&T3 / T2&T4	TCS253_PR2D_TRP-C100	NTSA0224
RCS lines	TCS254_RCS01_TRP-C101	NTSA0099
RCS lines	TCS255_RCS02_TRP-C101	NTSA0225
RCS lines	TCS256_RCS03_TRP-C102	NTSA0100
RCS lines	TCS257_RCS04_TRP-C102	NTSA0226
RCS lines	TCS258_RCS05_TRP-C103	NTSA0101
RCS lines	TCS259_RCS06_TRP-C103	NTSA0227
RCS lines	TCS260_RCS07_TRP-C104	NTSA0102
RCS lines	TCS261_RCS08_TRP-C104	NTSA0228
RCS lines	TCS262_RCS09_TRP-C105	NTSA0103
RCS lines	TCS263_RCS10_TRP-C105	NTSA0229
RCS lines	TCS264_RCS11_TRP-C106	NTSA0104
RCS lines	TCS265_RCS12_TRP-C106	NTSA0230
Helium Pressure Regulator	TCS266_PR1__TRP_P-C107	NTSA0105
Helium Pressure Regulator	TCS267_PR1__TRP_R-C107	NTSA0231
Helium Pressure Regulator	TCS268_PR2__TRP_P-C108	NTSA0106
Helium Pressure Regulator	TCS269_PR2__TRP_R-C108	NTSA0232
Pyro valves T1&T3 / T2&T4	TCS270_PVC03_TRP-C109	NTSA0107
Pyro valves T1&T3 / T2&T4	TCS271_PVC04_TRP-C109	NTSA0233
Pyro valves T1&T3 / T2&T4	TCS272_PVC07_TRP-C110	NTSA0108
Pyro valves T1&T3 / T2&T4	TCS273_PVC08_TRP-C110	NTSA0234
Pyro valves T1&T3 / T2&T4	TCS274_PVC09_TRP-C111	NTSA0109
Pyro valves T1&T3 / T2&T4	TCS275_PVC10_TRP-C111	NTSA0235
propellant tank +Z (cylinder)	TCS276_CYPSM_GAU-C130	NTSA0254
propellant tank +Z (cylinder)	TCS277_CYBSM_GAU-C130	NTSA0258
WIU	TCS280_WIU__TRP-C112	NTSA0110
TWT 1	TCS281_TWT1_TRP-C113	NTSA0111
TWT 2	TCS282_TWT2_TRP-C113	NTSA0237
EPC 1	TCS283_EPC1_TRP-C114	NTSA0112
EPC 2	TCS284_EPC2_TRP-C114	NTSA0238
TRSP1	TCS285_TRSP1_TRP-C115	NTSA0113

Unit	RSDB LNAME	RSDB NAME
TRSP2	TCS286_TRSP2_TRP-C115	NTSA0239
RFDU	TCS287_RFDU_TRP-C112	NTSA0236
RSI USO	TCS288_USO__TRP-C116	NTSA0114
CDMU 1	TCS300_CDMU1_TRP-C117	NTSA0115
CDMU 2	TCS301_CDMU2_TRP-C117	NTSA0241
RTU S/S	TCS302_RTUSS_TRP-C118	NTSA0116
RTU P/L	TCS303_RTUPL_TRP-C118	NTSA0242
SSMM	TCS304_SSMM_TRP-C116	NTSA0240
AIU	TCS320_AIU__TRP-C119	NTSA0117
RW 1	TCS321_RW1__H703_1-C21	NTSA0054
RW 1	TCS322_RW1__H703_2-C81	NTSA0079
RW 1	TCS323_RW1__H703_3-C21	NTSA0180
RW 2	TCS324_RW2__H728_1-C22	NTSA0055
RW 2	TCS325_RW2__H728_2-C81	NTSA0205
RW 2	TCS326_RW2__H728_3-C22	NTSA0181
RW 3	TCS327_RW3__H753_1-C23	NTSA0056
RW 3	TCS328_RW3__H753_2-C82	NTSA0080
RW 3	TCS329_RW3__H753_3-C23	NTSA0182
RW 4	TCS330_RW4__H778_1-C24	NTSA0057
RW 4	TCS331_RW4__H778_2-C82	NTSA0206
RW 4	TCS332_RW4__H778_3-C24	NTSA0183
WDE	TCS333_WDE__TRP-C119	NTSA0243
IMU 1	TCS334_IMU1_TRP-C120	NTSA0118
IMU 2	TCS335_IMU2_TRP-C120	NTSA0244
IMU 3	TCS336_IMU3_TRP-C60	NTSA0149
SAS 1 (+X)	TCS337_SASPX_STP-C121	NTSA0119
SAS 1 (+X)	TCS338_SASPX_TRP-C121	NTSA0245
SAS 2 (-X)	TCS339_SASMX_STP-C122	NTSA0120
SAS 2 (-X)	TCS340_SASMX_TRP-C122	NTSA0246
STR 1	TCS341_STR1_STP-C123	NTSA0121
STR 1	TCS342_STR1_H704_1-C25	NTSA0058
STR 1	TCS343_STR1_H704_2-C84	NTSA0082
STR 1	TCS344_STR1_H704_3-C25	NTSA0184
STR 2	TCS345_STR2_STP-C123	NTSA0247
STR 2	TCS346_STR2_H729_1-C26	NTSA0059
STR 2	TCS347_STR2_H729_2-C84	NTSA0208
STR 2	TCS348_STR2_H729_3-C26	NTSA0185
SST / CAM ELEC 1	TCS349_SSTE1_TRP-C124	NTSA0122
SST / CAM ELEC 2	TCS350_SSTE2_TRP-C124	NTSA0248
NAVCAM 1	TCS351_NAV1_STP-C125	NTSA0123
NAVCAM 1	TCS352_NAV1_H754_1-C27	NTSA0060
NAVCAM 1	TCS353_NAV1_H754_2-C83	NTSA0081
NAVCAM 1	TCS354_NAV1_H754_3-C27	NTSA0186
NAVCAM 2	TCS355_NAV2_STP-C125	NTSA0249

Unit	RSDB LNAME	RSDB NAME
NAVCAM 2	TCS356_NAV2_H779_1-C28	NTSA0061
NAVCAM 2	TCS357_NAV2_H779_2-C83	NTSA0207
NAVCAM 2	TCS358_NAV2_H779_3-C28	NTSA0187
Spare	TCSxxx_SPARE_01-C126	NTSA0124
Spare	TCSxxx_SPARE_02-C126	NTSA0250
Spare	TCSxxx_SPARE_03-C127	NTSA0125
Spare	TCSxxx_SPARE_04-C127	NTSA0251
Spare	TCSxxx_SPARE_05-C32	NTSA0191
Spare	TCSxxx_SPARE_06-C36	NTSA0255
Spare	TCSxxx_SPARE_07-C56	NTSA0145
Spare	TCSxxx_SPARE_08-C57	NTSA0146
Spare	TCSxxx_SPARE_11-C59	NTSA0148
Spare	TCSxxx_SPARE_12-C31	NTSA0190

Table 5-49: Thermistor telemetry

Telemetries giving the ON/OFF status of the SW controlled heaters are aquired from the PDU which is described in §5.3.2.9.

5.4.1.7. Subsystem Budgets

5.4.1.7.1. Power

Each LCL – with the exception of SS-PDU LCLs 15 and 19 - shall provide no more than a total of 20W at any time to a heater group.

The following table gives the maximum power draw by each LCL, calculated using the heater resistance and a main bus voltage of 27.7V.

LCL #	Max Power	LCL	Max Power
PL-PDU	W	PL-PDU	W
3	0	28	3.49
4	0	34	1.25
5	14.0	35	15.72
7	4.37	36	17.44
8	11.71	37	3.0
9	7.11	38	0
10	4.33	39	5.33
13	2.74	40	0.5
17	5.33	41	6.98
18	4.37	42	6.14
20	3.91	43	8.05
21	9.1	44	10.91
22	0	45	10.91
23	12.37	46	11.58
24	10.92	53	0
25	0	54	5.33
26	0		
27	3.49		
SS-PDU	W	SS-PDU	W
15	40.0	19	28.1 ([2])
16	12.3	20	9.21
17	0.1	21	7.52
18	5.48	22	19.55

Table 5-50: Maximum power per LCL

The maximum power per system mode drawn by the TCS can be seen in the following table. The table is based on the power budget and includes heater power for:

[2] SS-PDU-18 and 19 's loads are SW controlled run-up heater groups, so it may be unlikely that all heaters will be active at any one time, and they will only be required before the switch on of the units, not while they are operating.

- PSM Internal
- PSM external
- BSM
- Reaction Wheels and Navigation
- Tank and RCS Tubing
- Thrusters
- External Mechanism and Sensors

but does not include the payload heater power consumption.

System Mode									
	Launch	**Commis-sioning**	**NSHM**	**Safe mode ACM /**	**Flyby**	**DSHM**	**DSHM after Wake-up**	**NCM**	**Survival**
Max Power (W)	0	35.3	175.3	156.4	140.6	204.2	223.2	156.4	156.3

Table 5-51: Maxium Power per mission phase

5.4.1.7.2. Mass

Mass Budget Information can be found in [RO-MMB-TN-3153].

5.4.1.7.3. Thermistor Budget

Rules:

Rule A : If there is a SW circuit, the TRP has three thermistors

Rule B : If the unit is IC, the TCS places one thermistor on the STP, and two on the TRP

Rule C : If the unit is CC and has internal thermistors, the TCS places one thermistor on the TRP

Rule D: If the unit is CC and has no internal TM's and is a payload, the TCS places 2 TM's on the TRP

Rule E: If the unit is a non-P/L CC unit with no internal TM's, then it gets one TM on the TRP

		Results			Notes
Unit	**Type**	**STP**	**TRP**	**Rule**	
PAYLOAD					
ALICE	C/C	0	2	C	
CONSERT Antenna	I/C	1	1	B	
CONSERT Electronics	C/C	0	1	C	
COSIMA Sensor	C/C	0	0	C	
COSIMA Electronics	C/C	0	2	C	
GIADA	C/C	0	2	C	
MIDAS	C/C	0	2	C	
MIRO Telescope	I/C	1	2	B	
MIRO OptBench	C/C	0	1	C	
MIRO SE	C/C	0	2	C	
MIRO ME	C/C	0	2	C	
MIRO USO	C/C	0	2	C	
OSIRIS NAC	I/C	2	0	B	
OSIRIS WAC	I/C	2	0	B	
OSIRIS NAC CRB	C/C	0	2	C	
OSIRIS WAC CRB	C/C	0	2	C	
OSIRIS ELEC	C/C	0	2	C	
ROSINA DFMS SENSOR	I/C	0	0	B	
ROSINA DFMS	C/C	0	2	C	
ROSINA RTOF	C/C	0	1	C	
ROSINA COPS	C/C	0	2	C	
ROSINA DPU	C/C	0	2	C	
VIRTIS OPTICS PALLET	C/C	0	2	C	
VIRTIS COLD BOX	I/C	0	0	B	
VIRTIS ELECTRONICS	C/C	0	2	C	
VIRTIS PEMH	C/C	0	2	C	
VIRTIS PEMM	C/C	0	2	C	
RPC PIU	C/C	0	2	C	
RPC IES	C/C	0	2	C	
RPC ICA	I/C	1	2	B	
RPC LAP1	I/C	1	0	Special	
RPC LAP2	I/C	1	0	Special	
RPC MIP	I/C	1		Special	
RPC MAG OB	I/C	0	0	Special	
RPC MAG IB	I/C	1	0	Special	
SREM	I/C	1	1	B	
SSP ESS RF A	C/C	0	1	C	
SSP ESS RF B	C/C	0	1	C	
SSP ANT A	I/C	1	2	B	
SSP ANT B	I/C	1	2	B	
SSP ESS DPU	C/C	0	1	C	

		Results			Notes
Unit	**Type**	**STP**	**TRP**	**Rule**	
SSP Switchbox	C/C	0	1	C	
SSP ESS MSS	C/C	1	1	C	
SSP	I/C	0	0	Special	
SSPNUT PYPZ			1		
SSPNUT MYPZ			1		
SSPNUT PYMZ			1		
SSPNUT MYMZ			1		
POWER					
PDU -BSM	C/C	0	1	C	
PDU -PSM	C/C	0	1	C	
PCU	C/C	0	1	C	
BATT 1	C/C	0	3	A	
BATT 2	C/C	0	3	A	
BATT 3	C/C	0	3	A	
SA PY	I/C	0	0	Special	
SA MY	I/C	0	0	Special	
SAHD (x6)	C/C	0	0	Special	
SAHD (x6)	C/C	0	0	Special	
YOHD (x2)	C/C	0	0	Special	
YOHD (x2)	C/C	0	0	Special	
ANTENNAE					
MGA-S	I/C*	1	2	B	
MGA-X	I/C*	1	2	B	
LGA +Z	I/C*	1	2	B	
LGA -Z	I/C*	1	2	B	
MECHANISMS					
PZ Boom	I/C	1	0	Special	
MZ Boom	I/C	1	0	Special	
APM	I/C*	0	3	I/C Unit	
HGA Struts		3	0	Special	
HGA HDRM Short	I/C*	0	0	Special	
HGA HDRM PY	I/C*	0	0	Special	
HGA HDRM MY	I/C*	0	0	Special	
APME	C/C	0	4	Special	
SADM PY	C/C	0	3	A	
SADM MY	C/C	0	3	A	
SADE	C/C	0	1	C	
RCS					
PZ PROP TANK	C/C	0	3	A	
Upper Gauging			1	Special	
Lower Gauging			2	Special	
MZ PROP TANK	C/C	0	3	A	

		Results			Notes
Unit	**Type**	**STP**	**TRP**	**Rule**	
Upper Gauging			1	Special	
Lower Gauging			2	Special	
PY PRESS TANK	C/C	0	1	C	
MY PRESS TANK	C/C	0	1	C	
CYLINDER WALL - PSM			1		
CYLINDER WALL - BSM			1	Special	
THR1	C/C	0	3	A	Two on Prime MMH, one on redundant MMH
THR2	C/C		3	A	Two on Prime MMH, one on redundant MMH
THR3	C/C		3	A	Two on Prime MMH, one on redundant MMH
THR4	C/C		3	A	Two on Prime MMH, one on redundant MMH
THR5	C/C		3	A	Two on Prime MMH, one on redundant MMH
THR6	C/C		3	A	Two on Prime MMH, one on redundant MMH
THR7	C/C		3	A	Two on Prime MMH, one on redundant MMH
THR8	C/C		3	A	Two on Prime MMH, one on redundant MMH
THR9	C/C		3	A	Two on Prime MMH, one on redundant MMH
THR10	C/C		3	A	Two on Prime MMH, one on redundant MMH
THR11	C/C		3	A	Two on Prime MMH, one on redundant MMH
THR12	C/C		3	A	Two on Prime MMH, one on redundant MMH
20cm Downstream of PY He	C/C	0	1	Special	
20cm Downstream of MY He	C/C		1		
20cm Downstream of PR1	C/C		1		
20cm Downstream or PR2	C/C		1		
RCS Line 1	C/C		1		Located on +X +Y panel near 4 NC pyros for drain testing
RCS Line 2	C/C		1		Located on +X -Y panel near 4 NC pyros for drain testing
RCS Line 3	C/C		1		
RCS Line 4	C/C		1		
RCS Line 5	C/C		1		
RCS Line 6	C/C		1		
RCS Line 7	C/C		1		
RCS Line 8	C/C		1		
RCS Line 9	C/C		1		
RCS Line 10	C/C		1		

		Results			Notes
Unit	**Type**	**STP**	**TRP**	**Rule**	
RCS Line 11	C/C		1		
RCS Line 12	C/C		1		
Pressure Transducers	C/C	0	0	Special	
PR1	C/C		2		
PR2	C/C		2		
NC PYRO 3	C/C		1		
NC PYRO 4	C/C		1		
NC PYRO 7	C/C		1		
NC PYRO 8	C/C		1		
NC PYRO 9	C/C		1		
NC PYRO 10	C/C		1		
TTC					
WIU	C/C		1	C	
TWT 1	C/C		1	C	
TWT 2	C/C		1	C	
EPC 1	C/C		1	C	
EPC 2	C/C		1	C	
TRSP 1	C/C		1	C	
TRSP 2	C/C		1	C	
RFDU	C/C		1	C	
USO	C/C		1	C	(RSI USO)
DMS					
CDMU1	C/C		1	C	
CDMU2	C/C		1	C	
RTU -BSM	C/C		1	C	
RTU -PSM	C/C		1	C	
SSMM	C/C		1	C	
AOCMS					
AIU	C/C		1	C	
RW1	C/C		3	A	
RW2	C/C		3	A	
RW3	C/C		3	A	
RW4	C/C		3	A	
WDE	C/C		1	C	
IMU1	C/C		1	C	
IMU2	C/C		1	C	
IMU3	C/C		1	C	
SAS PZ	I/C	1	1	B	
SAS MZ	I/C	1	1	B	
ST1	I/C	1	3	A	
ST2	I/C	1	3	A	
SSTE1	C/C		1	C	

		Results			Notes
Unit	**Type**	**STP**	**TRP**	**Rule**	
SSTE2	C/C		1	C	
NAVCAM1	I/C	1	3	A	
NAVCAM2	I/C	1	3	A	
TOTALS					
Internal PL			37		
Margin			19		
Internal PL total including Margin			**56**		
Internal Bus			26		
TCS Thermistors			250		
Total			276		
Margin (%)			10%	4%	
Margin (#)			27	9	
Total including Margin			**303**	**285**	

Table 5-51a: Thermistor Budget

5.4.1.7.4. Timing

Timing for the SW will be handled by the SRD for the thermal SW.

Temperature limits governed by the SW, and thermostats, will be set such that the cyclic rate of switching on and off of the heaters is low, thus increasing reliability.

5.4.1.8. Thermistor Locations

The following table shows the thermistor locations on the spacecraft for each unit. Drawings, showing the thermistor location wrt other units are provided via hyperlinks to drawings in Annex 9/Thermal and /Payload. Further information on the location of thermal hardware is provided in RO-MMT-IF-3106, §5 and RO-DSS-IF-1201.

Results				Thermistor Names						Location						Diagram
				TCS Monitoring			TCS Control			TCS Monitoring			TCS Control			
Unit	**Type**	**STP**	**TRP**				1	2	3				1	2	3	
PAYLOAD																
ALICE	C/C	0	2		TCS001_ALICE_TRP_P	TCS002_ALICE_TRP_R					Ref Foot	Ref Foot				5
CONSERT Antenna	I/C	1	1	TCS006_CONAN_STP	TCS007_CONAN_TRP					nearby structure	TRP of Pyro					7
CONSERT Electronics	C/C	0	1		TCS009_CONEL_TRP						Ref Foot					1
COSIMA Electronics	C/C	0	2		TCS010_COSIM_TRP_P	TCS011_COSIM_TRP_R					Ref Foot	Ref Foot				1
GIADA	C/C	0	2		TCS012_GIADA_TRP_P	TCS013_GIADA_TRP_R					Ref Foot	Ref Foot				7
MIDAS	C/C	0	2		TCS014_MIDAS_TRP_P	TCS_090_MIDAS_TRP_R					Ref Foot	Ref Foot				7
MIRO Telescope	I/C	1	2	TCS015_MIRTE_STP	TCS016_MIRTE_TRP_P	TCS017_MIRTE_TRP_R				nearby structure	Ref Foot	Ref Foot				7
MIRO OptBench	C/C	0	1		TCS018_MIROB_TRP						Ref Foot					7
MIRO SE	C/C	0	2		TCS019_MIRSE_TRP_P	TCS091_MIRSE_TRP_R					Ref Foot	Ref Foot				2

Results				Thermistor Names						Location						Diagram
				TCS Monitoring			TCS Control			TCS Monitoring			TCS Control			
MIRO ME	C/C	0	2		TCS020_MIRME_TRP_P	TCS021_MIRME_TRP_R					Ref Foot	Ref Foot				2
MIRO USO	C/C	0	2		TCS022_MIRUS_TRP_P	TCS023_MIRUS_TRP_R					Ref Foot	Ref Foot				2
OSIRIS NAC	I/C	2	0	TCS024_NAC__STP_P	TCS092_NACSTP_R					nearby structure	nearby structure					6
OSIRIS WAC	I/C	2	0	TCS027_WAC__STP_R	TCS093_WACSTP_R					nearby structure	nearby structure					6
OSIRIS NAC CRB	C/C	0	2		TCS030_NACRB_TRP_P	TCS031_NACRB_TRP_R					Ref Foot	Ref Foot				5
OSIRIS WAC CRB	C/C	0	2		TCS032_WACRB_TRP_P	TCS033_WACRB_TRP_R					Ref Foot	Ref Foot				5
OSIRIS ELEC	C/C	0	2		TCS034_OSIEL_TRP_P	TCS035_OSIEL_TRP_R					Ref Foot	Ref Foot				2
ROSINA DFMS SENSOR	I/C	0	0													
ROSINA DFMS	C/C	0	2		TCS036_DFMS__TRP_P	TCS037_DFMS__TRP_R					Ref Foot	Ref Foot				7
ROSINA RTOF	C/C	0	1		TCS038_RTOF__TRP_P	TCS094_RTOF__TRP_R					Ref Foot	Ref Foot				2
ROSINA COPS	C/C	0	2		TCS039_COPS__TRP_P	TCS040_COPS__TRP_R					Ref Foot	Ref Foot				7
ROSINA DPU	C/C	0	2		TCS041_RODPU_TRP_P	TCS042_RODPU_TRP_R					Ref Foot	Ref Foot				1
VIRTIS OPTICS PALLET	C/C	0	2		TCS043_VIRTI_TRP_P	TCS044_VIRTI_TRP_R					Ref Foot	Ref Foot				6
VIRTIS COLD BOX	I/C	0	0													

Results				Thermistor Names						Location						Diagram
				TCS Monitoring			TCS Control			TCS Monitoring			TCS Control			
VIRTIS ELECTRONICS	C/C	0	2		TCS045_VIREL_TRP_P	TCS046_VIREL_TRP_R					Ref Foot	Ref Foot				1
VIRTIS PEMH	C/C	0	2		TCS047_VIRPH_TRP_P	TCS048_VIRPH_TRP_R					Ref Foot	Ref Foot				1
VIRTIS PEMM	C/C	0	2		TCS049_VIRPM_TRP_P	TCS050_VIRPM_TRP_R					Ref Foot	Ref Foot				1
RPC PIU	C/C	0	2		TCS051_RPCEL_TRP_P	TCS052_RPCEL_TRP_R					Ref Foot	Ref Foot				2
RPC IES	C/C	0	2		TCS053_IESTRP_P	TCS054_IES_TRP_R					Ref Foot	Ref Foot				7
RPC ICA	I/C	1	2	TCS055_ICA___STP	TCS056_ICATRP_P	TCS057_ICA_TRP_R				nearby structure	Ref Foot	Ref Foot				7
RPC LAP1	I/C	1	0	TCS058_LAP1__STP						boom						6
RPC LAP2	I/C	1	0	TCS096_LAP2__STP						boom						6
RPC MIP	I/C	1		TCS059_MIP___STP						boom						6
RPC MAG IB	I/C	1	0	TCS062_MAGIB_STP						boom						6
SREM	I/C	1	1	TCS064_SREM__STP	TCS065_SREM__TRP					nearby structure	Ref Foot					7
SSP ESS RF A	C/C	0	1		TCS067_ESSRA_TRP						Ref Foot					8
SSP ESS RF B	C/C	0	1		TCS068_ESSRB_TRP						Ref Foot					8
SSP ANT A	I/C	1	2	TCS069_ESSAA_STP	TCS070_ESSAA_TRP_P	TCS071_ESSAA_TRP_R				nearby structure	Ref Foot	Ref Foot				7
SSP ANT B	I/C	1	2	TCS072_ESSAB_STP	TCS073_ESSAB_TRP_P	TCS074_ESSAB_TRP_R				nearby structure	Ref Foot	Ref Foot				7

Results				Thermistor Names						Location						Diagram
				TCS Monitoring			TCS Control			TCS Monitoring			TCS Control			
SSP ESS DPU	C/C	0	1		TCS075_ESSEL_TRP						Ref Foot					8
SSP Switchbox	C/C	0	1		TCS076_ESSSW_TRP						Ref Foot					8
SSP ESS MSS	C/C	1	1	TCS078_MSS___STP	TCS077_MSSTRP					Ref Foot	Ref Foot					a
SSPNUT PYPZ			1		TCS079_NPYPZ_TRP						sep. nut					a
SSPNUT MYPZ			1		TCS080_NMYPZ_TRP						sep. nut					a
SSPNUT PYMZ			1		TCS081_NPYMZ_TRP						sep. nut					a
SSPNUT MYMZ			1		TCS082_NMYMZ_TRP						sep. nut					a
POWER																
PDU -BSM	C/C	0	1		TCS100_PDUSS_TRP						Ref Foot					3
PDU -PSM	C/C	0	1		TCS101_PDUPL_TRP						Ref Foot					1
PCU	C/C	0	1		TCS102_PCUTRP						Ref Foot					3
BATT 1	C/C	0	3				TCS103_BATT1_H705_1	TCS104_BATT1_H705_2	TCS105_BATT1_H705_3				Ref Foot	Ref Foot	Ref Foot	3
BATT 2	C/C	0	3				TCS106_BATT2_H780_1	TCS107_BATT2_H780_2	TCS108_BATT2_H780_3				Ref Foot	Ref Foot	Ref Foot	3
BATT 3	C/C	0	3				TCS109_BATT3_H730_1	TCS110_BATT3_H730_2	TCS111_BATT3_H730_3				Ref Foot	Ref Foot	Ref Foot	3
ANTENNAE																

Results				Thermistor Names						Location						Diagram
				TCS Monitoring			TCS Control			TCS Monitoring			TCS Control			
MGA-S	I/C*	1	2	TCS120_MGAS__STP	TCS121_MGAS__TRP_P	TCS122_MGAS__TRP_R				nearby structure	Ref Foot	Ref Foot				9
MGA-X	I/C*	1	2	TCS123_MGAX__STP	TCS124_MGAX__TRP_P	TCS125_MGAX__TRP_R				nearby structure	Ref Foot	Ref Foot				9
LGA +Z	I/C*	1	2	TCS126_LGAPZ_STP	TCS127_LGAPZ_TRP_P	TCS128_LGAPZ_TRP_R				nearby structure	Supporting bracket	Supporting bracket				7
LGA -Z	I/C*	1	2	TCS129_LGAMZ_STP	TCS130_LGAMZ_TRP_P	TCS131_LGAMZ_TRP_R				nearby structure	Supporting bracket	Supporting bracket				6
MECHANISMS																
PZ Boom	I/C	1	0	TCS140_BOOPZ_STP						close to +z boom hinge						
MZ Boom	I/C	1	0	TCS141_BOOMZ_STP						close to -z boom hinge						
APM	I/C*	0	3				TCS142_APM_H178_1	TCS143_APM	TCS144_APM_H178_3				Internal	Internal	Internal	NA
SADM PY	C/C	0	3				TCS155_SADPY_H756_1	TCS156_SADPY_H756_2	TCS157_SADPY_H756_3				SADM structure	SADM structure	SADM structure	2
SADM MY	C/C	0	3				TCS158_SADMY_H781_1	TCS159_SADMY_H781_2	TCS160_SADMY_H781_3				SADM structure	SADM structure	SADM structure	1
SADE	C/C	0	1		TCS161_SADE__TRP						Ref foot					3
RCS																
PZ PROP TANK	C/C	0	3	TCS200_MMH___H701_1	TCS201_MMHH701_2	TCS202_MMH_H701_3				Tank waist	Tank waist	Tank waist				11

Results				Thermistor Names						Location						Diagram
				TCS Monitoring			TCS Control			TCS Monitoring			TCS Control			
Upper Gauging			1		TCS203_MMHHI_GAU								Upper Tank Outlet			11
Lower Gauging			2		TCS204_MMHLO_GAU_P	TCS205_MMHLO_GAU_R								Lower Tank Outlet	Lower Tank Outlet	11
MZ PROP TANK	C/C	0	3	TCS206_NTO___H726_1	TCS207_NTOH726_2	TCS208_NTO_H726_3				Tank waist	Tank waist	Tank waist				11
Upper Gauging			1		TCS209_NTOHI_GAU								Upper Tank Outlet			11
Lower Gauging			2		TCS210_NTOLO_GAU_P	TCS211_NTOLO_GAU_R								Lower Tank Outlet	Lower Tank Outlet	11
PY PRESS TANK	C/C	0	1		TCS212_HEPY__TRP						Tank Outlet					12
MY PRESS TANK	C/C	0	1		TCS213_HEMY__TRP						Tank Outlet					12
Cylinder Wall -PSM	C/C	0	1		TCS276_CYPSM_GAU						Cylinder Wall					11
Cylinder Wall -BSM	C/C	0	1		TCS277_CYBSM_GAU						Cylinder Wall					11
THR1	C/C	0	3				TCS214_THR01_H129_1	TCS215_THR01_H129_2	TCS216_THR01_H129_3				Prime MMH	Prime MMH	Red MMH	11
THR2	C/C		3				TCS217_THR02_H179_1	TCS218_THR02_H179_2	TCS219_THR02_H179_3				Prime MMH	Prime MMH	Red MMH	11
THR3	C/C		3				TCS220_THR03_H329_1	TCS221_THR03_H329_2	TCS222_THR03_H329_3				Prime MMH	Prime MMH	Red MMH	11
THR4	C/C		3				TCS223_THR04_H379_1	TCS224_THR04_H379_2	TCS225_THR04_H379_3				Prime MMH	Prime MMH	Red MMH	11
THR5	C/C		3				TCS226_THR05_H130_1	TCS227_THR05_H130_2	TCS228_THR05_H130_3				Prime MMH	Prime MMH	Red MMH	11

Results				Thermistor Names						Location						Diagram
				TCS Monitoring			TCS Control			TCS Monitoring			TCS Control			
THR6	C/C		3				TCS229_THR06_H180_1	TCS230_THR06_H180_2	TCS231_THR06_H180_3				Prime MMH	Prime MMH	Red MMH	11
THR7	C/C		3				TCS232_THR07_H330_1	TCS233_THR07_H330_2	TCS234_THR07_H330_3				Prime MMH	Prime MMH	Red MMH	11
THR8	C/C		3				TCS235_THR08_H380_1	TCS236_THR08_H380_2	TCS237_THR08_H380_3				Prime MMH	Prime MMH	Red MMH	11
THR9	C/C		3				TCS238_THR09_H131_1	TCS239_THR09_H131_2	TCS240_THR09_H131_3				Prime MMH	Prime MMH	Red MMH	11
THR10	C/C		3				TCS241_THR10_H181_1	TCS242_THR10_H181_2	TCS243_THR10_H181_3				Prime MMH	Prime MMH	Red MMH	11
THR11	C/C		3				TCS244_THR11_H331_1	TCS245_THR11_H331_2	TCS246_THR11_H331_3				Prime MMH	Prime MMH	Red MMH	11
THR12	C/C		3				TCS247_THR12_H381_1	TCS248_THR12_H381_2	TCS249_THR12_H381_3				Prime MMH	Prime MMH	Red MMH	11
20cm Downstream of PY He	C/C	0	1		TCS250_HEPYD_TRP						on pipework					12
20cm Downstream of MY He	C/C		1		TCS251_HEMYD_TRP						on pipework					12
20cm Downstream of PR1	C/C		1		TCS252_PR1D__TRP						on pipework					12
20cm Downstream or PR2	C/C		1		TCS253_PR2D__TRP						on pipework					12
RCS Line 1	C/C		1		TCS254_RCS01_TRP						on pipework					10
RCS Line 2	C/C		1		TCS255_RCS02_TRP						on pipework					10

Results				Thermistor Names						Location						Diagram
				TCS Monitoring			TCS Control			TCS Monitoring			TCS Control			
RCS Line 3	C/C		1		TCS256_RCS03_TRP						on pipework					10
RCS Line 4	C/C		1		TCS257_RCS04_TRP						on pipework					10
RCS Line 5	C/C		1		TCS258_RCS05_TRP						on pipework					10
RCS Line 6	C/C		1		TCS259_RCS06_TRP						on pipework					10
RCS Line 7	C/C		1		TCS260_RCS07_TRP						on pipework					10
RCS Line 8	C/C		1		TCS261_RCS08_TRP						on pipework					10
RCS Line 9	C/C		1		TCS262_RCS09_TRP						on pipework					12
RCS Line 10	C/C		1		TCS263_RCS10_TRP						on pipework					11
RCS Line 11	C/C		1		TCS264_RCS11_TRP						on pipework					11
RCS Line 12	C/C		1		TCS265_RCS12_TRP						on pipework					11
PR1	C/C		2		TCS266_PR1TRP_P	TCS267_PR1_TRP_R					Ref foot	Ref foot				10
PR2	C/C		2		TCS268_PR2TRP_P	TCS269_PR2_TRP_R					Ref foot	Ref foot				10
NC PYRO 3	C/C		1		TCS270_PVC03_TRP						structure					10
NC PYRO 4	C/C		1		TCS271_PVC04_TRP						structure					10
NC PYRO 7	C/C		1		TCS272_PVC07_TRP						structure					10

Results				Thermistor Names						Location						Diagram
				TCS Monitoring			TCS Control			TCS Monitoring			TCS Control			
NC PYRO 8	C/C		1		TCS273_PVC08_TRP						structure					10
NC PYRO 9	C/C		1		TCS274_PVC09_TRP						structure					10
NC PYRO 10	C/C		1		TCS275_PVC10_TRP						structure					10
TTC																
WIU	C/C		1		TCS280_WIUTRP						Ref foot					4
TWT 1	C/C		1		TCS281_TWT1__TRP						Ref foot					4
TWT 2	C/C		1		TCS282_TWT2__TRP						Ref foot					4
EPC 1	C/C		1		TCS283_EPC1__TRP						Ref foot					4
EPC 2	C/C		1		TCS284_EPC2__TRP						Ref foot					4
TRSP 1	C/C		1		TCS285_TRSP1_TRP						Ref foot					4
TRSP 2	C/C		1		TCS286_TRSP2_TRP						Ref foot					4
RFDU	C/C		1		TCS287_RFDU__TRP						Ref foot					2
USO	C/C		1		TCS288_USOTRP						Ref foot					2
DMS																
CDMU1	C/C		1		TCS300_CDMU1_TRP						Ref foot					4
CDMU2	C/C		1		TCS301_CDMU2_TRP						Ref foot					4

Results				**Thermistor Names**						**Location**						**Diagram**
				TCS Monitoring			**TCS Control**			**TCS Monitoring**			**TCS Control**			
RTU -BSM	C/C		1		TCS302_RTUSS_TRP						Ref foot					2
RTU -PSM	C/C		1		TCS303_RTUPL_TRP						Ref foot					4
SSMM	C/C		1		TCS304_SSMM__TRP						Ref foot					2
AOCMS																
AIU	C/C		1		TCS320_AIUTRP						Ref foot					4
RW1	C/C		3				TCS321_RW1_H703_1	TCS322_RW1_H703_2	TCS323_RW1_H703_3				RW Structure	RW Structure	RW Structure	14
RW2	C/C		3				TCS324_RW2_H728_1	TCS325_RW2_H728_2	TCS326_RW2_H726_3				RW Structure	RW Structure	RW Structure	14
RW3	C/C		3				TCS327_RW3_H753_1	TCS328_RW3_H753_2	TCS329_RW3_H753_3				RW Structure	RW Structure	RW Structure	13
RW4	C/C		3				TCS330_RW4_H778_1	TCS331_RW4_H778_2	TCS332_RW4_H778_3				RW Structure	RW Structure	RW Structure	13
WDE	C/C		1		TCS333_WDETRP						Ref foot					4
IMU1	C/C		1		TCS334_IMU1__TRP						Ref foot					3
IMU2	C/C		1		TCS335_IMU2__TRP						Ref foot					3
IMU3	C/C		1		TCS336_IMU3__TRP						Ref foot					3
SAS PX	I/C	1	1	TCS337_SASPX_STP	TCS338_SASPX_TRP					nearby structure	Ref foot					7

Results				Thermistor Names						Location						Diagram
				TCS Monitoring			TCS Control			TCS Monitoring			TCS Control			
SAS MX	I/C	1	1	TCS339_SASMX_STP	TCS340_SASMX_TRP					nearby structure	Ref foot					7
ST1	I/C	1	3	TCS341_STR1__STP			TCS342_STR1__H704_1	TCS343_STR1__H704_2	TCS344_STR1__H704_3	nearby structure			Ref foot	Ref foot	Ref foot	5
ST2	I/C	1	3	TCS345_STR2__STP			TCS346_STR2__H729_1	TCS347_STR2__H729_2	TCS348_STR2__H729_3	nearby structure			Ref foot	Ref foot	Ref foot	5
SSTE1	C/C		1		TCS349_SSTE1_TRP						Ref Foot					1
SSTE2	C/C		1		TCS350_SSTE2_TRP						Ref Foot					1
NAVCAM1	I/C	1	3	TCS351_NAV1__STP			TCS352_NAV1__H754_1	TCS353_NAV1__H754_2	TCS354_NAV1__H754_3	nearby structure			Ref Foot	Ref Foot	Ref Foot	5
NAVCAM2	I/C	1	3	TCS355_NAV2__STP			TCS356_NAV2__H779_1	TCS357_NAV2__H779_2	TCS358_NAV2__H779_3	nearby structure			Ref Foot	Ref Foot	Ref Foot	5

Table 5-51b: Thermistor Location

5.4.1.9. Heater Circuit Diagrams

Schematics of heater circuit diagrams together with basic TM/TC information are shown below.

5.4.1.9.1. HW Heater LCLs

LCL-5

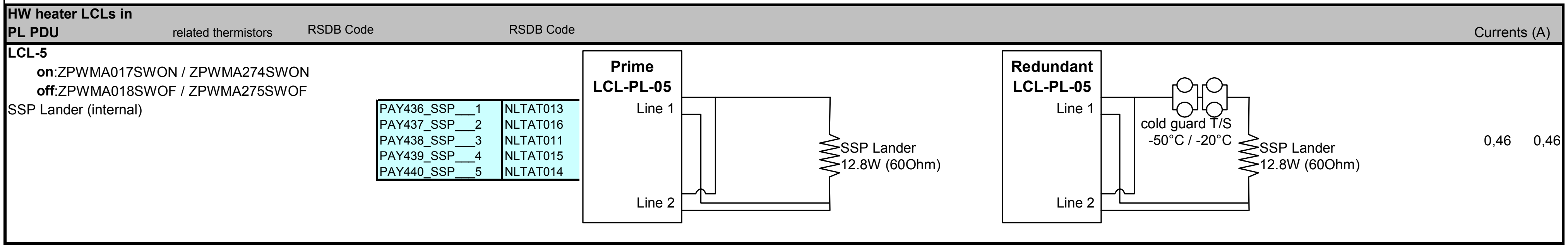


Figure 5-92a: LCL PL-05 (SSP Lander)

LCL-7

HW heater LCLs in PL PDU	related thermistors	RSDB Code		RSDB Code	Currents (A)	
LCL-7						
on:ZPWMA021SWON / ZPWMA278SWON						
off:ZPWMA022SWOF / ZPWMA279SWOF						
Miro ME	TCS020_MIRME_TRP_P	NTSA0002				
	TCS021_MIRME_TRP_R	NTSA0128				
Miro SE	TCS019_MIRSE_TRP_P	NTSA0256	PAY414_MIRSE_1	NMRAT101	0,06	0,06
	TCS091_MIRSE_TRP_R	NTSA0260				
					0,10	0,10
				sum:	0,16	0,16

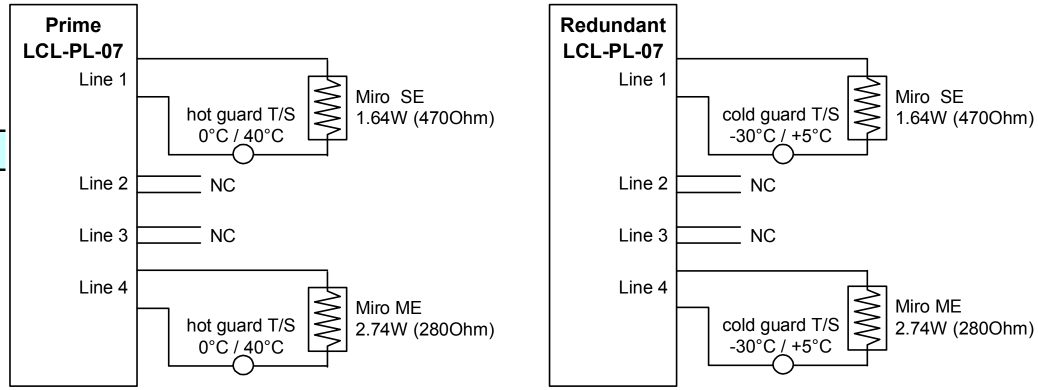


Figure 5-92b: LCL PL-07 (Miro SE/ME)

LCL-8

HW heater LCLs in PL PDU	related thermistors	RSDB Code	RSDB Code			Currents (A)
LCL-8 **on**:ZPWMA023SWON / ZPWMA280SWON **off**:ZPWMA024SWOF / ZPWMA281SWOF						
Virtis PEM H	TCS047_VIRPH_TRP_P	NTSA0005			0,13	0,13
	TCS048_VIRPH_TRP_R	NTSA0131				
Osiris WAC CRB	TCS032_WACRB_TRP_P	NTSA0010			0,10	0,10
	TCS033_WACRB_TRP_R	NTSA0136				
SSP RXTX1 / RXTX2	TCS067_ESSRA_TRP	NTSA0147			0,20	0,20
	TCS068_ESSRB_TRP	NTSA0023				
				sum:	0,42	0,42

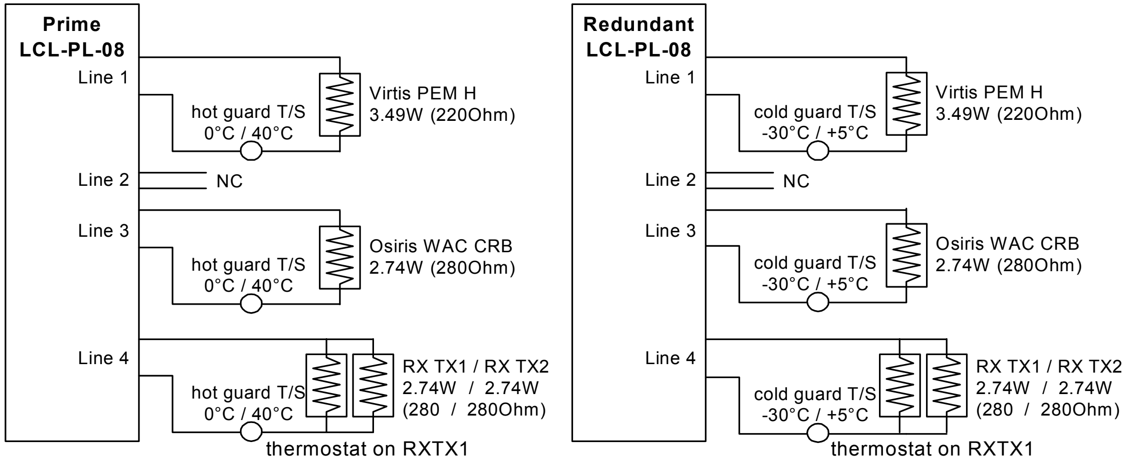


Figure 5-92c: LCL PL-08 (Virtis PEMH ; Osiris WAC ; RXTX1/2)

LCL-9

HW heater LCLs in PL PDU

LCL-9
on:ZPWMA025SWON / ZPWMA282SWON
off:ZPWMA026SWOF / ZPWMA283SWOF

HW heater LCLs in PL PDU	related thermistors	RSDB Code		RSDB Code	Currents (A)	
Consert EU	TCS009_CONEL_TRP	NTSA0065	PAY404_CONEL_1 PAY405_CONEL_2	NCNAT101 NCNAT001	0,10	0,10
Osiris NAC CRB	TCS030_NACRB_TRP_P TCS031_NACRB_TRP_R	NTSA0009 NTSA0135			0,10	0,10
Midas	TCS014_MIDAS_TRP_P TCS090_MIDAS_TRP_R	NTSA0063 NTSA0189	PAY410_MIDAS_1 PAY411_MIDAS_2	NMDAT101 NMDAT001	0,06	0,06
				sum:	0,26	0,26

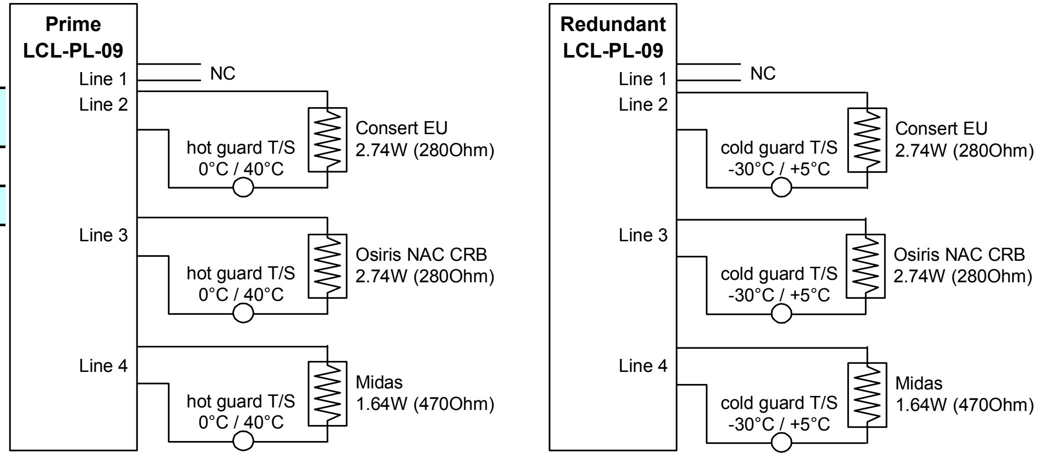


Figure 5-92d: LCL PL-09 (Consert EU, Osiris NAC, Midas)

LCL-10

HW heater LCLs in PL PDU	related thermistors	RSDB Code		RSDB Code	Currents (A)	
LCL-10						
on:ZPWMA027SWON / ZPWMA284SWON						
off:ZPWMA028SWOF / ZPWMA285SWOF						
Rosina DPU	TCS041_RODPU_TRP_P	NTSA0014			0,06	0,06
	TCS042_RODPU_TRP_R	NTSA0140				
Cosima	TCS010_COSIM_TRP_P	NTSA0066	PAY406_COSIM_1	NCSAT101	0,04	0,04
	TCS011_COSIM_TRP_R	NTSA0192	PAY407_COSIM_2	NCSAT001		
RPC PIU	TCS051_RPCEL_TRP_P	NTSA0016			0,06	0,06
	TCS052_RPCEL_TRP_R	NTSA0142				
				sum:	0,16	0,16

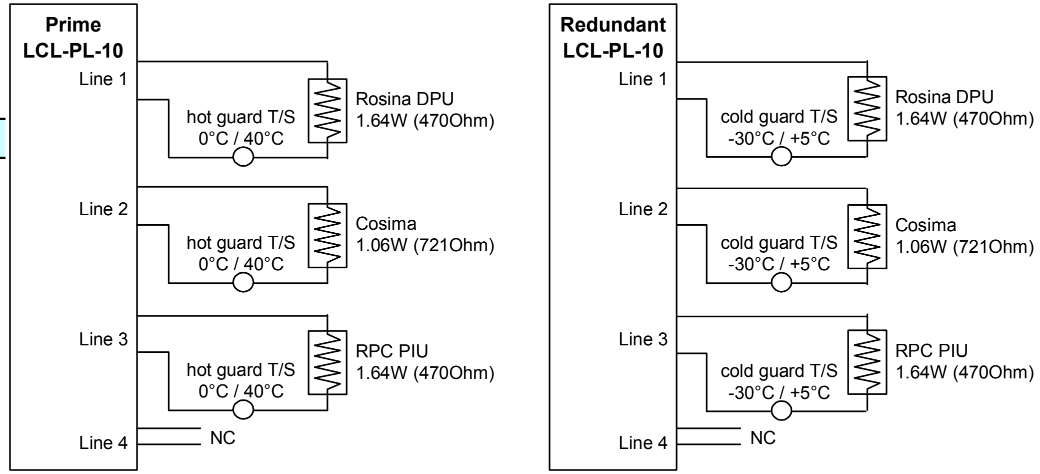


Figure 5-92e: LCL PL-10 (Rosina DPU; Cosmia, RPC PIU)

LCL-13

HW heater LCLs in PL PDU	related thermistors	RSDB Code	RSDB Code	Currents (A)	
LCL-13 **on**:ZPWMA033SWON / ZPWMA290SWON **off**:ZPWMA034SWOF / ZPWMA291SWOF					
Alice	TCS001_ALICE_TRP_P TCS002_ALICE_TRP_R	NTSA0062 NTSA0188		0,10	0,10

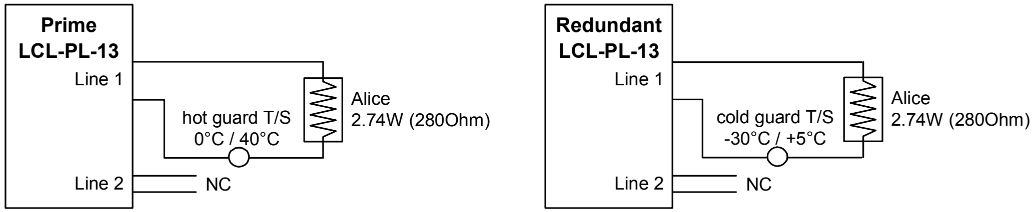


Figure 5-92f: LCL PL-13 (Alice)

LCL-17

HW heater LCLs in PL PDU	related thermistors	RSDB Code		RSDB Code		Currents (A)	
LCL-17 **on**:ZPWMA041SWON / ZPWMA298SWON **off**:ZPWMA042SWOF / ZPWMA299SWOF							
SSP MSS	TCS077_MSS___TRP_P	NTSA0027	PAY434_MSS___1	NLTAT002		0,19	0,19
	TCS078_MSS___TRP_R	NTSA0153	PAY435_MSS___2	NLTAT001			

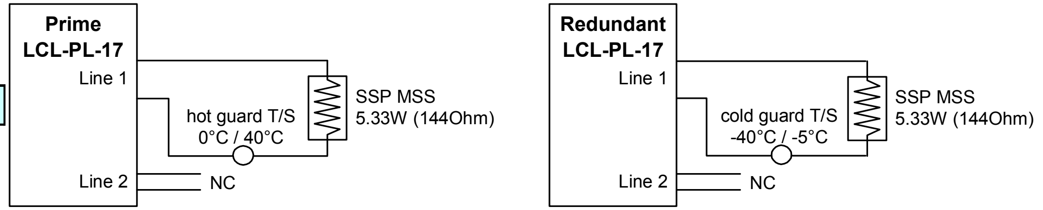


Figure 5-92g: LCL PL-17 (SSP MSS Housing)

LCL-18

HW heater LCLs in PL PDU	related thermistors	RSDB Code		RSDB Code	Currents (A)	
LCL-18						
on:ZPWMA043SWON / ZPWMA300SWON						
off:ZPWMA044SWOF / ZPWMA301SWOF						
SSP ESS	TCS075_ESSEL_TRP	NTSA0026			0,06	0,06
RPC IES (TCS)	TCS053_IES___TRP_P	NTSA0017	PAY429_IES___1	NRPAT001		
	TCS054_IES___TRP_R	NTSA0143				
RPC IES					0,10	0,10
				sum:	0,16	0,16

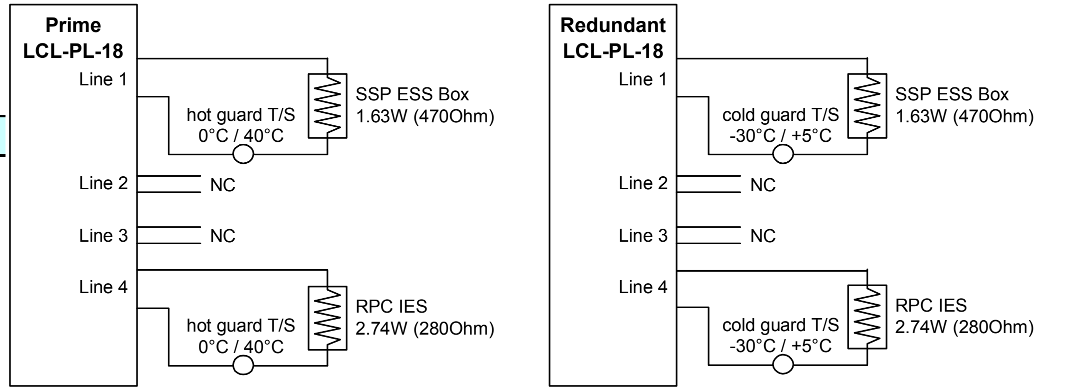
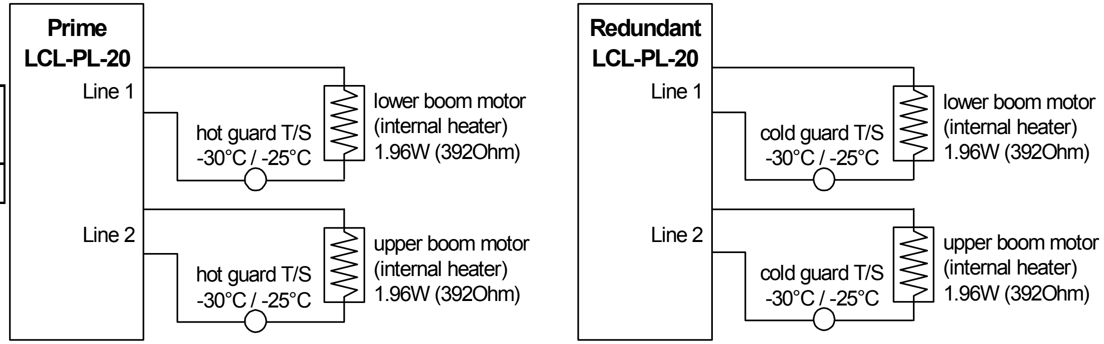


Figure 5-92h: LCL PL-18 (SSP ESS Box; RPC IES)

LCL-20

HW heater LCLs in PL PDU	related thermistors	RSDB Code		RSDB Code	Currents (A)	
LCL-20 **on**:ZPWMA047SWON / ZPWMA304SWON **off**:ZPWMA048SWOF / ZPWMA305SWOF						
upper boom motor	TCS141_BOOMZ_STP	NTSA0091	PLA522_BOOMZ_1 PLA523_BOOMZ_2	NSTAXB30 NSTAXB40		
lower boom motor	TCS140_BOOPZ_STP	NTSA0216	PLA520_BOOPZ_1 PLA521_BOOPZ_2	NSTAXB10 NSTAXB20		



	Currents (A)	
	0,07	0,07
	0,07	0,07
sum:	0,14	0,14

Figure 5-92i: LCL PL-20 (Lower/Upper Boom Motor)

LCL-21

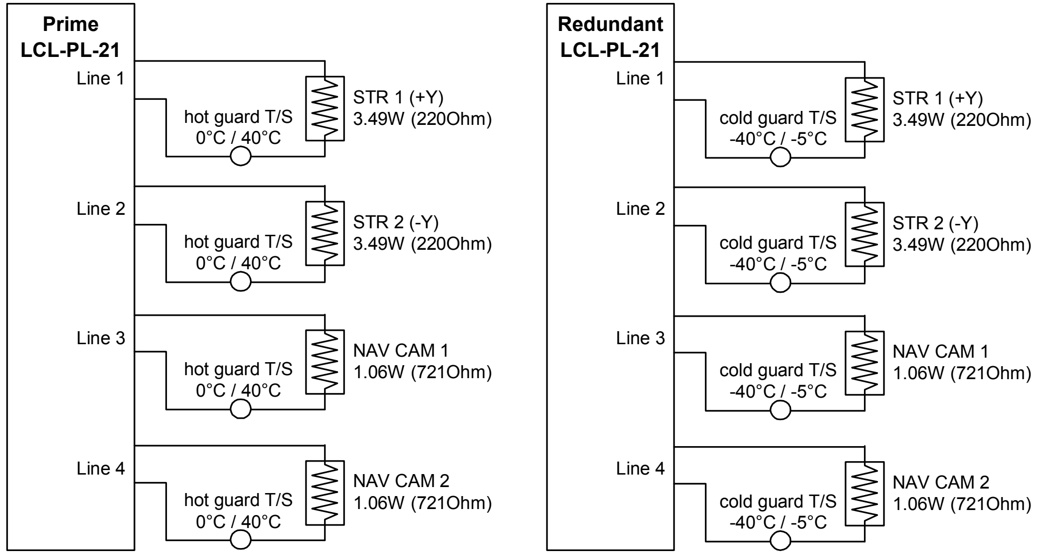
HW heater LCLs in PL PDU related thermistors RSDB Code RSDB Code Currents (A)

LCL-21

on:ZPWMA049SWON / ZPWMA306SWON

off:ZPWMA050SWOF / ZPWMA307SWOF

	Related thermistors	RSDB Code
STR 1	TCS342_STR1__H704_1	NTSA0058
	TCS343_STR1__H704_2	NTSA0082
	TCS344_STR1__H704_3	NTSA0184
	TCS341_STR1__STP	NTSA0121
STR 2	TCS346_STR2__H729_1	NTSA0059
	TCS347_STR2__H729_2	NTSA0208
	TCS348_STR2__H729_3	NTSA0185
	TCS345_STR2__STP	NTSA0247
CAM 1	TCS352_NAV1__H754_1	NTSA0060
	TCS353_NAV1__H754_2	NTSA0081
	TCS354_NAV1__H754_3	NTSA0186
	TCS351_NAV1__STP	NTSA0123
CAM 2	TCS356_NAV2__H779_1	NTSA0061
	TCS357_NAV2__H779_2	NTSA0207
	TCS358_NAV2__H779_3	NTSA0187
	TCS355_NAV2__STP	NTSA0249



Currents (A)	
0,13	0,13
0,13	0,13
0,04	0,04
0,04	0,04
sum: 0,33	0,33

Figure 5-92j: LCL PL-21 (STR ; Navcam)

LCL-23

HW heater LCLs in PL PDU	related thermistors	RSDB Code	RSDB Code	Currents (A)	
LCL-23					
on:ZPWMA053SWON / ZPWMA310SWON					
off:ZPWMA054SWOF / ZPWMA311SWOF					
RCS line 1	TCS254_RCS01_TRP	NTSA0099		0,07	0,07
RCS line 2	TCS255_RCS02_TRP	NTSA0225		0,07	0,07
RCS line 3	TCS256_RCS03_TRP	NTSA0100		0,06	0,06
RCS line 4	TCS257_RCS04_TRP	NTSA0226		0,24	0,24
				sum: 0,45	0,45

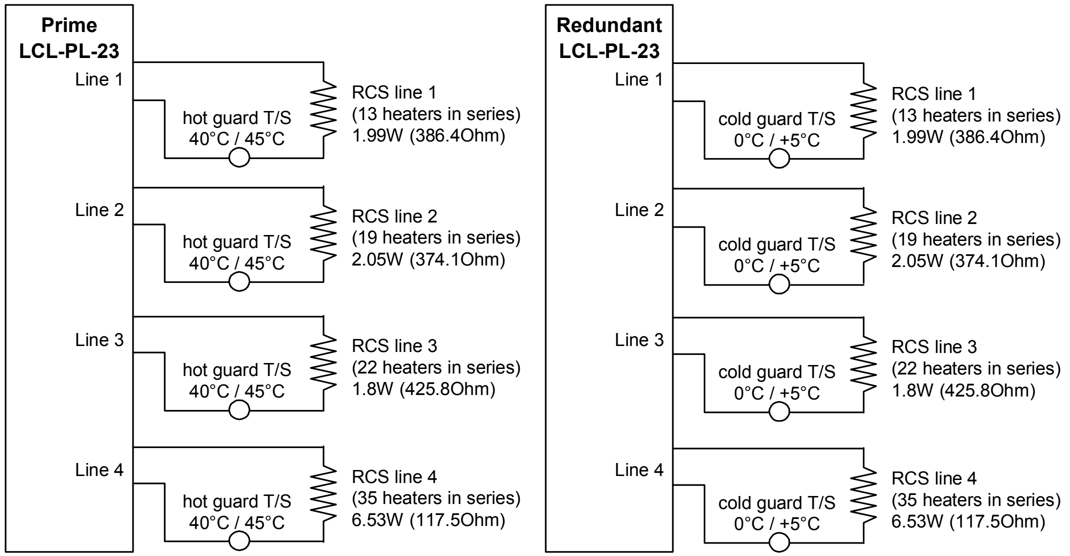


Figure 5-92k: LCL PL-23 (RCS Line 1…4)

EADS Astrium GmbH	ROSETTA Users Manual (Vol. 1)	Doc. No.: RO-DSS-MA-1001
Project: ROSETTA		Issue: 5 Date: 31.10.03
		Sheet: 5-256

LCL-24

HW heater LCLs in PL PDU	related thermistors	RSDB Code	RSDB Code	Currents (A)	
LCL-24 **on**:ZPWMA055SWON / ZPWMA312SWON **off**:ZPWMA056SWOF / ZPWMA313SWOF					
RCS line 5	TCS258_RCS05_TRP	NTSA0101		0,21	0,21
RCS line 6	TCS259_RCS06_TRP	NTSA0227		0,06	0,06
RCS line 7	TCS260_RCS07_TRP	NTSA0102		0,04	0,04
RCS line 8	TCS261_RCS08_TRP	NTSA0228		0,07	0,07
				sum: 0,38	0,38

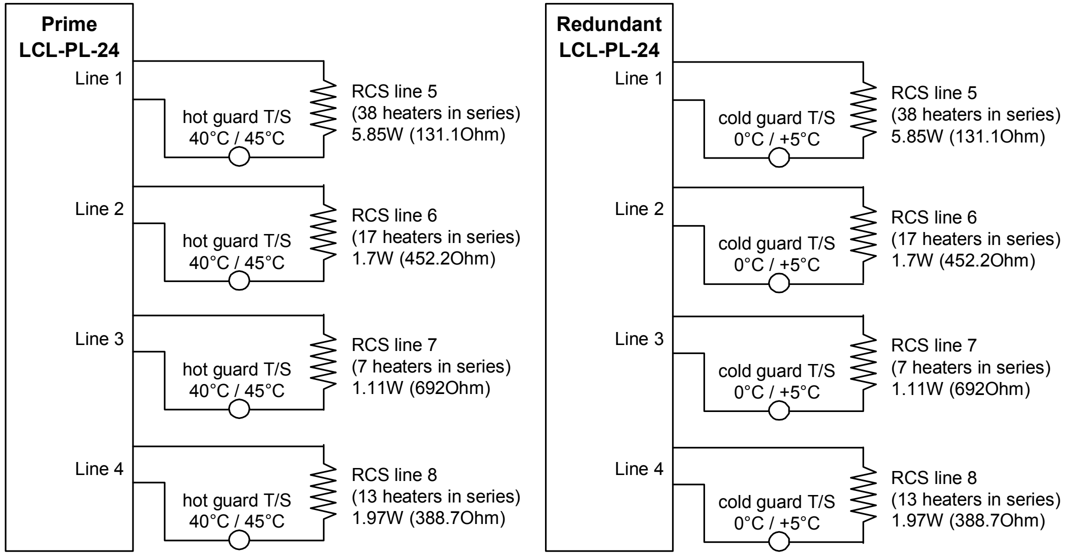


Figure 5-92l: LCL PL-24 (RCS Line 5…8)

LCL-27

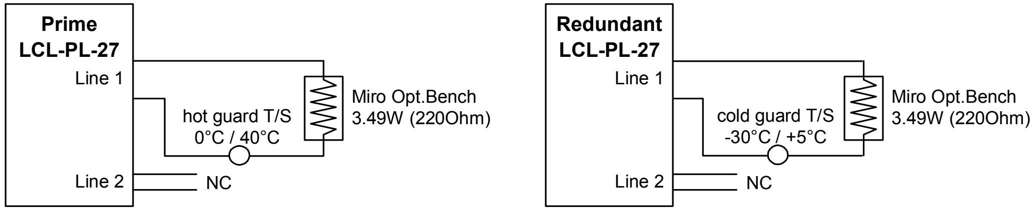
HW heater LCLs in PL PDU	related thermistors	RSDB Code		RSDB Code		Currents (A)	
LCL-27 **on**:ZPWMA061SWON / ZPWMA318SWON **off**:ZPWMA062SWOF / ZPWMA319SWOF							
Miro Optical bench	TCS018_MIROB_TRP	NTSA0194	PAY412_MIROB_1 PAY413_MIROB_2	NMRAT102 NMRAT002		0,13	0,13

Figure 5-92m: LCL PL-27 (MIRO Optical Bench)

LCL-28

HW heater LCLs in PL PDU	related thermistors	RSDB Code	RSDB Code	Currents (A)	
LCL-28 **on**:ZPWMA063SWON / ZPWMA320SWON **off**:ZPWMA064SWOF / ZPWMA321SWOF					
Virtis PEM M	TCS049_VIRPM_TRP_P TCS050_VIRPM_TRP_R	NTSA0006 NTSA0132		0,13	0,13

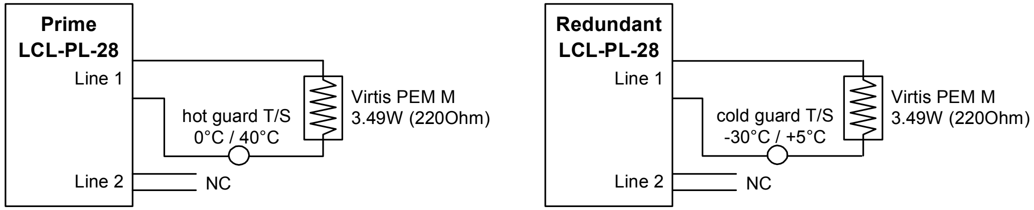


Figure 5-92n: LCL PL-28 (VIRTIS PEMM)

LCL-34

HW heater LCLs in PL PDU	related thermistors	RSDB Code		RSDB Code	Currents (A)	
LCL-34 **on**:ZPWMA075SWON / ZPWMA332SWON **off**:ZPWMA076SWOF / ZPWMA333SWOF						
Rosina DFMS (intern	TCS036_DFMS__TRP_P TCS037_DFMS__TRP_R	NTSA0012 NTSA0138	PAY421_DFMS__1 PAY422_DFMS__2	NRNAT101 NRNAT001	0,05	0,05

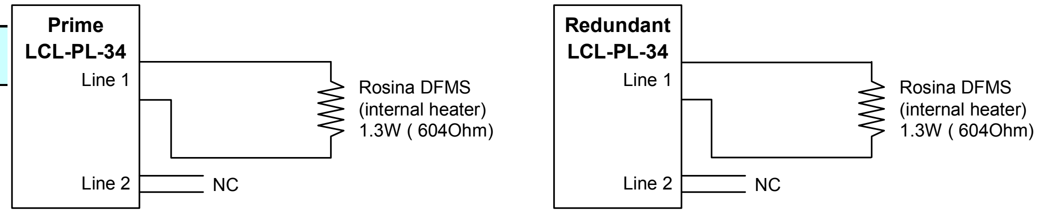


Figure 5-92o: LCL PL-34 (ROSINA DFMS)

LCL-35

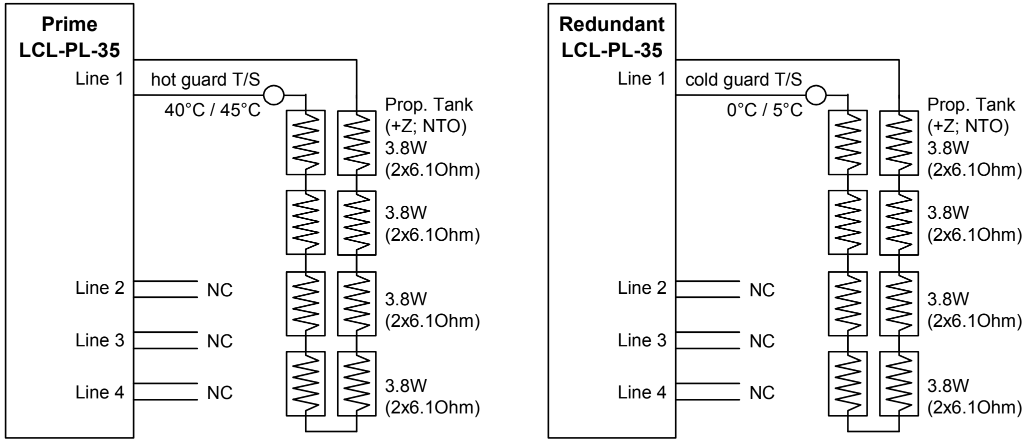
HW heater LCLs in PL PDU	related thermistors	RSDB Code	RSDB Code		Currents (A)	
LCL-35 **on**:ZPWMA077SWON / ZPWMA334SWON **off**:ZPWMA078SWOF / ZPWMA335SWOF					0,55	0,55
upper tank	TCS200_MMH___H701_1 TCS201_MMH___H701_2 TCS202_MMH___H701_3	NTSA0040 NTSA0072 NTSA0166				

Figure 5-92p: LCL PL-35 (Prop Tank +z)

LCL-36

HW heater LCLs in PL PDU	related thermistors	RSDB Code	RSDB Code	Currents (A)	
LCL-36 **on**:ZPWMA079SWON / ZPWMA336SWON **off**:ZPWMA080SWOF / ZPWMA337SWOF					
lower tank	TCS206_NTO___H726_1	NTSA0041		0,61	0,61
	TCS208_NTO___H726_3	NTSA0167			
	TCS207_NTO___H726_2	NTSA0198			

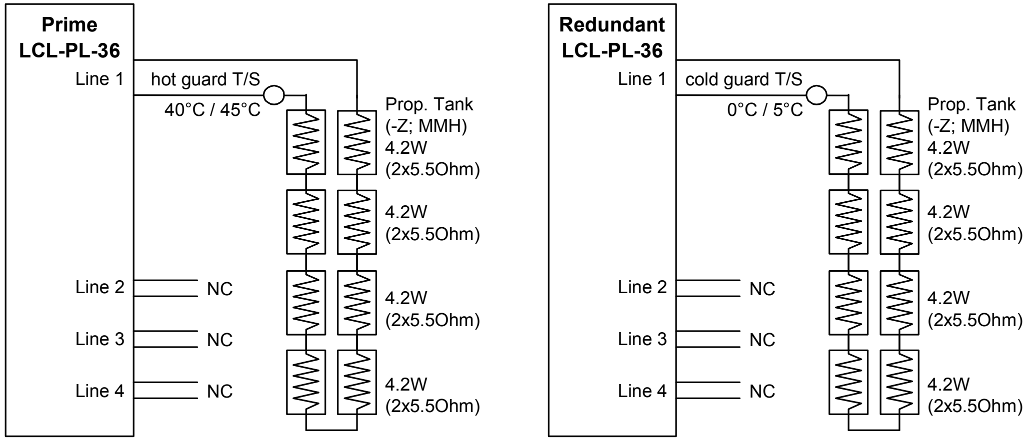


Figure 5-92q: LCL PL-36 (Prop Tank –z)

LCL-37

HW heater LCLs in PL PDU	related thermistors	RSDB Code	RSDB Code		Currents (A)	
LCL-37						
on:ZPWMA081SWON / ZPWMA338SWON						
off:ZPWMA082SWOF / ZPWMA339SWOF						
RCS line 9	TCS262_RCS09_TRP	NTSA0103			0,03	0,03
RCS line 10	TCS263_RCS10_TRP	NTSA0229			0,01	0,01
RCS line 11	TCS264_RCS11_TRP	NTSA0104			0,04	0,04
RCS line 12	TCS265_RCS12_TRP	NTSA0230			0,03	0,03
				sum:	0,11	0,11

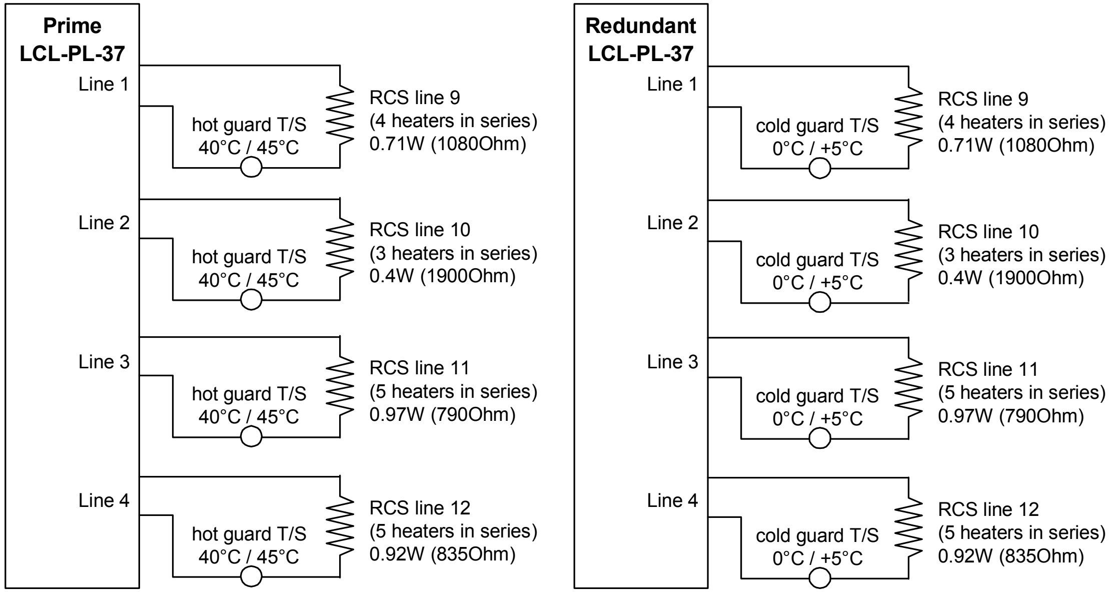


Figure 5-92r: LCL PL-37 (RCS Line 9…12)

LCL-39

HW heater LCLs in PL PDU	related thermistors	RSDB Code	RSDB Code		Currents (A)	
LCL-39 on:ZPWMA085SWON / ZPWMA342SWON off:ZPWMA086SWOF / ZPWMA343SWOF						
Osiris ME	TCS034_OSIEL_TRP_P TCS035_OSIEL_TRP_R	NTSA0011 NTSA0137			0,19	0,19

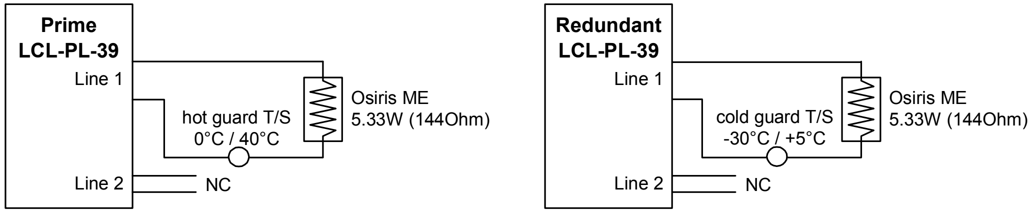


Figure 5-92s: LCL PL-39 (OSIRIS Electronics)

LCL-40

HW heater LCLs in PL PDU	related thermistors	RSDB Code		RSDB Code	Currents (A)
LCL-40 **on**:ZPWMA087SWON / ZPWMA344SWON **off**:ZPWMA088SWOF / ZPWMA345SWOF					0,02
IES (internal)	TCS053_IES___TRP_P TCS054_IES___TRP_R	NTSA0017 NTSA0143	PAY429_IES___1	NRPAT001	

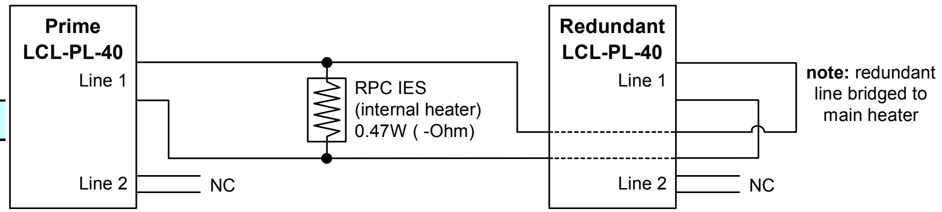
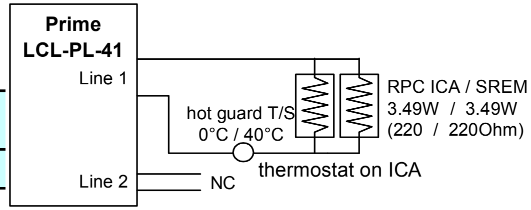


Figure 5-92t: LCL PL-40 (RPC IES internal)

LCL-41

HW heater LCLs in PL PDU	related thermistors	RSDB Code		RSDB Code	Currents (A)	
LCL-41 **on**:ZPWMA089SWON / ZPWMA346SWON **off**:ZPWMA090SWOF / ZPWMA347SWOF						
RPC ICA; SREM	TCS056_ICA___TRP_P	NTSA0018	PAY430_ICA___1	NRPAT002	0,25	0,25
	TCS057_ICA___TRP_R	NTSA0144				
	TCS055_ICA___STP	NTSA0084				
	TCS065_SREM__TRP_P	NTSA0022	PAY432_SREM__1	NSEAT001		
	TCS064_SREM__STP	NTSA0085				



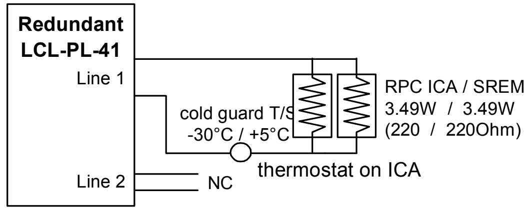


Figure 5-92u: LCL PL-41 (RPC ICA;SREM)

LCL-42

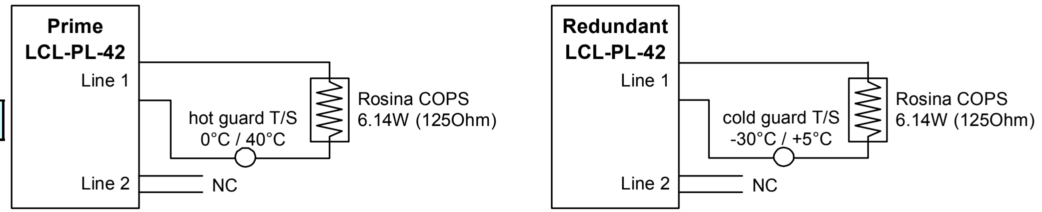
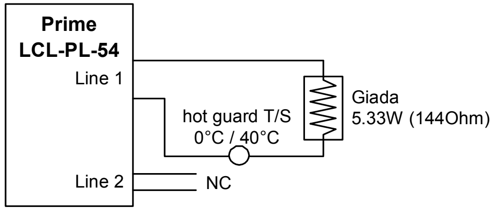
HW heater LCLs in PL PDU	related thermistors		RSDB Code	RSDB Code		Currents (A)	
LCL-42 **on**:ZPWMA091SWON / ZPWMA348SWON **off**:ZPWMA092SWOF / ZPWMA349SWOF							
Rosina COPS	TCS039_COPS__TRP_P TCS040_COPS__TRP_R	NTSA0013 NTSA0139	PAY441_COPS__1	NRNAT103		0,22	0,22

Figure 5-92v: LCL PL-42 (ROSINA COPS)

LCL-54

HW heater LCLs in PL PDU	related thermistors	RSDB Code	RSDB Code	Currents (A)	
LCL-54 **on**:ZPWMA115SWON / ZPWMA372SWON **off**:ZPWMA116SWOF / ZPWMA373SWOF					
Giada	TCS012_GIADA_TRP_P TCS013_GIADA_TRP_R	NTSA0067 NTSA0193		0,19	0,19



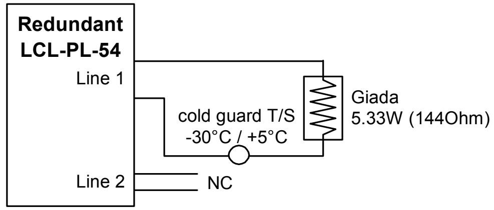


Figure 5-92w: LCL PL-54 (GIADA)

5.4.1.9.2. HW/SW Heater LCLs

LCL-43

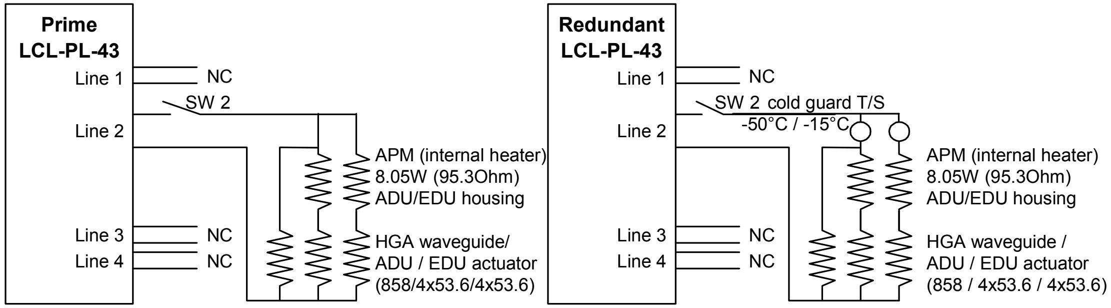
HW/SW heater LCLs in PL PDU	related thermistors	RSDB Code	RSDB Code	Currents (A)	
LCL-43 **on**:ZPWMA093SWON / ZPWMA350SWON **off**:ZPWMA094SWOF / ZPWMA351SWOF					
APM	TCS142_APM___H178_1 TCS143_APM___H178_2 TCS144_APM___H178_3	NTSA0037 NTSA0196 NTSA0163		0,29	0,29
HSW on:ZPWMA173SWON / ZPWMA430SWON **HSW off**:ZPWMA174SWOF / ZPWMA431SWOF					

Figure 5-92aa: LCL PL-43 (APM; HGA)

LCL-44

HW/SW heater LCLs in PL PDU | related thermistors | RSDB Code | RSDB Code | Currents (A)

LCL-44

on:ZPWMA095SWON / ZPWMA352SWON

off:ZPWMA096SWOF / ZPWMA353SWOF

	related thermistors	RSDB Code
thruster module 1	TCS214_THR01_H129_1	NTSA0042
	TCS215_THR01_H129_2	NTSA0073
	TCS216_THR01_H129_3	NTSA0168

HSW on:ZPWMA179SWON / ZPWMA436SWON

HSW off:ZPWMA180SWOF / ZPWMA437SWOF

	related thermistors	RSDB Code
thruster module 2	TCS217_THR02_H179_1	NTSA0043
	TCS218_THR02_H179_2	NTSA0199
	TCS219_THR02_H179_3	NTSA0169

HSW on:ZPWMA181SWON / ZPWMA438SWON

HSW off:ZPWMA182SWOF / ZPWMA439SWOF

	related thermistors	RSDB Code
thruster module 3	TCS220_THR03_H329_1	NTSA0044
	TCS221_THR03_H329_2	NTSA0074
	TCS222_THR03_H329_3	NTSA0170

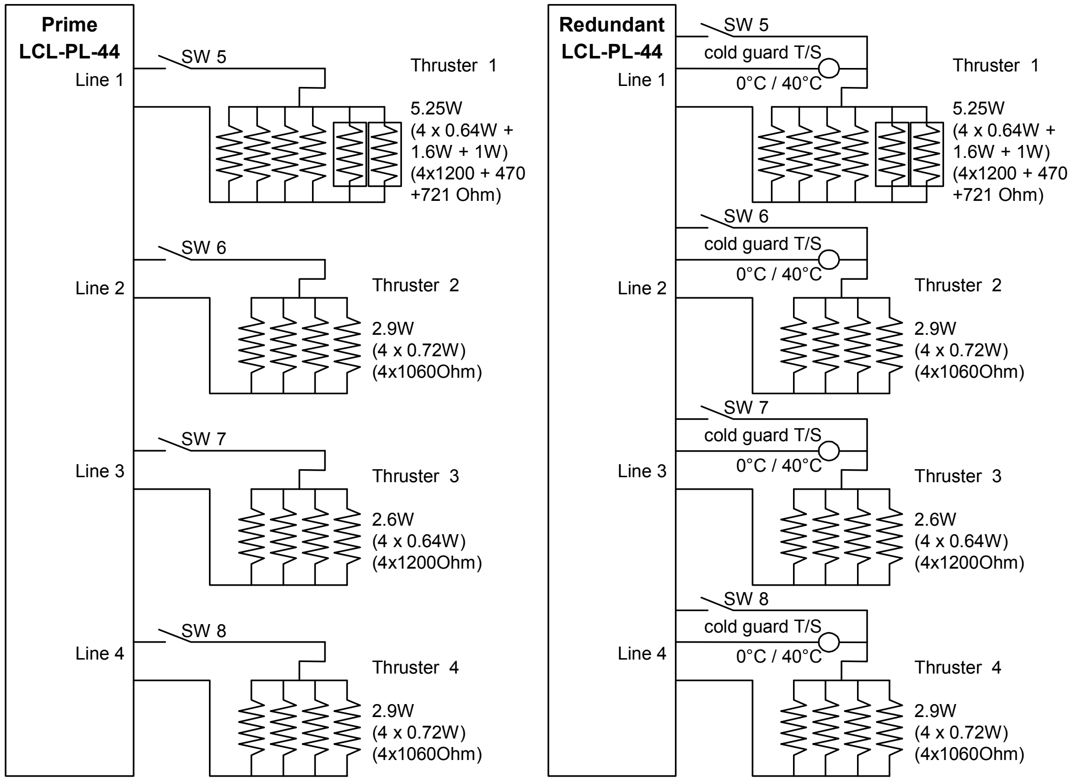
HSW on:ZPWMA183SWON / ZPWMA440SWON

HSW off:ZPWMA184SWOF / ZPWMA441SWOF

	related thermistors	RSDB Code
thruster module 4	TCS223_THR04_H379_1	NTSA0200
	TCS224_THR04_H379_2	NTSA0200
	TCS225_THR04_H379_3	NTSA0171

HSW on:ZPWMA185SWON / ZPWMA442SWON

HSW off:ZPWMA186SWOF / ZPWMA443SWOF



	Currents (A)	
	0,19	0,19
	0,10	0,10
	0,09	0,09
	0,10	0,10
sum:	0,49	0,49

Figure 5-92ab: LCL PL-44 (Thruster 1…4)

LCL-45

HW/SW heater LCLs in PL PDU	related thermistors	RSDB Code	RSDB Code		Currents (A)	
LCL-45						
on:ZPWMA097SWON / ZPWMA354SWON						
off:ZPWMA098SWOF / ZPWMA355SWOF						
thruster module 5	TCS226_THR05_H130_1	NTSA0046				
	TCS227_THR05_H130_2	NTSA0075			0,10	0,10
	TCS228_THR05_H130_3	NTSA0172				
HSW on:ZPWMA187SWON / ZPWMA444SWON						
HSW off:ZPWMA188SWOF / ZPWMA445SWOF						
thruster module 6	TCS229_THR06_H180_1	NTSA0047				
	TCS230_THR06_H180_2	NTSA0201				
	TCS231_THR06_H180_3	NTSA0173				
HSW on:ZPWMA189SWON / ZPWMA446SWON					0,09	0,09
HSW off:ZPWMA190SWOF / ZPWMA447SWOF						
thruster module 7	TCS232_THR07_H330_1	NTSA0048				
	TCS233_THR07_H330_2	NTSA0076				
	TCS234_THR07_H330_3	NTSA0174				
HSW on:ZPWMA191SWON / ZPWMA448SWON						
HSW off:ZPWMA192SWOF / ZPWMA449SWOF						
thruster module 8	TCS235_THR08_H380_1	NTSA0049			0,10	0,10
	TCS236_THR08_H380_2	NTSA0202				
	TCS237_THR08_H380_3	NTSA0175				
HSW on:ZPWMA193SWON / ZPWMA450SWON						
HSW off:ZPWMA194SWOF / ZPWMA451SWOF					0,19	0,19
				sum:	0,49	0,49

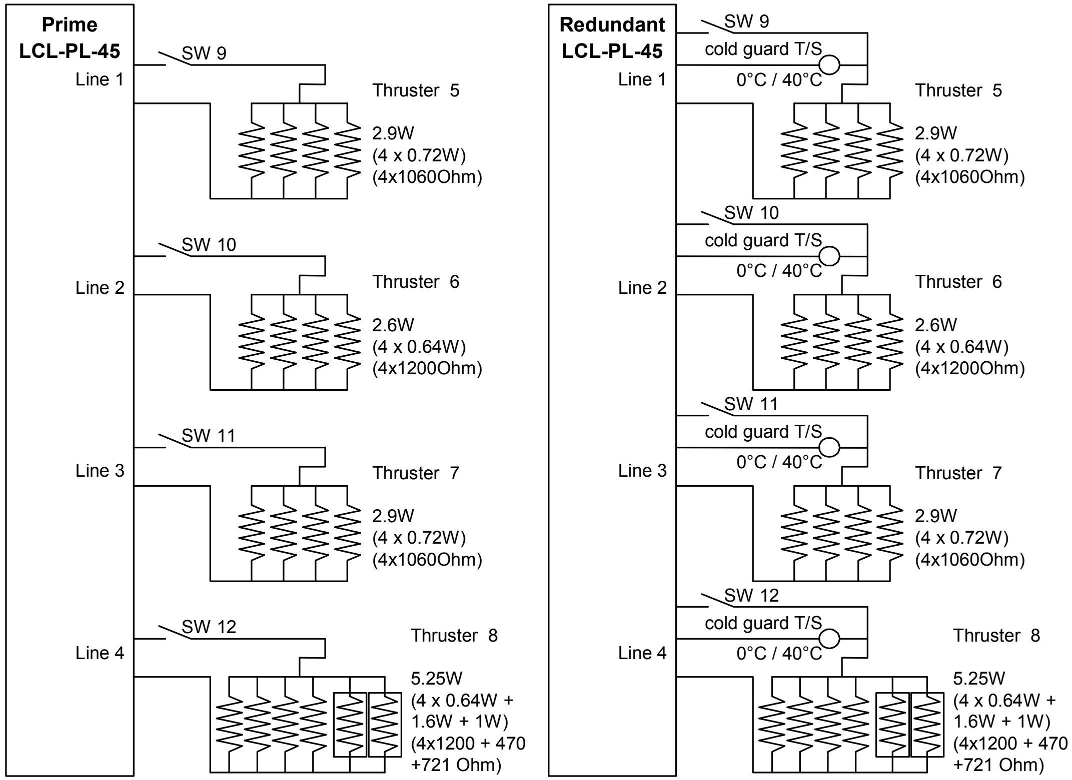


Figure 5-92ac: LCL PL-45 (Thruster 5…8)

LCL-46

HW/SW heater
LCLs in PL PDU related thermistors — Currents (A)

LCL-46

on:ZPWMA099SWON / ZPWMA356SWON

off:ZPWMA100SWOF / ZPWMA357SWOF

thruster module 9

TCS238_THR09_H131_1	NTSA0050
TCS239_THR09_H131_2	NTSA0077
TCS240_THR09_H131_3	NTSA0176

HSW on:ZPWMA195SWON / ZPWMA452SWON

HSW off:ZPWMA196SWOF / ZPWMA453SWOF

thruster module 10

TCS241_THR10_H181_1	NTSA0051
TCS242_THR10_H181_2	NTSA0203
TCS243_THR10_H181_3	NTSA0177

HSW on:ZPWMA197SWON / ZPWMA454SWON

HSW off:ZPWMA198SWOF / ZPWMA455SWOF

thruster module 11

TCS244_THR11_H331_1	NTSA0052
TCS245_THR11_H331_2	NTSA0078
TCS246_THR11_H331_3	NTSA0178

HSW on:ZPWMA199SWON / ZPWMA456SWON

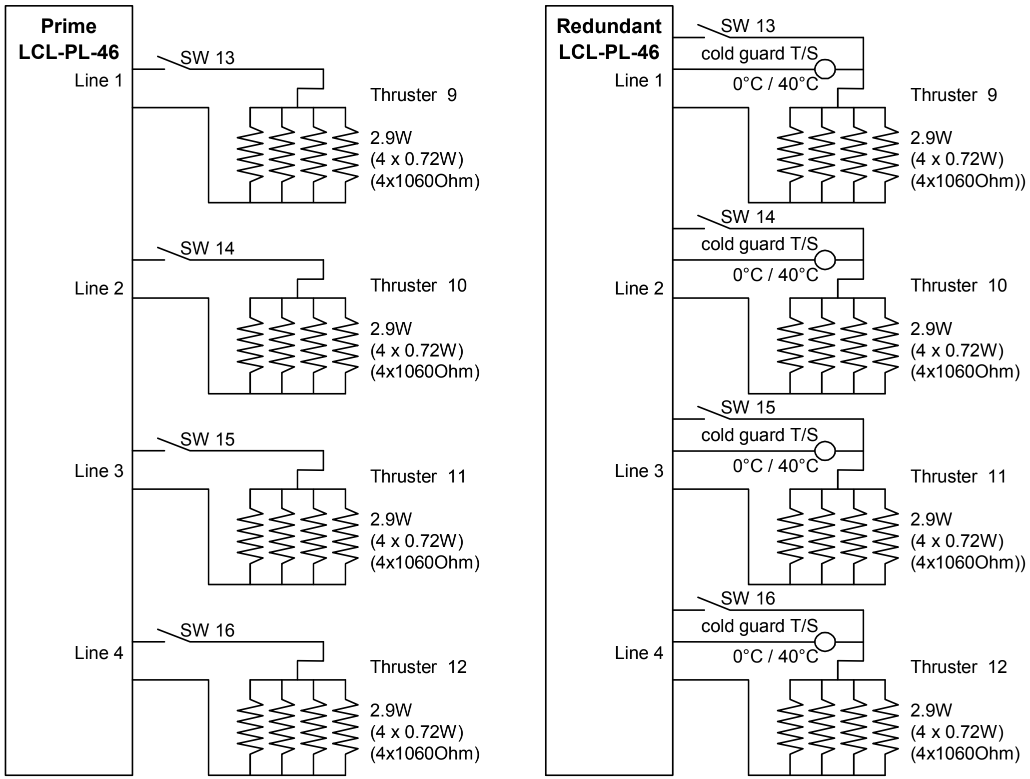
HSW off:ZPWMA1200SWOF / ZPWMA457SWOF

thruster module 12

TCS247_THR12_H381_1	NTSA0053
TCS248_THR12_H381_2	NTSA0204
TCS249_THR12_H381_3	NTSA0179

HSW on:ZPWMA201SWON / ZPWMA458SWON

HSW off:ZPWMA1202SWOF / ZPWMA459SWOF



Currents (A)	
0,10	0,10
0,10	0,10
0,10	0,10
0,10	0,10
sum: 0,42	0,42

Figure 5-92ad: LCL PL-46 (Thruster 9…12)

5.4.1.9.3. SW Heater LCLs

LCL-15

SW heater LCLs in SS PDU	related thermistors	RSDB Code		RSDB Code	Currents (A)	
LCL-15						
on:ZPWM2045SWON / ZPWM2316SWON						
off:ZPWM2046SWOF / ZPWM2317SWOF						
Virtis Decontaminatio	TCS043_VIRTI_TRP_P	NTSA0004	PAY425_VIRTI_1	NVRAT101	1,39	1,39
	TCS044_VIRTI_TRP_R	NTSA0130	PAY426_VIRTI_2	NVRAT102		
			PAY427_VIRTI_3	NVRAT001		
			PAY428_VIRTI_4	NVRAT002		
HSW on:ZPWM2109SWON / ZPWM2380SWON						
HSW off:ZPWM2110SWOF / ZPWM2381SWOF						

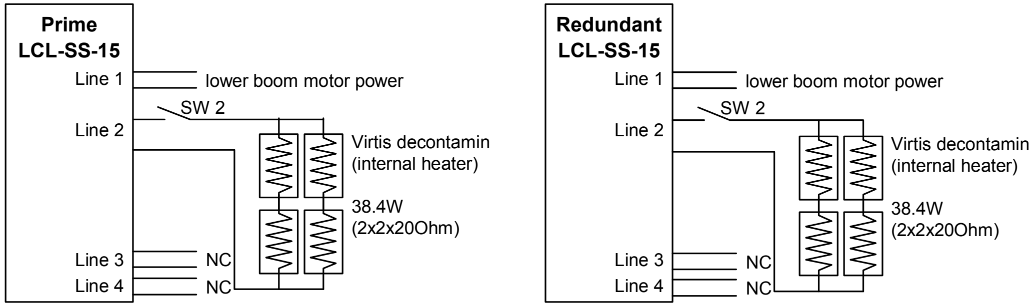


Figure 5-92ae: LCL SS-15 (Virtis Decontamination)

LCL-16

SW heater LCLs in SS PDU related thermistors RSDB Code RSDB Code Currents (A)

LCL-16

on:ZPWM2047SWON / ZPWM2318SWON

off:ZPWM2048SWOF / ZPWM2319SWOF

upper tank gauging

TCS204_MMHLO_GAU_P	NTSA0093
TCS205_MMHLO_GAU_R	NTSA0219
TCS203_MMHHI_GAU	NTSA0094

HSW on:ZPWM2119SWON / ZPWM2390SWON

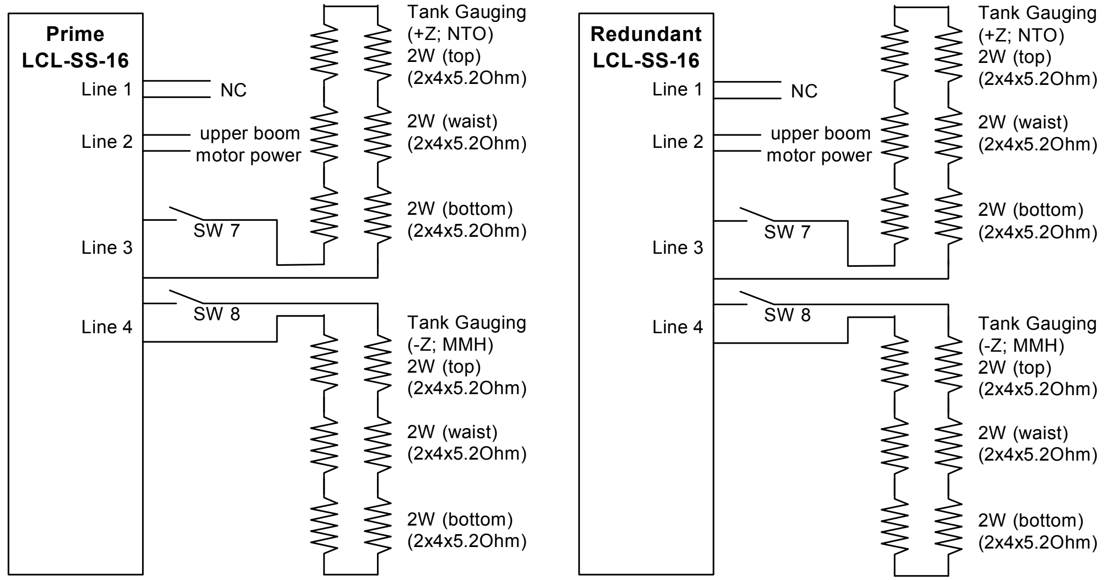
HSW off:ZPWM2120SWOF / ZPWM2391SWOF

lower tank gauging

TCS210_NTOLO_GAU_P	NTSA0095
TCS211_NTOLO_GAU_R	NTSA0221
TCS209_NTOHI_GAU	NTSA0220
TCS276_CYPSM_GAU	NTSA0254
TCS277_CYPSM_GAU	NTSA0258

HSW on:ZPWM2121SWON / ZPWM2392SWON

HSW off:ZPWM2122SWOF / ZPWM2393SWOF



Currents (A)	
0,22	0,22
0,22	0,22
sum: 0,43	0,43

Figure 5-92af: LCL SS-16 (Tank Gauging)

LCL-17

SW heater LCLs in SS PDU	related thermistors	RSDB Code		RSDB Code	Currents (A)	
LCL-17						
on:ZPWM2049SWON / ZPWM2320SWON						
off:ZPWM2050SWOF / ZPWM2321SWOF						
Virtis CCD (internal)	TCS043_VIRTI_TRP_P	NTSA0004	PAY425_VIRTI_1	NVRAT101	0,003	0,003
	TCS044_VIRTI_TRP_R	NTSA0130	PAY426_VIRTI_2	NVRAT102		
			PAY427_VIRTI_3	NVRAT001		
			PAY428_VIRTI_4	NVRAT002		
HSW on:ZPWM2123SWON / ZPWM2394SWON						
HSW off:ZPWM2124SWOF / ZPWM2395SWOF						

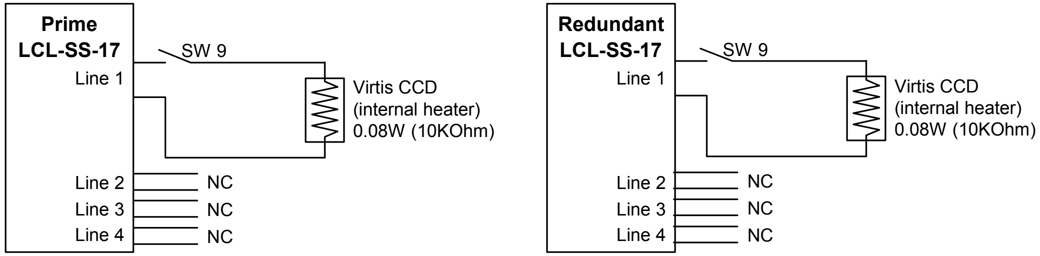


Figure 5-92ag: LCL SS-17 (Virtis CCD)

LCL-18

SW heater LCLs in SS PDU	related thermistors	RSDB Code	RSDB Code	Currents (A)	
LCL-18					
on:ZPWM2051SWON / ZPWM2322SWON					
off:ZPWM2052SWOF / ZPWM2323SWOF					
RWA 1	TCS321_RW1___H703_1	NTSA0054		0,10	0,10
	TCS322_RW1___H703_2	NTSA0079			
	TCS323_RW1___H703_3	NTSA0180			
HSW on:ZPWM2131SWON / ZPWM2402SWON					
HSW off:ZPWM2132SWOF / ZPWM2403SWOF					
RWA 2	TCS324_RW2___H728_1	NTSA0055		0,10	0,10
	TCS325_RW2___H728_2	NTSA0205			
	TCS326_RW2___H728_3	NTSA0181			
HSW on:ZPWM2133SWON / ZPWM2404SWON					
HSW off:ZPWM2134SWOF / ZPWM2405SWOF					
			sum:	0,20	0,20

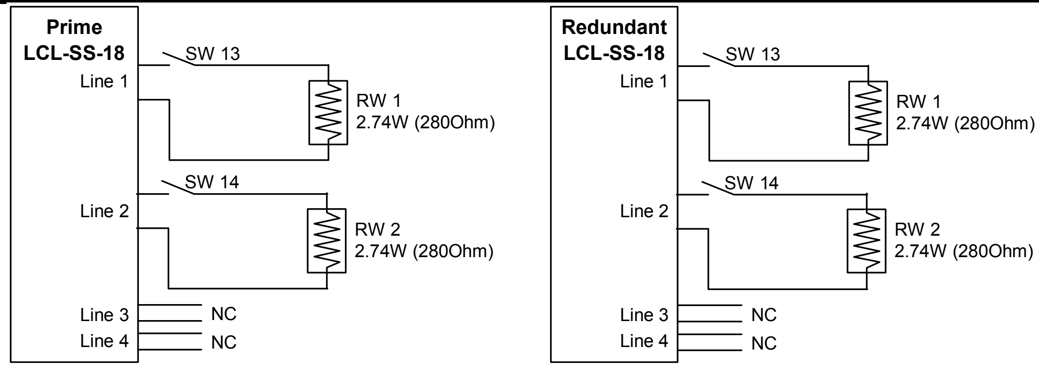
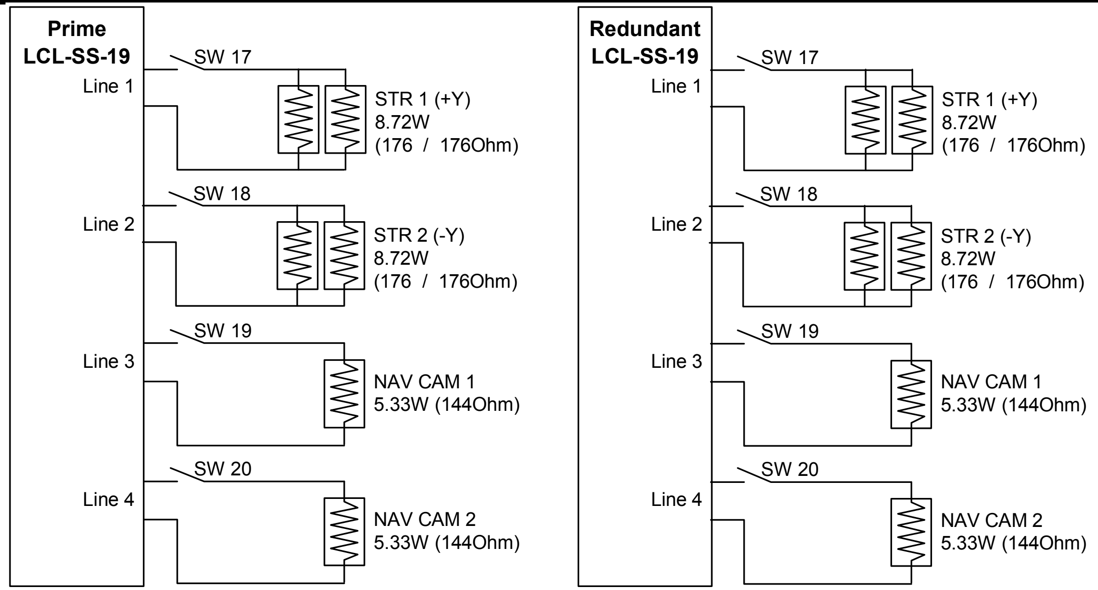


Figure 5-92ah: LCL SS-18 (RW 1,2)

LCL-19

SW heater LCLs in SS PDU	related thermistors	RSDB Code	RSDB Code
LCL-19			
on:ZPWM2053SWON / ZPWM2324SWON			
off:ZPWM2054SWOF / ZPWM2325SWOF			
STR 1	TCS342_STR1__H704_1	NTSA0058	
	TCS343_STR1__H704_2	NTSA0082	
	TCS344_STR1__H704_3	NTSA0184	
	TCS341_STR1__STP	NTSA0121	
HSW on:ZPWM2139SWON / ZPWM2410SWON			
HSW off:ZPWM2140SWOF / ZPWM2411SWOF			
STR 2	TCS346_STR2__H729_1	NTSA0059	
	TCS347_STR2__H729_2	NTSA0208	
	TCS348_STR2__H729_3	NTSA0185	
	TCS345_STR2__STP	NTSA0247	
HSW on:ZPWM2141SWON / ZPWM2412SWON			
HSW off:ZPWM2142SWOF / ZPWM2413SWOF			
CAM 1	TCS352_NAV1__H754_1	NTSA0060	
	TCS353_NAV1__H754_2	NTSA0081	
	TCS354_NAV1__H754_3	NTSA0186	
	TCS351_NAV1__STP	NTSA0123	
HSW on:ZPWM2143SWON / ZPWM2414SWON			
HSW off:ZPWM2144SWOF / ZPWM2415SWOF			
CAM 2	TCS356_NAV2__H779_1	NTSA0061	
	TCS357_NAV2__H779_2	NTSA0207	
	TCS358_NAV2__H779_3	NTSA0187	
	TCS355_NAV2__STP	NTSA0249	
HSW on:ZPWM2145SWON / ZPWM2416SWON			
HSW off:ZPWM2146SWOF / ZPWM2417SWOF			



Currents (A)	
0,31	0,31
0,31	0,31
0,19	0,19
0,19	0,19
sum: 1,01	1,01

Figure 5-92ai: LCL SS-19 (STR; Navcam)

LCL-20

SW heater LCLs in SS PDU | related thermistors | RSDB Code | RSDB Code | Currents (A)

LCL-20

on:ZPWM2055SWON / ZPWM2326SWON
off:ZPWM2056SWOF / ZPWM2327SWOF

Battery 1

TCS103_BATT1_H705_1	NTSA0034
TCS104_BATT1_H705_2	NTSA0069
TCS105_BATT1_H705_3	NTSA0160

HSW on:ZPWM2147SWON / ZPWM2418SWON
HSW off:ZPWM2148SWOF / ZPWM2419SWOF

Battery 3

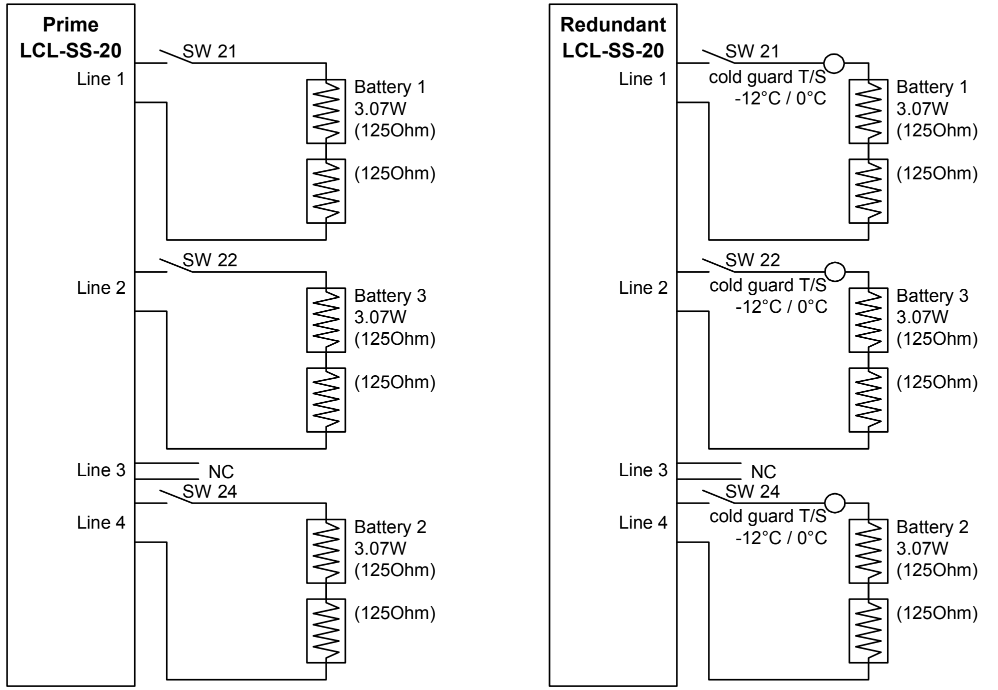
TCS109_BATT3_H730_1	NTSA0036
TCS110_BATT3_H730_2	NTSA0070
TCS111_BATT3_H730_3	NTSA0162

HSW on:ZPWM2153SWON / ZPWM2424SWON
HSW off:ZPWM2154SWOF / ZPWM2425SWOF

Battery 2

TCS106_BATT2_H780_1	NTSA0035
TCS107_BATT2_H780_2	NTSA0195
TCS108_BATT2_H780_3	NTSA0161

HSW on:ZPWM2149SWON / ZPWM2420SWON
HSW off:ZPWM2150SWOF / ZPWM2421SWOF



Heater	Currents (A)	
Battery 1	0,11	0,11
Battery 3	0,11	0,11
Battery 2	0,11	0,11
sum:	0,33	0,33

Figure 5-92aj: LCL SS-20 (Batteries)

LCL-21

SW heater LCLs in SS PDU	related thermistors	RSDB Code	RSDB Code	Currents (A)	
LCL-21					
on:ZPWM2057SWON / ZPWM2328SWON					
off:ZPWM2058SWOF / ZPWM2329SWOF					
SADM +Y	TCS155_SADPY_H756_1	NTSA0038			
	TCS156_SADPY_H756_2	NTSA0071			
	TCS157_SADPY_H756_3	NTSA0164			
HSW on:ZPWM2159SWON / ZPWM2430SWON				0,14	0,14
HSW off:ZPWM2160SWOF / ZPWM2431SWOF					
SADM -Y	TCS158_SADMY_H781_1	NTSA0039			
	TCS159_SADMY_H781_2	NTSA0197			
	TCS160_SADMY_H781_3	NTSA0165			
HSW on:ZPWM2161SWON / ZPWM2432SWON					
HSW off:ZPWM2162SWOF / ZPWM2433SWOF				0,14	0,14
			sum:	0,27	0,27

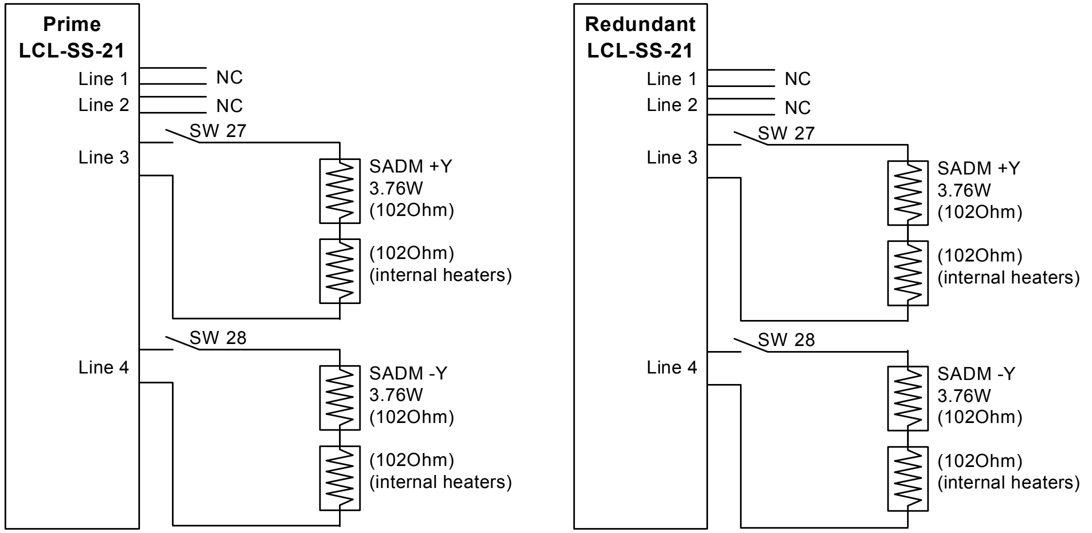


Figure 5-92ak: LCL SS-21 (SADM)

LCL-22

SW heater LCLs in SS PDU related thermistors RSDB Code RSDB Code Currents (A)

LCL-22

on:ZPWM2059SWON / ZPWM2330SWON

off:ZPWM2060SWOF / ZPWM2331SWOF

	related thermistors	RSDB Code		RSDB Code
Osiris NAC / WAC st	TCS024_NAC___STP_P	NTSA0007	PAY415_NAC___1	NSRAT001
	TCS092_NAC___STP_R	NTSA0133	PAY416_NAC___2	NSRAT002
			PAY417_NAC___3	NSRAT004
			PAY418_NAC___4	NSRAT005

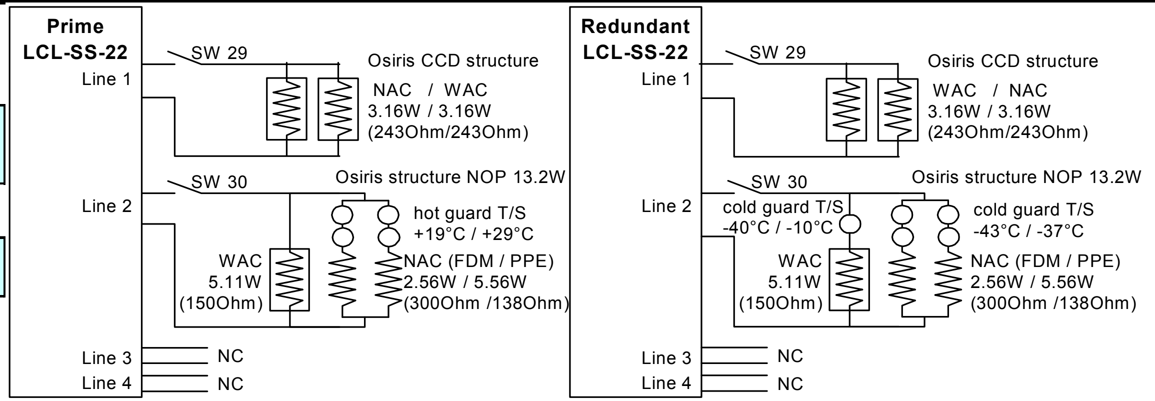
HSW on:ZPWM2163SWON / ZPWM2434SWON

HSW off:ZPWM2164SWOF / ZPWM2435SWOF

	related thermistors	RSDB Code		RSDB Code
Osiris NAC / WAC C(	TCS027_WAC___STP_P	NTSA0008	PAY419_WAC___1	NSRAT003
	TCS093_WAC___STP_R	NTSA0134	PAY420_WAC___2	NSRAT006

HSW on:ZPWM2165SWON / ZPWM2436SWON

HSW off:ZPWM2166SWOF / ZPWM2437SWOF



Currents (A)		
	0,23	0,23
	0,48	0,48
sum:	0,71	0,71

Figure 5-92al: LCL SS-22 (Osiris)

5.4.2. Propulsion Subsystem

5.4.2.1. General

The subsystem consists of two main sections; a high pressure gas section and a low pressure gas/liquid propellant section.

The high pressure section provides storage, control & supply of helium to the low pressure section. The low pressure section provides propellant storage & delivery to a set of 24 10 Newton dual valve thrusters used for attitude and orbit control.

The system is capable of operating in both regulated and blowdown modes. Redundancy of function is provided.

The subsystem will be able to operate when the spacecraft is three axis or spin stabilised provided the spin rate does not exceed 1 RPM . Beyond the specified spin rate propellant pumping within the tank may fail depending on amount of propellant remaining at the time. Firing of thrusters would still be possible from the reserves within the refillable reservoir but this supply is finite. If more than 1 RPM is not planned then the reserve is a contingency.

All materials that are used within the subsystem will be compatible with the propellants or vapours where they are exposed for the duration of the mission. Titanium alloy will constitute the majority of the wetted area with some suitable stainless steels and small amounts of Teflon for valve seats.

The subsystem will be maintained within a temperature range such that the components do not exceed their temperature limits . Temperature manipulation can be used to aid thruster performance (adjusting tank pressure to manipulate mixture ratio) during blowdown phases.

Keeping the temperature of the propellant within the tanks lower than the temperature of the pressurant feed pipework will promote propellant vapour condensation in the tank rather than the pressurant pipe-work .

The pipework and components will be supported on brackets made of material with a low thermal conductance.

5.4.2.2. Propellant storage and Delivery

The propellant storage & delivery section is very simple & reliable employing a minimum of components.

The propellant is stored in two identical tanks each having a volume of 1108 litres and are designed, using fracture mechanics, to MIL-STD 1552 and CSG safety regulations.

The tanks are mounted centrally within the spacecraft on the Z-axis to minimise C of G shift when propellant is used and to promote the desired overall spacecraft mass properties (Ixx>Izz). The tank volume is such that the total impulse for the mission can be met with the required margins.

To monitor the status of the remaining propellant load during the mission a combination of propellant accounting based on thruster use and the Astrium UK method of Thermal Gauging is proposed. This is detailed in a technical note RO-MMB-TN-3124.

Isolation of the propellant from the thrusters is provided by normally closed pyrotechnic valves (PVNC 23, 24, 25 & 26) which satisfy the CSG range safety requirement for two independent inhibits and functional redundancy is provided by arranging valves in parallel as well as each valve containing a pair of initiators . The valves are positioned such that access to fit the initiators at the launch site is achievable with minimum disruption to the spacecraft.

Filters (F5 & F6) are provided to protect the thrusters from debris which may be generated by the activation of the pyrotechnic valves or other potential sources of contamination.

Access for filling, draining the tanks is provided by manual valves above (TP 6 & 7) and below (FDV 10 & 11) the propellant tanks the location of which is designed as far as possible to allow simple draining of the tanks

The manual valves downstream of the pyrotechnic valves (TP 14 & 15) allow access for pressurising and testing the thrusters and feed lines and, in conjunction with the tank fill valves, leak testing of the pyrotechnic valves.

Pressure transducers (PT 5 & 6) are provided below the filters to measure the thruster inlet pressure (there will be additional pressure drops from the transducers to the thrusters but at such low flow rates these are small and are accounted for by pressure modelling of the system. These transducers will be used for thruster performance prediction and hence propellant gauging. PT5 acts as a parallel redundant unit for PT3 on the oxidiser side after priming of propellant lines, likewise for PT4 & PT6 on the fuel side.

The propellant supply terminates with 24 thrusters each having a dual valve incorporating a latching function upstream of a conventional flow control valve. The flow control valve is monostable and is closed by magnetic force and hence fails closed. In both valves the oxidiser and fuel flow devices are mechanically linked to assure simultaneous operation. This design provides the maximum flexibility & redundancy in response to any failure of a thruster or its flow control valve.

5.4.2.3. Pressurant Storage and Delivery

Pressurant is stored in 2 high pressure tanks of 68 litres in volume. Access to the pressurant tanks is provided by a single fill/vent valve (FDV1), while pressure measurement is provided by a single pressure transducer (PT1).

The delivery system is more complex than conventional bipropellant systems because of the need to operate the system in regulated mode on two occasions, rather than the more normal one, with operation in blowdown mode at all other times.

The pressurant tanks are isolated from the rest of the delivery system at launch by a series of normally closed pyrotechnic valves (PVNC 3,4,2,32) with two normally open valves (PVNO 1,31) in series to allow re-closure of the pressure supply line after the first propellant tank pressurisation. There is a pressure transducer (PT2) below the pyrotechnic valves to confirm operation of the pyrotechnic valves.

A filter (F1) is situated downstream of the pyrotechnic valves to catch any debris created by the actuation of the valves.

Downstream of the filter there is a pair of regulators (PR 1&2), in parallel for redundancy, one of which (PR2) is isolated at both inlet and outlet by a redundant pair of normally closed pyrotechnic valves (PVNC 7,8,9,10) (with a debris filter F2 on the inlet side of the regulator). The other regulator (PR1), nominally to be used for the whole mission, has normally open pyrotechnic valves at both the inlet (PVNO 5) and the outlet (PVNO 6) to enable it to be completely isolated in case of regulator failure. Should this oocur the second regulator can then be used for the rest of the mission.

Each regulator (PR1 & PR2) itself consists of a series of redundant pair of valves providing protection against “open” failure cases. Hence PR1 & PR2 together provide full series/parallel redundancy.

Downstream of the regulators the pressure supply splits into two identical branches, one for each propellant tank.

Each section contains a filter (F3 & F4) to protect the downstream components from possible pyrotechnic debris followed by a set of series and parallel check valves (4 valves in each of the two branches). One of the series pairs in each branch has two normally open pyrotechnic valves upstream to allow the branch to be isolated after the first regulated phase of the mission. Each series pair of check valves in both branches has a parallel redundant pair of normally closed pyrotechnic valves downstream to allow pressurant into the propellant tanks when the valves are activated, thereby isolating the two propellants & vapor from each other during ground & launch phases.

Each propellant tank has two normally open pyrotechnic valves in series in the pressurant port supply line to enable the tanks to be isolated after the final pressure regulated mode/phase. This ensures that there will be no possibility of propellant or vapours mixing in the common pressurant pipework during the remainder of the mission.

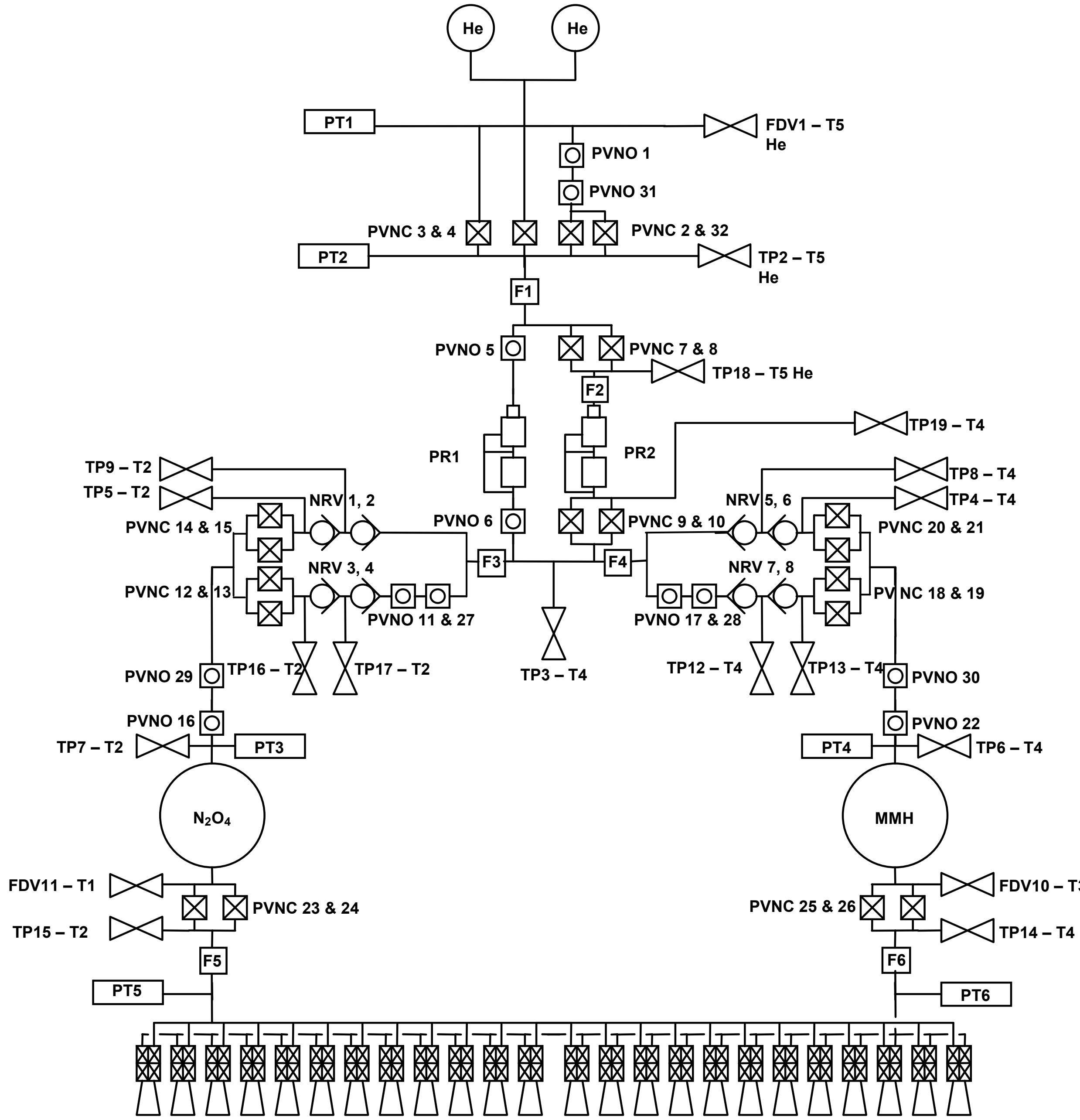


Figure 5-92: RCS Subsystem Schematic

Each tank pressurant line is fitted with a pair of pressure transducers (PT3 & PT4) to allow the monitoring of tank pressure for subsystem health monitoring and as means for predicting thruster performance (as a back-up for the transducers in the propellant lines).

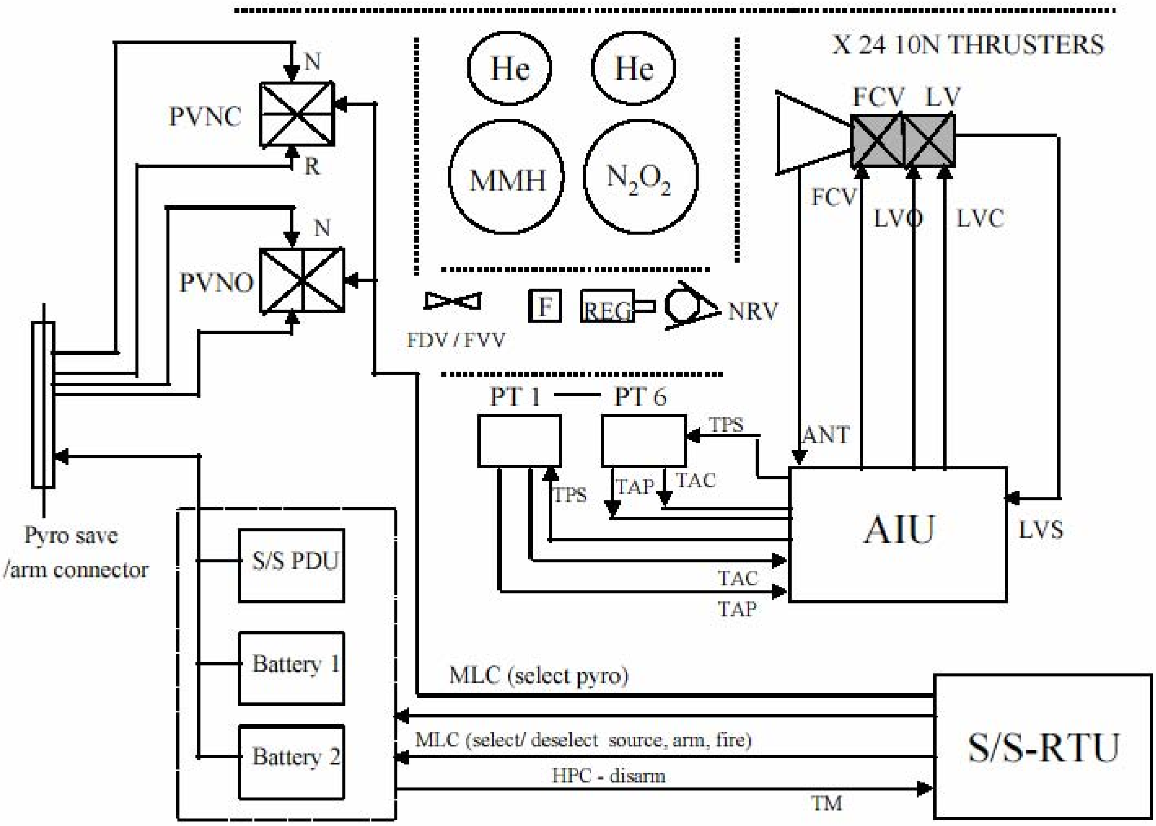
Throughout the pressurant supply components there are gas fill ports used to condition the system for component testing, for ground storage and for launch.

Figure 5-92 shows the RCS Subsystem Schematic

5.4.2.4. Subsystem Layout

5.4.2.4.1. Overall Layout

A block diagram is given in figure 5-93 including the external interfaces to the Avionics.



PVNO – pyro valve, normally open

PVNC – pyro valve, normally closed

FDV/FVV – Fill and Drain Valves /Fill and Vent Valves

PT – Pressure Transducers

F - Filter

NRV – Non-Return valve

REG – Double regulator

Figure 5-93: RCS Subsystem Block Diagram

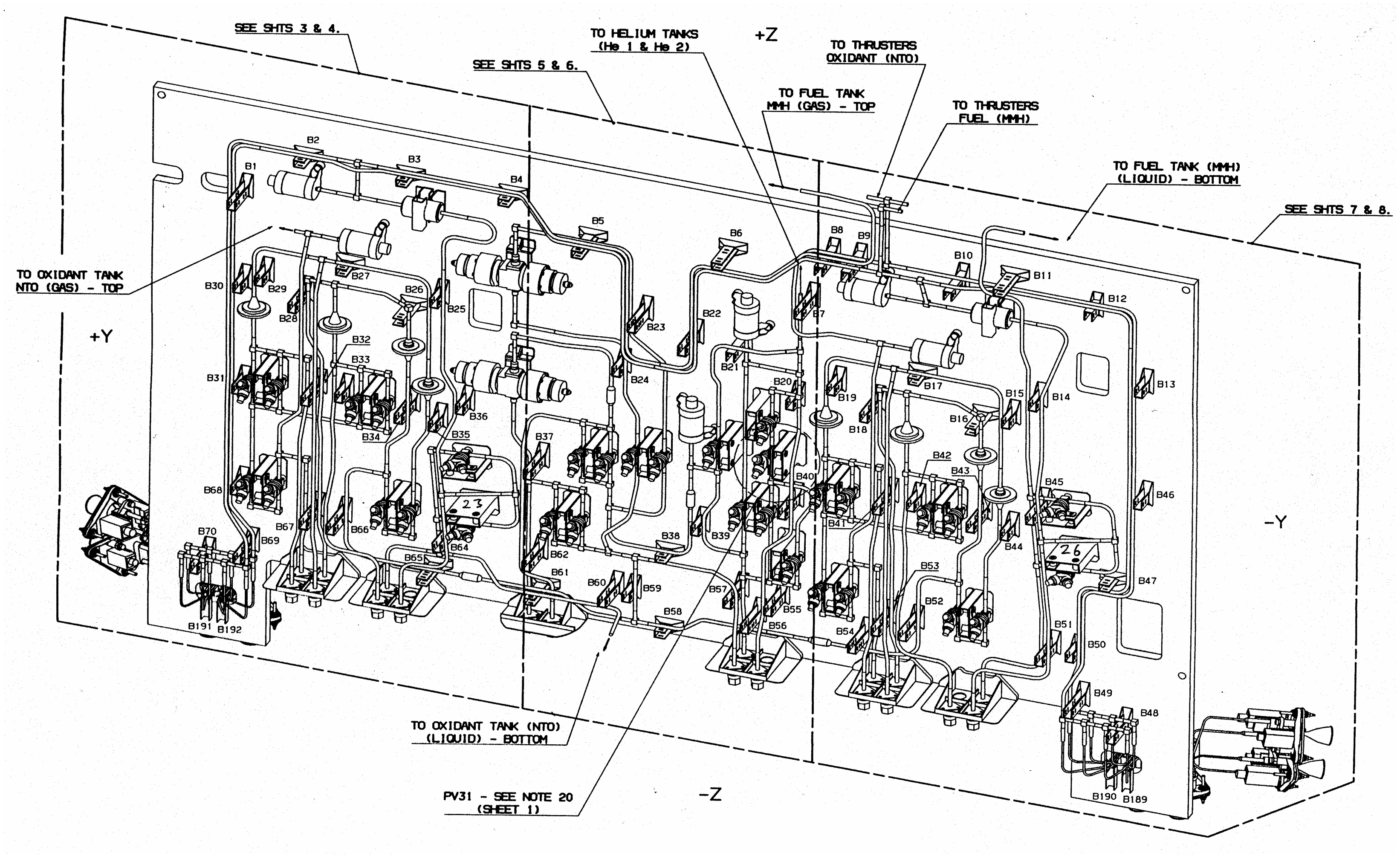


Figure 5-94: Component accommodation on –x panel

Additional drawings in A3 format are included in Annex 9\Propulsion.

5.4.2.4.2. Subsystem Components

The RCS consists of the following main units.

Equipment	Number of main components	Number of redundant components
Thrusters	12	12
NO Pyrotechnic valves	12; valve redundancy by design; each valve is redundant on initiator level	
NC Pyrotechnic valves	20; valve redundancy by design; each valve is redundant on initiator level	
Pressure transducers	6	0
Propellant filter	2	0
Gas filter	4	0
LP NTO FDV	1	0
LP NTO FVV	6	0
LP MMH FDV	1	0
LP MMH	8	0
HP He	3	0
Non return valves*	4	4
Regulator	1**	1**
NTO tank	1	0
MMH tank	1	0
Pressurant tank	2	0

* series redundant

** internally series redundant

The accommodation of the components is shown in figure 5-94.

5.4.2.5. Unit Description

5.4.2.5.1. Propellant Tanks

5.4.2.5.1.1. Tank accommodation and description

The CPS comprises two identical propellant tanks, one for mono-methyl-hydrazine (MMH) and one for nitrogen tetroxide (N_2O_4). They are both manufactured by Astrium GmbH (Bremen). The two tanks are located within the central cylinder of the spacecraft to minimise movement of the CoG as propellant is used. The tanks have threaded pick-up points to allow attachment of support equipment. They are attached within the structure using the 24 tag attachments which are integral to the tanks.

The accommodation of the tanks is shown in figure 5-95.

The tank is essentially a pressure vessel comprising two Cassini shaped titanium domes fixed to either side of a central cylinder.

A propellant management device (PMD), is used to ensure that gas free propellants are delivered to the thrusters during all mission phases and modes of operation (regulated and blow down mode). The main part of the PMD is housed in the lower hemisphere close to the propellant outlet.

The PMD consists of Propellant Acquisition Vanes (PAV) which pump the propellant inside a Propellant Refillable Reservoir (PRR).

They are mainly thin plates running approximately parallel to the tank wall from gas to propellant port. The acquisition vanes within the PRR are located in such a way as to pump the propellant (with the aid of capillary forces) into the angular wedge, the preferred propellant position under 0-g due to the special shape.

The PRR and PAV are designed to ensure that a propellant supply is available even when inertial forces on the spacecraft are such that propellant would normally be driven away from the outlet. The caught propellant will be pumped either via one or more of the 4 upper screen adapters through a tubing manifold to the outlet or / and via the sump screen or / and via one or more of the 4 lower screen adapters.

A cross sectional view of the tank and the major elements are shown in figure 5-96.

For further details please refer to “Propellant Tank Technical Design Description, RO-RIBRE-TN-0001.

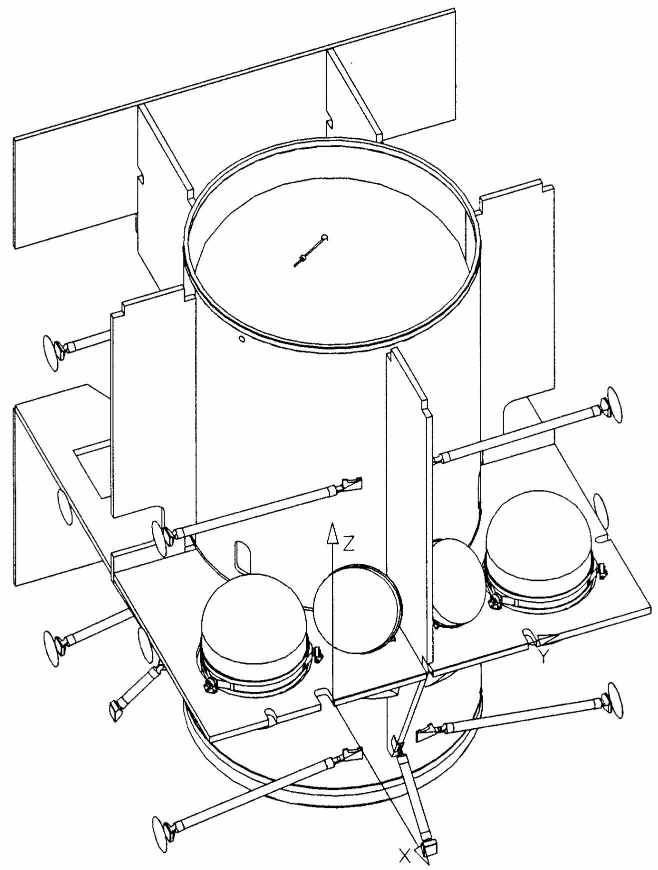


Figure 5-95: Accommodation of tanks within the spacecraft

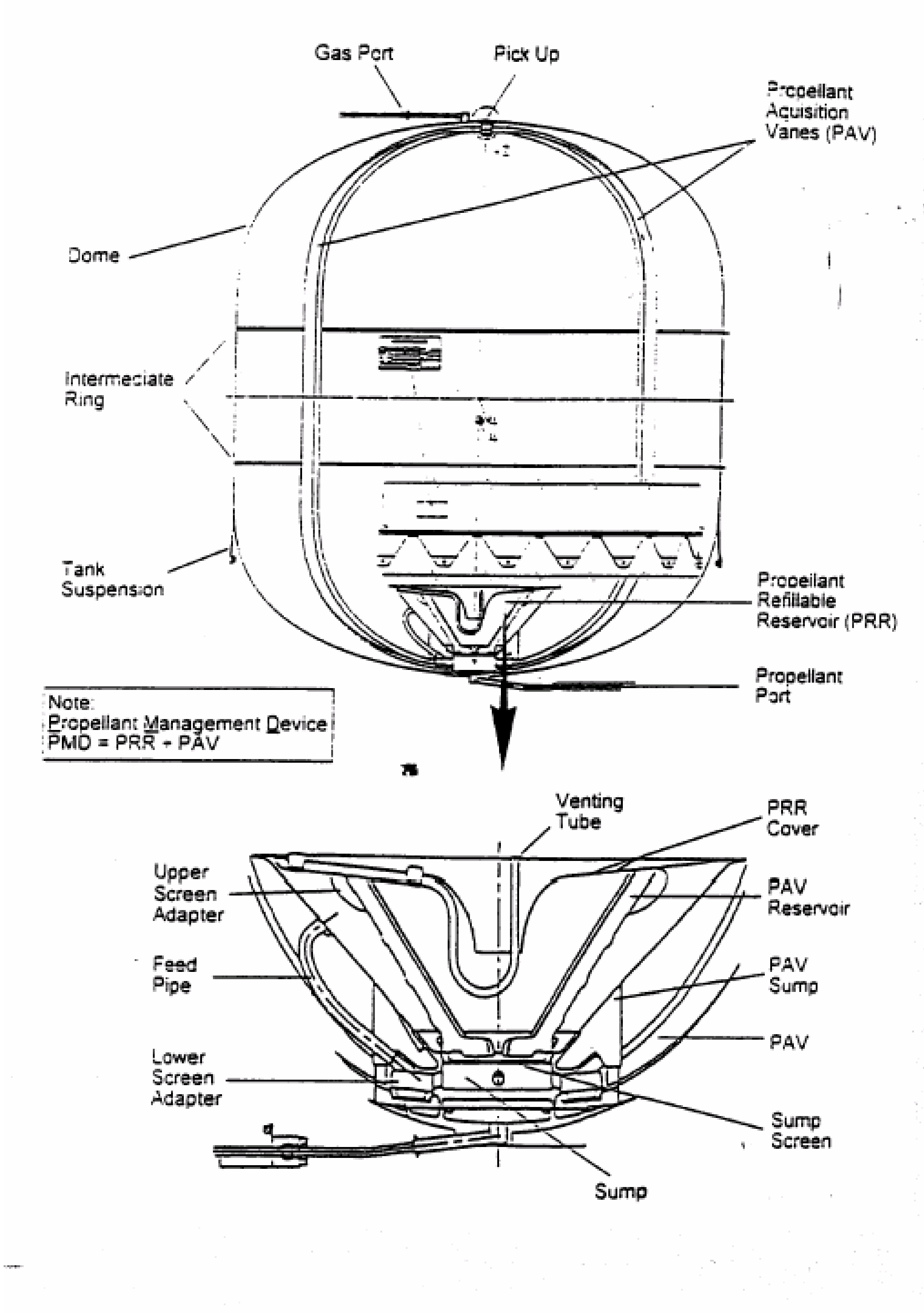


Figure 5-96: Cross Sectional Diagram of Propellant Tank and Propellant Management Device

5.4.2.5.1.2. Thermal Hardware

Each tank is equipped with both a HW prime and redundant circuit (each consisting of 4 mats joined together). Both prime and redundant circuits are wrapped around the bottom half of the tank near to the central cylinder interface. They will maintain tank

temperatures above 0°C during cold phases in the mission. There are 6 thermistors per tank used for monitoring tank temperature evolution (x 3) and propellant gauging (x 3).

For thermal propellant gauging (see section) there is also a prime and redundant heater circuit consisting of twelve 0.5 W heater mats delivering 6W of heater power to each tank. There are three thermistors per tank and a further two on the central cylinder. Nominally all three thermistors on the tank will be used for propellant gauging but two is adequate.

The key performance parameters of the propellant tank are:

- Unpressurised volume =1108 litres per tank
- Propellant capacity = 1894 kg (total,i.e. 714 kg MMH, 1180 kg MON)
- Expulsion efficiency = 99.5%
- Maximum launch pressure = 14.0 bar
- MEOP during on-orbit mission = 19.3 bar
- Burst pressure = 29.85 bar
- Propellant retention of PRR = 6.6 litres during 6° /sec spin
- Propellant retention of outer region = 1.85 litres during 6° /sec spin
- Usable sponge capacity = 6.3 litres
- Operating temperature range = 0 to 45°C
- Leakage rate: 1.3 E-8 scc/s (NTO)
  5.2E-7 scc/s (MMH)

5.4.2.5.1.3. PRR Propellant Availability

During certain phases in the mission the spacecraft will be required to perform thruster manoeuvres or be spinning in hibernation mode. These AOCS modes have a direct effect on the configuration of the propellant within the tanks since they will generate certain sizes and directions of forces on the propellant. Consequently this affects the amount of propellant available in the PRR. For example during a – Z manoeuvre all propellant in the tanks will move the furthest from the PMDs.

For details of available propellant as a function of accelerations and tank fill level is given in “Functional Performance Analysis”, RO-RIBRE-TN-004.

5.4.2.5.2. Pressure Drop between Propellant Tanks and Thrusters

A worst case estimate of the maximum possible pressure drop due to liquid flow in pipework from the propellant tanks to any one thruster is as follows:

Oxidiser pressure drop ≤ 74 mbar

Fuel Pressure drop ≤ 68 mbar

The results were achieved assuming simultaneous thruster firings of a maximum of five thrusters (6, 9, 10, 11 and 12). See “Rosetta Propulsion Subsystem Pressure Drop Analysis”, RO-MMB-AN-3002 for details.

5.4.2.5.2.1. Propellant Mass Determination

This section summarises the recommended techniques for providing an estimate of the remaining propellant mass at any time during the mission.

There are two methods used for calculating the mass of the remaining propellant:-

(a) Accounting method - this method relies on the knowledge of thruster usage and calibration, together with propellant inlet pressure and temperature, to predict propellant use and hence the mass of propellant remaining.

(b) Thermal Propellant Gauging Technique (TPGT) - this method is based on the fact that if a partially insulated body (the tanks) is heated at a constant rate then, provided that all its material properties are constant with temperature and that the heat lost to the environment is linearly dependant on the temperature difference to the environment, the temperature rise of the body will follow a simple exponential form.

These two methods are described below and include operational constraints where appropriate. For a more detailed description of the two techniques see “Rosetta Propellant Mass Detzermination”, RO-MMB-TN-3124.

Accounting Method

This method requires complete knowledge of all thruster operations, both commanded and autonomous. The consumed propellant mass is determined from the completed thruster duty cycles using influence coefficients that have been derived from ground test data.

Steady state fuel and oxidant flow rates determined using these thruster influence coefficients can then be used to derive propellant consumption. A 1.01% accuracy has been determined for flow rate based upon 0.3% accuracy (full range) for pressure transducers and 1% accuracy for influence coefficients. If the most accurate pressure transducers are used and the uncertainty in the influence coefficients is 1% then the ROSETTA propellant gauging requirement of ± 8 kg can be met for the first 800 kg of propellant use by this accounting method.

Thermal Propellant Gauging Technique

This method is based on the fact that the heat loss from a body is directly proportional to the temperature difference between that body and the surrounding environment.

The technique involves supplying heater power to the tanks for a particular time duration such that a rise in tank temperature is generated. (The times required for this activity may be in the order of 1 to 2 weeks depending on the remaining propellant mass at the time of the test). Ground based software processes change in temperature telemetry (provided by three thermistors located on each propellant tank) to obtain an estimate for remaining propellant mass.

There are four primary conditions that need to be satisfied before a propellant measurement can be made using TPGT:

- The tank temperatures should be sufficiently low to allow the tank to achieve thermal equilibrium without exceeding the maximum allowable tank temperature (40°C) with the tank heaters on.
- Prior to and during this operation no other significant thermal inputs are allowed, i.e no switching of large power consuming devices.
- There must be sufficient time between thruster firings to allow the tanks to achieve thermal stability.
- The total mass of the residual propellant should be such that the resultant measurement accuracy meets (or is close to) the requirements (better than ± 0.5% of initial load)

For details see “Thermal Propellant Gauging Implementation”, RO-MMB-TN-3191 which also identifies opportunities for TPGT.

5.4.2.5.2.2. Residuals

Static Residuals

Static residuals refer to trapped liquid propellant and propellant vapour that cannot be extracted from the propellant tanks or pipework. Estimates for oxidant and fuel static residuals per tank including feed lines are:

HOT CASE: N_2O_4 – 19.1 kg

MMH - 5.9 kg

COLD CASE: N_2O_4 - 11.5 kg

MMH – 5.8 kg

Figure 5-97 shows the variation of static residuals for each propellant tank (including feed lines) with temperature. MMH variations are negligible but N_2O_4 variation is more significant. Oxidant is more sensitive to temperature such that it produces more vapour as temperature increases.

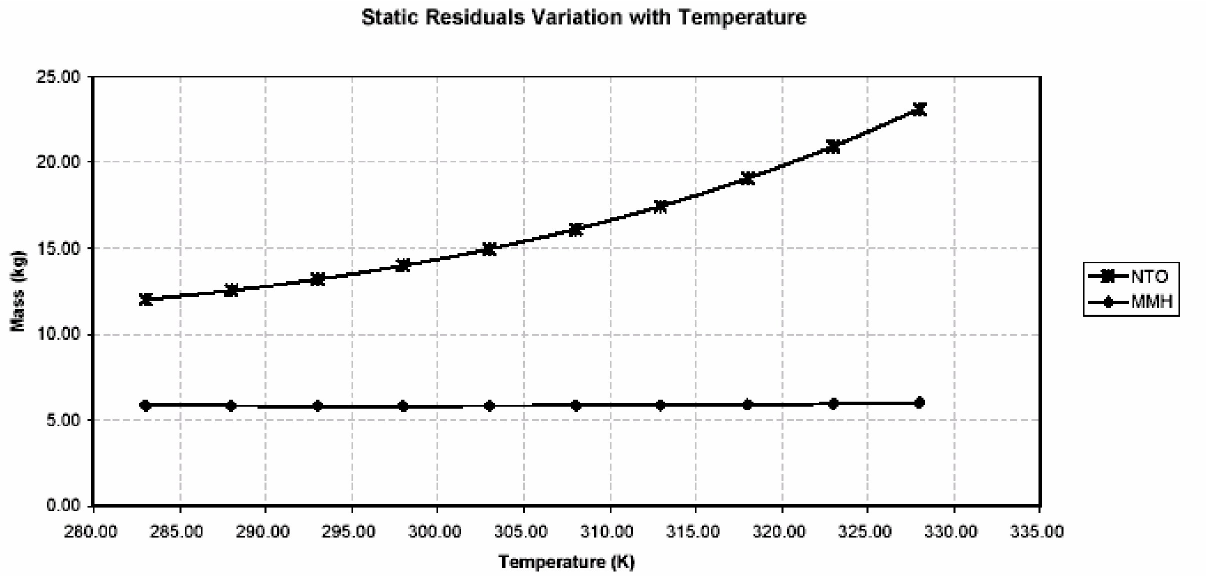


Figure 5-97: Static Residuals per Tank (including feed lines) as a function of temperature

5.4.2.5.3. Dynamic Residuals

Dynamic residuals refer to propellant that cannot be used during the mission due to use of non-optimum mixture ratios. Before launch a loading ratio of oxidant to fuel will have been chosen based on predictions of temperature and other parameters which consequently predict how the mixture ratio will evolve throughout the mission. However, in reality the mixture ratio will fluctuate about this mean mixture ratio during cold and hot phases. During cold phases the pressure in the tanks will drop such that a lower mixture ratio will be delivered to the thrusters. During hot phases the mixture ratio will rise due to the fact that oxidant temperature rises faster than the fuel temperature so creating a pressure difference between the two tanks. However on average the RCS will be required to perform large manoeuvres during cold phases and small manoeuvres during hot phases such that overall the EOL propellant ratio will reflect the BOL propellant ratio. Therefore there will be more oxidant left in the tanks at the end of the mission.

The determination of dynamic residuals is part of the propellant. However an allowance of 5 kg has been assumed in the Pressurisation Strategy Analysis RO-MMB-TN-3185.

5.4.2.5.4. Pressurant Tanks

5.4.2.5.4.1. Description

The RCS comprises two pressurant tanks (supplied by Aerospatiale Matra) whose function is to store helium under high pressure.

This gas will be used to pressurise the propellant tanks when the RCS is in regulated mode .The pressurant tank itself is a carbon filament wound vessel impregnated with resin with a liner made of titanium alloy. Each tank has a volume of 68 litres.

For a detailed unit description please refer to “Pressurant Tank Product Description”, RS CT XXX B DS 001.

There are no heaters required for the pressurant tanks. However there is one thermistor present on the bottom boss (metallic part) of each tank (situated near the outlet) for temperature monitoring throughout the mission. (There is also a thermistor located on pipework 20 cm downstream of each pressurant tank).

5.4.2.5.4.2. Performance Parameters

Pressurised volume = 68 litres

Rate of change of volume with pressure ~ 0.006 litres/bar

Maximum expected operating pressure = 310 bar

Burst pressure = > 800 bar

Helium leakage < 10-6 scc/s at MEOP

Qualification in orbit temperature range = -35°C to 55°C

5.4.2.5.4.3. Operational Constraints

No pressurisation must start at a temperature lower than 18°C.

The maximum temperature reached on the tank during pressurisation must not exceed 45°C.

The minimum temperature reached on the tank during depressurisation must not be < –20°C.

5.4.2.5.4.4. Accommodation

The pressurant tanks are located in cutouts on the -Z floor and attached to the floor using 3 bearings.

The accommodation of the pressurant tanks in the spacecraft is shown in figure 5-95.

5.4.2.5.5. Thrusters

5.4.2.5.5.1. Description

The function of the thrusters (manufactured by Astrium GmbH) is to provide the Delta V capability, pure forces, attitude and orbit correction torques required to maintain the Rosetta spacecraft on its planned mission trajectories. The thrusters are bipropellant

devices which have the capability of operating in steady state and pulse modes in regulated and blow down modes (see section 1.6).

The thruster design incorporates a latch valve upstream of the existing single seat flow control valve to provide the capability to isolate each thruster individually. This latest evolution is also being qualified for the next generation of Spacebus and Eurostar platforms, as well as Mars Express.

Each thruster consists of a redundant bipropellant valve (itself comprising an upstream bistable latch valve and downstream normally closed flow control valve), a coaxial vortex injector assembly and a combustion chamber with nozzle. Both units are physically and operationally independent of each other but share essentially identical designs, with differences being limited to slightly different torque motor set-up parameters and the inclusion of a microswitch for position indication of the latch valve. In both units the fuel and oxidiser flow is controlled simultaneously by one actuating device, therefore eliminating the possibility of timing errors between parallel flow paths for the fuel and oxidiser. Each flow path incorporates a poppet and seat for simple and reliable flow control, which share a common mechanical link to the torque motor armature in order to achieve simultaneous operation.

The coaxial vortex injector promotes propellant atomisation and mixing as well as the cooling film at the wall chamber. The propellants are injected into the combustion chamber by two coaxial swirl atomisers, where a portion of the fuel droplets establishes a very thin and continuous cooling film on the chamber wall to prevent local hot spots. Such hot spots limit the overall combustion rate which in turn degrades the resultant performance.

The combustion chamber and the expansion nozzle are manufactured as a single part from platinum/rhodium 90/10 alloy thus eliminating the need for any coating and welded to the injector. The expansion ratio of the nozzle is 150:1 and the exit is stiffened by a machined ring to prevent deformation during hot firing.

A filter is incorporated in both the fuel and oxidiser inlet ports of each thruster assembly to protect the valves and thruster from seat damage, valve blockage or injector clogging. A side view of the thruster identifying the major elements is presented in Figure 5-98.

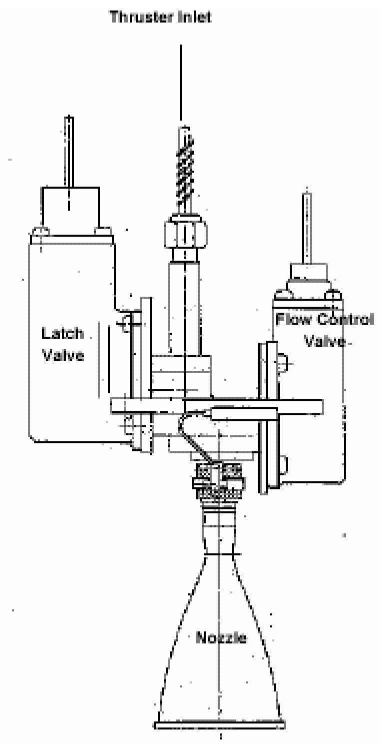


Figure 5-98: Side view of dual valve thruster

For a detailed thruster description see “10 N Thruster Design Description for EUROSTAR 3000”, 003 TN 030-02.

5.4.2.5.5.2. Thermal hardware

On each thruster there is a HW/SW prime and redundant heater situated on both MMH and NTO valves. For each thruster module (consisting of a prime and redundant thruster), all prime heaters are connected together by one power line and likewise for all redundant heaters. Regarding thermistors, there is one prime and one redundant thermistor on each MMH valve i.e 2 prime and 2 redundant thermistors per thruster module.

Each thruster itself has an internal thermistor (Heraeus PT200) which measures the thruster chamber temperature.

5.4.2.5.5.3. General Performance Parameters

The key performance parameters of the thrusters are:

- Nominal thrust level = 10N ±0.2N (all thrusters)
- Maximum Expected Operating Pressure (MEOP 1) = 20 bar
- MEOP 2 = 61 bar
- Nominal operating pressure range = 11.5 to 18 bar bar see figure 5-97
- Thrust level range = 7.4 to 11.7N (steady state)
- Nominal flow rate = 3.50g/s
- Flow Rate Range = 2.6 to 4.1g/s
- Nominal Mixture Ratio = 1.525
- Mixture Ratio Range =1.2 to 2.1
- Nominal Chamber Pressure = 9 bar
- Specific Impulse > 285.4s (all thrusters)
- Total burn time = 44 hours per thruster
- Longest single burn (steady-state) = 12.2 hours (per thruster)
- External leakage from valve assembly upto closed FCV < 1x10E-6scc/sec
- External leakage downstream of FCV < 1 x10E-4 scc/s of helium
- Internal leakage across seat < 3 x10E-4 scc/s of helium
- Operating temperature range = 0°C to 45°C

5.4.2.5.5.4. Electrical Characteristics

- Nominal operating voltage range (Rosetta) = 25 to 28 V
- Overvoltage = 32 Vdc (for one minute).

- Power consumption < 3.5 W (per motor at 28Vdc @21°C).
- FCV coil resistance = 242 ±10 Ohm at 21°C.
- LV coil resistance = 345 ± 35 Ohm at 21°C.
- Microswitch coil resistance < 1.0 Ohm.
- FCV coil inductance >250 mH at 21°C.
- LV coil inductance > 250mH at 21°C.
- Insulation resistance > 100 Mohm at 21°C.
- LV and FCV Pull-in voltage > 22 V dc.
- FCV drop out voltage > 3 Vdc.
- Nominal thermistor output = 200 Ohms at 0°C.
- FCV, opens < 10ms and closes< 2ms.
- LV open and close response at 28 Vdc < 20ms (activating pulse duration = 50 – 100ms)

5.4.2.5.5.5. External Interfaces

The AIU (AOCS Interface Unit) provides the following interfaces to each of the 24 thrusters:

- Latching Valve Open driver (LVO) to open the isolation valve.
- 1 Latching Valve Close driver (LVC) to close the isolation valve.
- 1 Flow Control Valve driver (FCV) to command the valve.
- 1 thruster Latching Valve Status channel (LVS) to report the open/closed status of the LV.
- 1 thruster thermistor conditioning channel (ANT) to monitor the temperature of the thruster chamber.

5.4.2.5.5.6. Thruster Accommodation

The 24 thrusters are grouped in pairs of two, one of each pair being the main and one the redundant one. The nominal thruster coordinates and thrust axis directions with respect to the spacecraft axes are given in table 5-52 and are shown in figure 5-99. The combinations of thrusters to produce directional forces and torques are shown in table 5-53.

Thruster	Co-ordinates in S/C axes			Direction Cosines w.r.t S/C axes			Thrust
	X	Y	Z	X	Y	Z	
1A	-1231.9	-1139.5	2176.8	0.4698	0.8660	-0.1710	10
2A	1231.9	-1139.5	2176.8	-0.4698	0.8660	-0.1710	10
3A	-1231.9	-1139.5	-84.252	0.4698	0.8660	0.1710	10
4A	1231.9	-1139.5	-84.252	-0.4698	0.8660	0.1710	10
5A	1231.9	1139.5	-84.252	-0.4698	-0.8660	0.1710	10
6A	-1231.9	1139.5	-84.252	0.4698	-0.8660	0.1710	10
7A	1231.9	1139.5	2176.8	-0.4698	-0.8660	-0.1710	10
8A	-1231.9	1139.5	2176.8	0.4698	-0.8660	-0.1710	10
9A	-1160	-903	-199.2	0.0000	0.0000	1.0000	10
10A	1160	-903	-199.2	0.0000	0.0000	1.0000	10
11A	1160	903	-199.2	0.0000	0.0000	1.0000	10
12A	-1160	903	-199.2	0.0000	0.0000	1.0000	10
Thruster	Co-ordinates in S/C axes			Direction Cosines			Thrust
	X	Y	Z	X	Y	Z	
1B	-1238	-1150.9	2101.9	0.4698	0.8660	-0.1710	10
2B	1238	-1150.9	2101.9	-0.4698	0.8660	-0.1710	10
3B	-1238	-1150.9	-9.371	0.4698	0.8660	0.1710	10
4B	1238	-1150.9	-9.371	-0.4698	0.8660	0.1710	10
5B	1238	1150.9	-9.371	-0.4698	-0.8660	0.1710	10
6B	-1238	1150.9	-9.371	0.4698	-0.8660	0.1710	10
7B	1238	1150.9	2101.9	-0.4698	-0.8660	-0.1710	10
8B	-1238	1150.9	2101.9	0.4698	-0.8660	-0.1710	10
9B	-1160	-827	-199.2	0.0000	0.0000	1.0000	10
10B	1160	-827	-199.2	0.0000	0.0000	1.0000	10
11B	1160	827	-199.2	0.0000	0.0000	1.0000	10
12B	-1160	827	-199.2	0.0000	0.0000	1.0000	10

Table 5-52: Table of Thruster coordinates and corresponding thrust cosine directions

Composite Manoeuvre Type	Thruster Combinations
+ Fx	1A, 3A, 6A, 8A / 1B, 3B, 6B, 8B.
- Fx	2A, 4A, 5A, 7A / 2B, 4B, 5B, 7B.
+ Fy	1A, 2A, 3A, 4A / 1B, 2B, 3B, 4B.
- Fy	5A, 6A, 7A, 8A, / 5B, 6B, 7B, 8B.
+ Fz	9A, 10A, 11A, 12A / 9B, 10B, 11B, 12B.
- Fz	1A, 2A, 7A, 8A / 1B, 2B, 7B, 8B.
+ Tx	1A, 3A, 6A, 8A / 1B, 3B, 6B, 8B.
- Tx	2A, 4A, 5A, 7A / 2B, 4B, 5B, 7B.
+ Ty	1A, 4A, 5A, 8A / 1B, 4B, 5B, 8B.
- Ty	2A, 3A, 6A, 7A / 2B, 3B, 6B, 7B.
+ Tz	2A, 4A, 6A, 8A / 2B, 4B, 6B, 8B.
- Tz	1A, 3A, 5A, 7A / 1B, 3B, 5B, 7B.

Table 5-53: Table of thruster combinations for composite manoeuvres

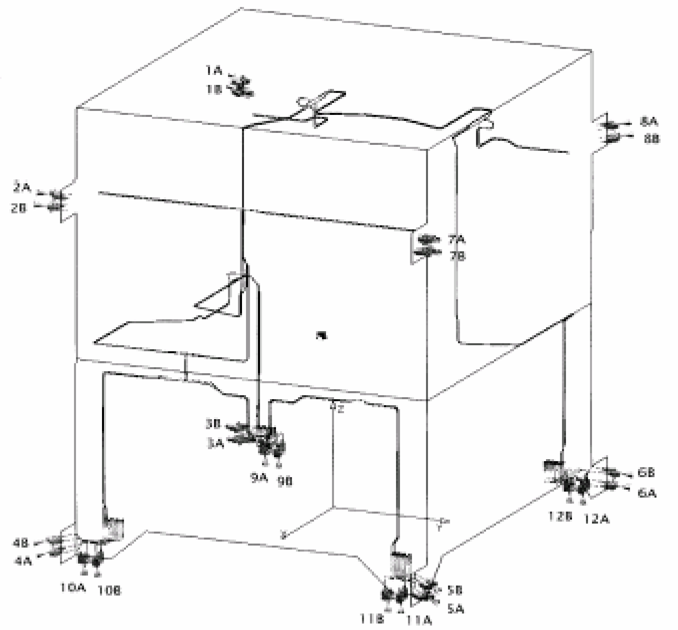


Figure 5-99: Accommodation of Thrusters

5.4.2.5.5.7. Thruster Operation

The thrusters must only be operated when the propellant tank pressures lie within the allowable thruster operating area called the thruster pressure box. Figure 5-100 shows the required operating pressure box for the Rosetta thrusters.

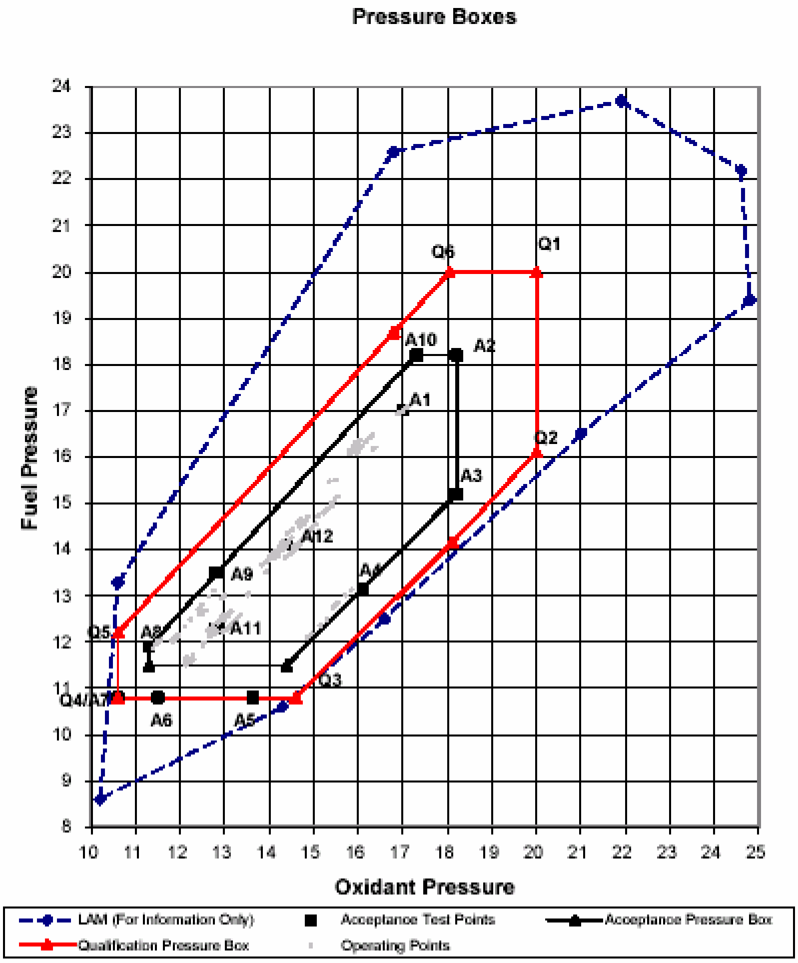


Figure 5-100: Required thruster operating box

5.4.2.5.6. Pyrotechnic Valves

5.4.2.5.6.1. General Description

Two types of pyro valves are used in the RCS, normally closed gas (16 of) and liquid (4 of) pyro valves (see figure 5-101) and normally open gas pyro valves (12 of) (see figure 5-102). The type of pyro valve reflects the initial status before actuation. Each pyro valve includes a dual initiator for redundancy, the initiator in turn detonating a secondary explosive booster charge. All pyro valves are manufactured by Conax. In the case of a normally closed pyro valve, initiation forces a ram to push on a shear notch which blocks the flow path. This permanently opens the flow path connecting upstream and downstream volumes. In the case of a normally open pyro valve, initiation forces a cutter blade (attached to the end of the ram) to move forward and block the flow path. The flow path is then permanentlyclosed.

Both the normally open valves and normally closed gas valves are used in high and low pressure applications within the pressurant supply system. The liquid normally closed pyro valves are used within the propellant feed lines. All pyro valves are operated via the power subsystem but commanded by the DMS (Data Management System).

For a detailed unit description please refer to “CONAX Technical Proposal for Model 1832-205”.

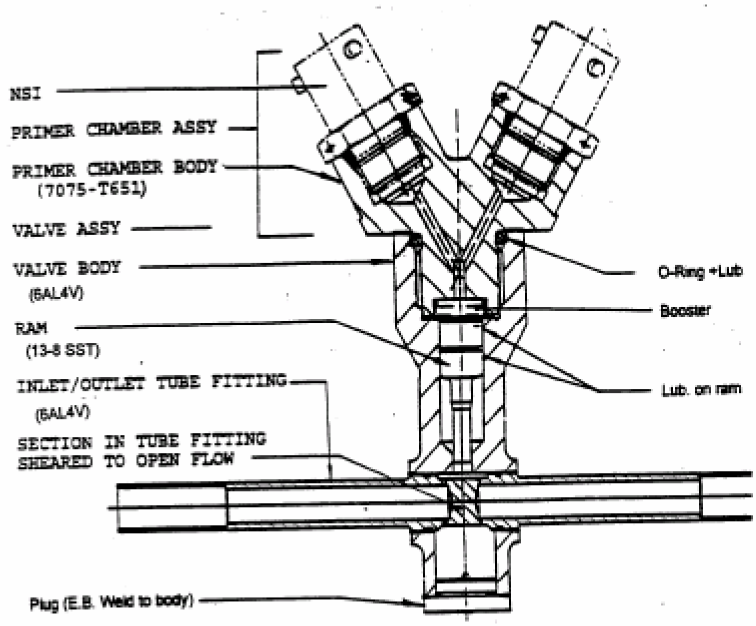


Figure 5-101: Cross section through Normally Closed Pyro Valve

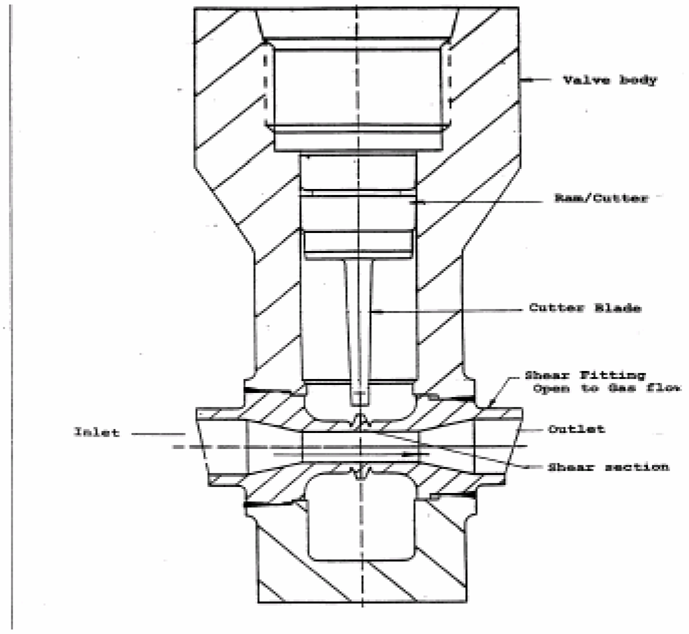


Figure 5-102: Normally Open Pyro Valve

5.4.2.5.6.2. Performance Parameters

The key performance parameters of the pyrotechnic valves are:

- Maximum expected Operating Pressure: 310 bar
- Max Proof Pressure (1.5 x MEOP) : 465 bar
- Min Burst Pressure (4 x MEOP): 1240 bar
- Firing qualification temperature range : -30°C to +50°C
- No firing qualification temperature range: -60°C to 60°C
- Pressure drop: 0.008 bar at 0.033g/s @ 24 to 310 bar
- Pre-fire external leakage, < 1.0 x10-6 scc/s @ 210 bar for 6 mins
- Post –fire external and internal leakage < 1.0 x10-6 scc/s @ 210 bar for 6 mins
- Minimum recommended firing current : 4.0 A
- Response Time: 5 ms (max)
- Nominal supply voltage = 22.0 to 27.0 Vdc
- Max supply voltage = 42.5 Vdc

5.4.2.5.6.3. Thermal hardware

Normally open pyro valves 3, 4, 7, 8, 9 and 10 each have one dedicated heater. If during regulation mode regulator 1 fails then it is necessary to check the temperature of pyros 7 to 10 before firing them (which consequently initiate regulator 2). Again it is necessary to check the temperature of pyros 3 and 4 before they are fired during regulation 2.

5.4.2.5.6.4. Operational Constraints

Before a sequence of pyro valve firing for each operational mode begins, the following pre-requisites apply for the S/S-PDU:

- TM power is switched on for TM buffering i.e buffer is on for storing firing currents.
- Pyro group arm, bus and battery power lines are disabled.
- Pyro buffers are reset.

The bus is not used as a main energy source but intended as a back-up source in case both batteries fail. Each pyro is fired separately to reduce excess shock loads. As each pyro is fired the main initiator will be fired first followed by the redundant initiator.

There are 8 main and 8 redundant pyro buffers in the S/S-PDU. Each buffer stores the firing current profile for one pyro. If a pyro fails there may be a need to access this current telemetry. However since only eight buffers are available it is necessary to reset the buffers before a ninth pyro is fired. For each RCS operational mode there is a maximum of 6 pyros valves which are fired. Therefore, before the start of each operational mode e.g regulation or isolation, the buffers must be reset but will not need to be reset again unless there is a regulator failure which means 6 more pyros are fired.

5.4.2.5.6.5. External Interfaces

The pyrotechnic valves are interfaced with the power subsystem as shown in Figure 5-103. Memory Load Commands (MLC) from the DMS operate various relays within the network of power interface lines so as to fire the pyros in a sequenced manner. The status of each MLC including the firing current TM is relayed from the PDU to the DMS via the S/S-RTU. The pyro electronics comprise a number of components which together control pyro firing. Input power switches are used to select the power input source; battery 1 or 2 (connected to main side of PDU) or main bus with back-up energy source. The redundant side is supplied by battery 3 and battery 2 (shared with the main side of the PDU) or the main bus power. The back-up energy source comprises a bank of capacitors which store energy and is sized to support the main bus during the pyro firing functions. Protection devices limit the recharging current between the main power bus and the capacitor bank and also the maximum current drawn from the main power bus during pyro firing. Reverse blocking diodes (2 in series) protect the different energy sources. Nominal and redundant current limiters

(LCL N and LCL R) in series limit the maximum firing current to the required current level (4.5 to 6.0A) in normal operation and also in the event of a short circuit in a pyro circuit (6.0A max). An Arm switch selects the output group and provides safety protection. The pyro circuit to be fired is selected via selection relays. They provide an antistatic resistor connection over the pyro circuit when non-activated. The current measurement function allows to sample and A/D convert the pyro firing current. MLC interfaces carry ON/OFF commands to the power selection switches, arm and pyro selection relays. They are also used for pyro firing. Each MLC command is cross-coupled from nominal and redundant sides. Relay status interfaces provide the status of the relays.

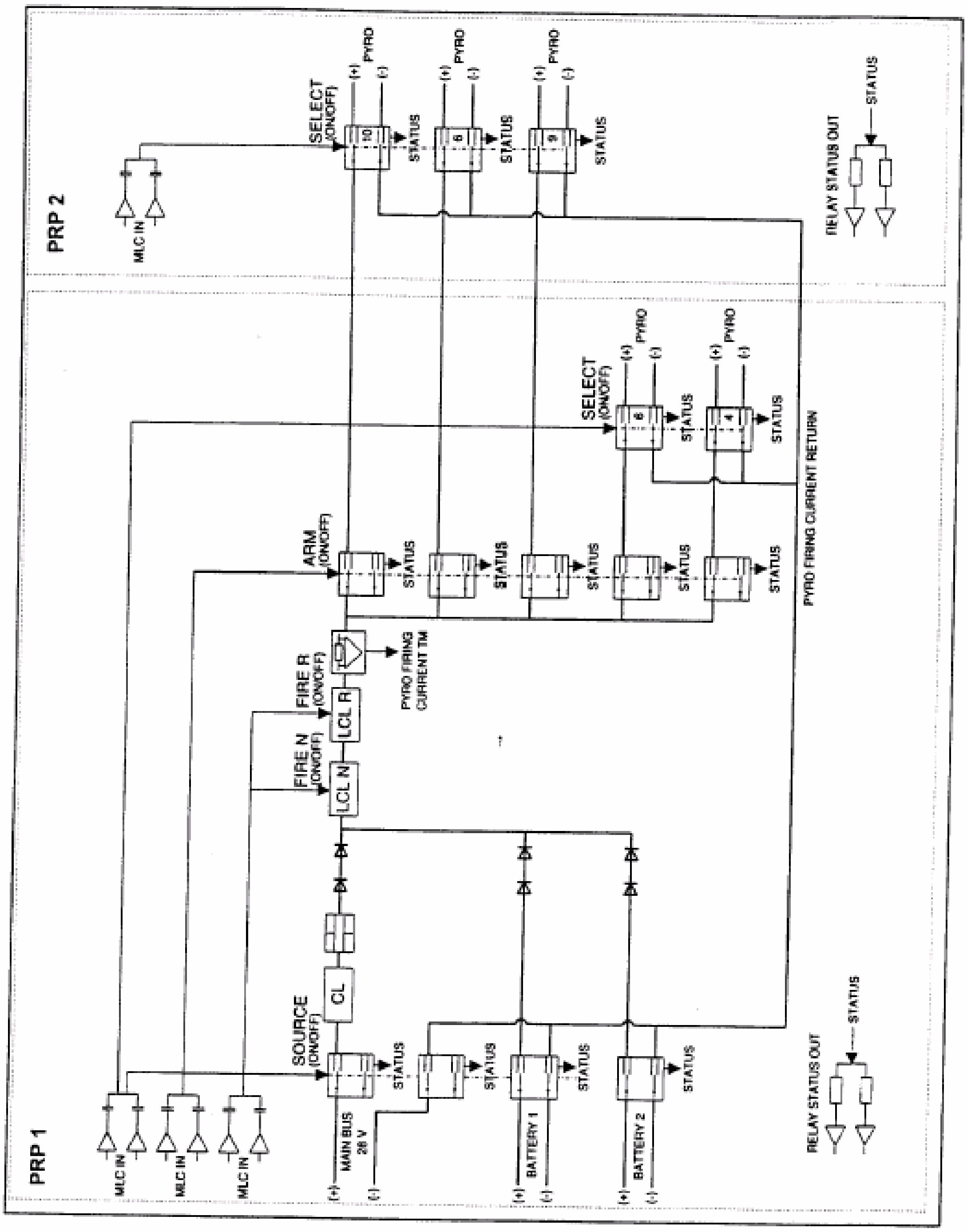


Figure 5-103: Functional Block Diagram of Pyrotechnic valves

5.4.2.5.7. Pressure Transducers

5.4.2.5.7.1. Functional Description

Pressure transducers (manufactured by Snecma Moteurs) are used to monitor the pressures in the propellant and pressurant feed lines. The pressure transducer is an all welded titanium design which uses a detector subassembly to translate pressure information into an electrical signal via a series of strain gauges that are bonded to the surface of the sensitive element.

The RCS utilises two types of pressure transducer. One type monitors the pressurant helium high pressure gas supply and is designed to operate in the pressure range 0 to 300 bar. The other type monitors the propellants pressure (low pressure) and is designed to operate in a pressure range 0 to 22 bar. Each pressure transducer is fitted with a thermistor to monitor temperatures.

Pressure transducers PT 5 and 6 are provided downstream of the filters to measure the thruster inlet pressure. These transducers will be used for thruster performance prediction and hence propellant gauging. PT 1 and 2 monitor pressures in the high pressure lines from the pressurant tanks. PT 3 and 4 measure pressures at the propellant tank inlets and provide back-up for PT 5 and 6.

The accuracy of the pressure transducers is nominally 0.7% of full scale, however, for the Rosetta application this is improved to 0.3% by the addition of a thermistor mounted on the transducer body to allow uncertainties due to thermal drift over the operational temperature range to be compensated.

5.4.2.5.7.2. Performance Parameters

The key performance of the pressure transducers are:-

- Pressure range of low pressure PT = 0 to 22 bar
- Pressure range of high pressure PT = 0 to 300 bar
- HP operating temperature range = -15 to +40°C
- LP operating temperature range = - 30 to 40°C
- Output voltage error = ±0.3%
- Input Voltage =26.0 to 28.5 VDC
- Typical calibrated accuracy ± 0.066bar for low pressure units
  ± 0.9 bar for high pressure units
- Maximum output signal = 5V (based on HP linear scale factor = 16.667mV/bar

5.4.2.5.7.3. External Interfaces

The AIU provides the following interfaces for powering the pressure transducers and receiving pressure and temperature telemetry.

- 6 x Power supply outputs (TPS)
- 6 x Analogue inputs for transducer analogue pressure signals (TAP)
- 6 x conditioned analogue inputs for the PT thermistor acquisition (TAC)

See Figure 5-93 which illustrates these interfaces with the AIU.

5.4.2.5.8. Fill and Drain Valves (FDV) and Fill and vent Valves (FVV Fill)

5.4.2.5.8.1. Functional Description

The purpose of the fill and drain valves (FDV) is to allow the connection of ground support equipment to the subsystem for filling with simulants and propellants, draining and pressurisation. Fill and vent valves (FVV) are provided to facilitate pressure testing and set pressures in various sections prior to launch. Both FDVs and FVVs are located at the –Z edge of the lower +X panel for easy access.

The fill and drain/vent valve design has two parts. The flight half coupling (FHC) which forms part of the propulsion subsystem configuration, and the ground half coupling (GHC) which forms part of the ground support equipment used to service the subsystem. The FHC and GHC form the leak tight interface between the propulsion subsystem and the ground support equipment for loading and off-loading pressurant, simulant and propellant.

The major elements of the FHC are the titanium body, the stainless steel actuating shaft and the ceramic ball. The stainless steel actuating shaft is used to open and close the valve, and is operated by the GHC when it is connected.

Both the FHC and GHC designs are identical with the exception of the different thread size and form on the FHC body and GHC coupling nut, of which there are five different types corresponding to:-

- Type T1 – NTO LP Liquid (M18 x 1.5 LH)
- Type T2 – NTO LP Gas (M16 x 1.5 LH)
- Type T3 – MMH LP Liquid (M18 x 1.5 RH)
- Type T4 – MMH LP Gas (M16 x 1.5 RH)
- Type T5 – He HP Gas (11/16-16-UN RH)

The different threads ensure that the GHC can only be connected to the corresponding FHC of the same type, thus preventing incorrect loading or off-loading of pressurant, simulant or propellant.

All FDVs and FVVs are supplied by Raufoss Technology. For a detailed unit description please refer to “Raufoss Design Description” GFDVV-CF-823168-811-RAU.

5.4.2.5.8.2. Performance Parameters

The key performance parameters of the FDVs and FVVs are

- External Leakage rate (cap on) < 1 x 10^{-6} scc/hr Helium

5.4.2.5.9. Filter

5.4.2.5.9.1. Functional Description

The propulsion subsystem comprises 2 low pressure propellant filters and 4 high pressure helium filters (used in both high and low pressure locations), all manufactured by VACCO Industries. The propellant filters are panel mounted and the helium filters pipe mounted. Their function is to filter the propellants and helium to prevent contamination from flowing into thruster manifolds, regulators & non-return valves. The filters are also required to prevent contamination of the RCS when filled with simulant fluids, cleaning fluids and purging gases.

Both types are all titanium designs with the filtration achieved through the use of a stack of chemically etched discs stacked on top of one another. The filtration is achieved as the propellant flows between the discs, from the circumference towards the centre, through the passages that are chemically etched onto the surfaces of the discs. The resulting design has high strength and is insensitive to migration of constituents, a problem that can compromise performance in mesh type filters.

For a detailed unit description please refer to VACCO Technical Proposal, A98-0433, Rev A.

5.4.2.5.9.2. Performance Parameters

The key performance parameters of the filter are:

- Absolute filtration rating (liquid) = 40 microns
- Absolute filtration rating (gas) = 25 microns
- Pressure drop for clean filter: Propellant < 0.016 bar

  Pressurant < 0.05 bar
- Pressure drop for dirty filter (propellant only) and with the following mass of AC course dust absorbed:

  0.75g – 0.26 bar max

  1.00 g – 0.40 bar max

5.4.2.5.10. Pressure Regulator

5.4.2.5.10.1. Functional Description

The double regulator is used to control the pressure level of the propellant tanks by regulating the pressure of the helium gas which flows through it. The RDS 2000 regulator, supplied by Aerospatiale, comprises two single regulators. Regulator 1 has a pressure set point of 17 bar and regulator 2, 17.5 bar. Both regulators have valves which are assembled in series. When regulator 1 is used (nominal mode) the valve of regulator 2 is constantly open. The valve of regulator 1 will only open if the pressure in the downstream pipework (from regulator outlet to oxidant and fuel tanks) is lower than 17 bar. The valve of regulator 1 will only close when the pressure in this downstream pipework reaches 17 bar indicating that the tanks have been pressurised to 17 bar. If the valve of regulator 1 fails open, regulator 2 will automatically take over, regulating the passing helium gas to 17.5 bar instead of 17 bar.

To protect the internal mechanisms of the regulator from particle contamination, a 10 micron filter is included in the valve inlet. To protect the regulator from reverse flow contamination during testing, a second 10 micron filter is included in the valve outlet. Although the regulator is internally redundant, a second regulator is provided in parallel to the nominal regulator for unit redundancy.

5.4.2.5.10.2. Performance Parameters

The key performance parameters of the regulator are:

- Inlet MEOP range = 310 to 22 bar
- Inlet proof pressure (1.5 x MEOP) = 465 bar .
- Inlet burst pressure (4 x MEOP) > 1240 bar
- Outlet MEOP = 22 bar
- Outlet Proof pressure (1.5 x MEOP) = 33 bar
- Outlet burst pressure (4 x MEOP) > 88 bar
- Primary regulator pressure set point = 17 bar
- Secondary regulator pressure set point= 17.5 bar
- Nominal flow rate range = 0 to 0.6g/s
- Entrance flow limit = 12 g/s
- External leak < 10-6 cm3 /s
- Qualification temperature = -30 to 50°C

5.4.2.5.10.3. Thermal Hardware

There are no heaters attached to the regulators. One thermistor is attached to each regulator and there is also a thermistor located on pipework 20 cm downstream of each regulator outlet.

5.4.2.5.10.4. Operational Constraints

During isolation the inlet pressure must drop to approximately 70 bar (to prevent leakage through regulator outlet) but not below 50 bar before firing pyros in lines below regulator outlet.

5.4.2.5.11. Non Return Valves (NRV)

5.4.2.5.11.1. Functional Description

The Non-Return Valves (supplied by Polyflex Aerospace Ltd) are implemented into the RCS to prevent the uncontrolled interaction of MMH and N_2O_4.under all operating conditions. The valve permits flow in a single direction only, allowing the passage of helium gas into the propellant tanks for pressurisation. In the reverse direction, the back flow of highly reactive propellant vapours is blocked, preventing any subsequent combustion. Whilst preventing reverse fluid flows the NRVs must also minimise the forward flowing pressure loss of helium during pressurisation of the tanks. There are 8 NRVs located in downstream pipework between the regulator outlets and propellant tank inlets.

5.4.2.5.11.2. Performance Parameters

The key performance parameters of the non-return valves are:

- MEOP = 22.5 bar
- External leakage (He) = 1 x 10^{-6} scc/s
- Internal (reverse) leaking < 2.5cc/hr at any reverse pressure differential between 0 and MEOP
- Max expected flow rate at MEOP (40°C to –60°C) = 0.026g/s to 0.039g/s.
- Max. pressure drop for range of flow rates < 0.014 bar differential

5.4.2.6. Subsystem Operations Modes

5.4.2.6.1. Introduction

The Rosetta RCS has the following operational modes:

- **Launch Phase**
  Prior to launch the propellant tanks are pressurised at 13 bar The thruster latch valves are open and the propellant lines down stream the tanks to the thrusters are pressurised to 3 bar.
- **Venting /priming**
  Liquid lines between propellant tanks and thrusters are vented by opening flow command valves (FCVs) on thrusters. These liquid lines are then primed (filled with propellant) by initiating normally closed pyro valves.
- **Regulation**
  The tanks are regulated to 17 bar as pressurant gas is allowed to flow through the prime regulator. Two regulations are executed during the mission.
- **Blow down**
  Pressurant gas is isolated from the propellant tanks at launch by normally closed pyro valves and subsequently by initiating normally open pyro valves. There are three blow down phases throughout the mission.

5.4.2.6.2. RCS Operational Mode Descriptions

5.4.2.6.2.1. Launch

Prior to launch the tanks are pressurised to 13 bar, the propellant lines to the thrusters are 3 bar and all thruster latch valves are open. Initial post separation manoeuvres are performed with the system in blow down.

5.4.2.6.2.2. Venting / Priming

Venting and priming are initialised autonomously. Before venting the thrusters, LVS telemetry is used to check that the latch valves are open. In order to vent the thrusters, all FCVs are opened for 2 minutes by FCV commands from the AIU. During venting the line pressures on PT 5 and PT 6 decrease from 3 bar and stabilise to 0 bar. This normally takes around 2 minutes. The FCVs and subsequently the TLVs are closed after 3 minutes.

After venting has been completed the liquid lines are primed by propellant which involves firing a selection of pyros in sequence.

Before any pyros are fired the Pyro buffers are reset such as to record firing currents. The NTO liquid lines are primed first by firing normally closed pyro valves 23 and 24. Normally closed pyro valves 25 and 26 are then fired to prime the MMH liquid lines.

PT 5 and 6 should identify a pressure increase in these liquid lines from 0 to 13 bar (the end pressure might be slightly less than 13 bar due to pressurant absorption into propellant during launch). The TLV are opened for 10 seconds.

5.4.2.6.2.3. Regulation

Two regulations occur during the mission and are initiated via different pyrotechnic valves:

Regulation 1

Before any pyros are fired the Pyro buffers are reset. First PVNC 12, 13,18 and 19 are fired (in this order). This unblocks the pressurant lines between the regulator outlet and each tank. 10 minutes later, PVNC 2 is fired followed by PVNC 32. This allows high pressure helium to pressurise the pressurant pipework down to the regulator inlet. Since the pressure below the regulator is less than17 bar (primary regulator pressure set point) the main regulator valve will be open and pressurises the tanks. During pressurisation the regulator will allow pressurant gas to flow through it until each tank is pressurised to 17 bar. Pressure transducers 1 to 6 will be used to monitor pressure change characteristics throughout this regulation initialisation period.

This sequence of pyro firing minimises the possibility of over pressurisation of the downstream regulator pipework due to the delay in the regulator closing.

Regulation 2

Before any pyros are fired the Pyro buffers are reset. First PVNC 14, 15, 20 and 21 are fired (in this order). This re-opens the pressurant lines between the regulator outlet and each tank. (Immediately after PVNC 14A has been fired, PT 2 will record a rapid drop in pressure from approximately 50 bar, PT 3 and 5 should stabilise to ~11 bar). 10 minutes later PVNC 3 is fired followed by PVNC 4. This allows high pressure helium to pressurise the pressurant pipework down to the regulator inlet. (PT1 will record a drop in pressure whilst PT2 will record an increase). Since the pressure below the regulator is less than 17 bar the regulator will be open and will pressurise the tanks. During pressurisation the regulator will allow pressurant gas to flow through it until each tank is pressurised to 17 bar. PT1 to PT6 are used throughout the pressurisation process to monitor pressure change characteristics.

5.4.2.6.2.4. Blow down

Blow down refers to a scenario when the pressurant gas is isolated from the pressurant tanks. The RCS then operates in blow down, pressurised by the helium present in the propellant tanks at the time of the isolation. Within the mission there are three phases when the RCS operates in blow down. These are:

Blow down phase 1 - before regulation 1

Blow down phase 2 - after regulation 1 before regulation 2

Blow down phase 3 - after regulation 2 until end of mission

Blow down Phase 1

Prior to launch the tanks are pressurised to 13 bar and therefore any post separation manoeuvres are performed in blow down from 13 bar.

Blow down Phase 2

Before any pyros are fired the Pyro buffers are reset. PVNO 31 is fired first followed by PVNO 1. This isolates the regulator from the pressurant tanks. PT 2 is used to check that the pressure falls between the pyro valves and regulator inlets. When the pressure falls to approximately 70 bar but not less than ~ 50 bar, normally open pyro valves 11, 27, 28 and 17 are fired in order. This may involve waiting a few days or performing X thruster firings in order to reduce the pressure to ~ 50 bar. This simultaneously isolates NRVs 3, 4, 7 and 8 and prevents mixing of propellant vapours in the common pressurant pipework.

Blow down Phase 3

This phase begins after the completion of RVM-1 in regulated mode. Again all Pyro buffers are reset before any pyro is fired. PVNO 5 is fired first followed by PVNO 6. This isolates the regulator inlet from the pressurant system to prevent downstream over pressurisation during the remainder of the mission. PVNO 16, 29, 22 and 30 are then fired in order. This simultaneously isolates NRVs 1, 2, 5 and 6 and prevents mixing of propellant vapours in the common pressurant pipework.

5.4.2.6.3. Nominal Pressurisation Strategy

At launch the tanks are pressurised to 13 bar. Up until the first regulation, the RCS will operate in blow down mode. If a launch correction manoeuvre (first delta-V) is required the tanks will be pressurised to 17 bar prior to this event. If no correction manoeuvre is required then this first regulation is delayed until the Mars gravity assist phase and can cover either the approach manoeuvres to Mars (TCM-3 &4) or DSM-1 (after Mars fly-by) depending on the mission scenario. (The RCS then returns to blowdown). Prior to the deep space hibernation test, the RCS will enter blow down mode operating from 17 bar pressure. The RCS remains in this second blow down phase until RVM-1. Prior to this manoeuvre the RCS is regulated for the second and last time. Before entering Deep Space Hibernation Mode (DSHM) the tanks are isolated. The RCS operates in blow down mode until the end of the mission.

For details of the pressurisation strategy see “Pressurisation Strategy Analysis”, RO-MMB-TN-3185.

5.4.2.6.3.1. Pressurisation Strategy Drivers

When deciding the above strategy the following points were taken into consideration:

- The propulsion design allows for two regulated phases.
- It is preferable that the tank pressures be maintained above 10.5 bar for operation of the thrusters.
- It is preferable that the RCS should not be in regulated mode when the spacecraft is not visible from the ground and that the duration of regulated phases be minimised.

The start of the first regulation phase is determined by the time of the first mission delta-V manoeuvre. In the case where a launch correction manoeuvre is required, regulation should be performed immediately after spacecraft acquisition. It is then necessary to return to blowdown, as the proceeding manoeuvre is the DSHM test (an unregulated case). If no launch correction is required then the first regulation can be delayed until the Mars fly-by phase. If this is further delayed then the tank pressures will drop too low such that they exceed the limit of the thruster operating pressure. To keep the duration of the delayed regulation phase to a minimum (i.e < 40 days in regulated mode) the regulated phase can cover either the Mars approach manoeuvres or DSM-1.

Depending on the magnitude of the delta-V required for the launch correction manoeuvre (max is predicted to be 195 m/s) it may not be necessary to regulate at this point in the mission. When making this decision it should be checked that the pressures do not fall too low as to jeopardise others manoeuvres leading up to delayed initial pressurisation.

Whether a launch correction manoeuvre is required or not the second regulation is required immediately prior to RVM-1. Moving this regulation until later in the mission can lead to two situations depending on the mission scenario:

- unacceptably low pressures for operation of the thrusters during RVM-3
- unacceptably high pressures during the comet observation phase

If the initial tank load was 120% and no launch correction is required then the tanks have low pressure prior to the second regulation.This is due to low ullage volume at the end of the first regulated phase. A combination of an extra 20% propellant mass and the requirement for no launch correction manoeuvre produce this small ullage. Consequently during blow down, the pressure falls faster dropping to < 10.5 bar before the second regulation takes place. This case also results in low pressures being seen during the comet rendezvous manoeuvres.

For hot spacecraft cases during the comet observation phase the mixture ratio (oxidant mass : fuel mass) reaches 1.90. Because the mixture ratio is at the limit to what the thruster is qualified to, the thrusters could under-perform. Consequently RVM-1 cannot be executed with a good accuracy. The large mixture ratio is due to a large shift in temperature as the comet moves from deep space and approaches the Sun. The oxidant tank sees a greater temperature shift than the fuel tank and has a higher vapour pressure such that there is a pressure imbalance between the two tanks and therefore a high mixture ratio results. In order to minimise the effect the oxidant tank temperature is limited to 45°C.

The limit to how long the 2nd regulation could be delayed would be up to just before rendezvous manoeuvres 1-4. This is since the tanks pressures would have dropped well below 10.5 bar (after RVM-1) and would not be able to deliver the large delta-V required for rendezvous (1110m/s). Depending on predictions for tank pressure evolution, only some or none of the 4 RDVMs could be executed in regulated mode. If the RDVMs were all regulated at 17 bar then the tank pressure would proceed to increase greatly. This is caused by the rise in spacecraft temperature as the spacecraft nears the sun and all payloads are switched on for comet operations. Consequently the tanks would reach MEOP (19.3 bar) and may rupture if this pressure exceeds 29.25 bar (burst pressure).

Figure 5-104 and 5-105 illustrate how the tank pressures evolve over the mission for the hot thermal case with no launch correction and launch correction respectively.

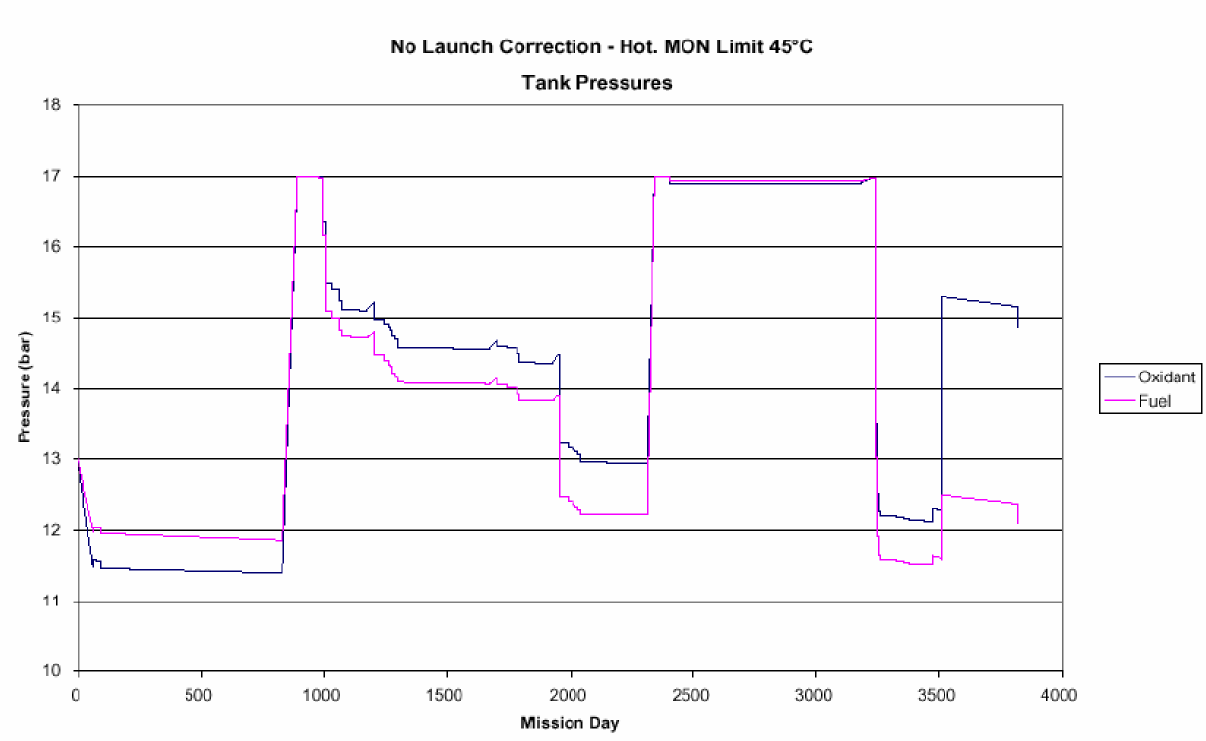


Figure 5-104: Predicted Pressure Evolution – Hot Case, no launch correction

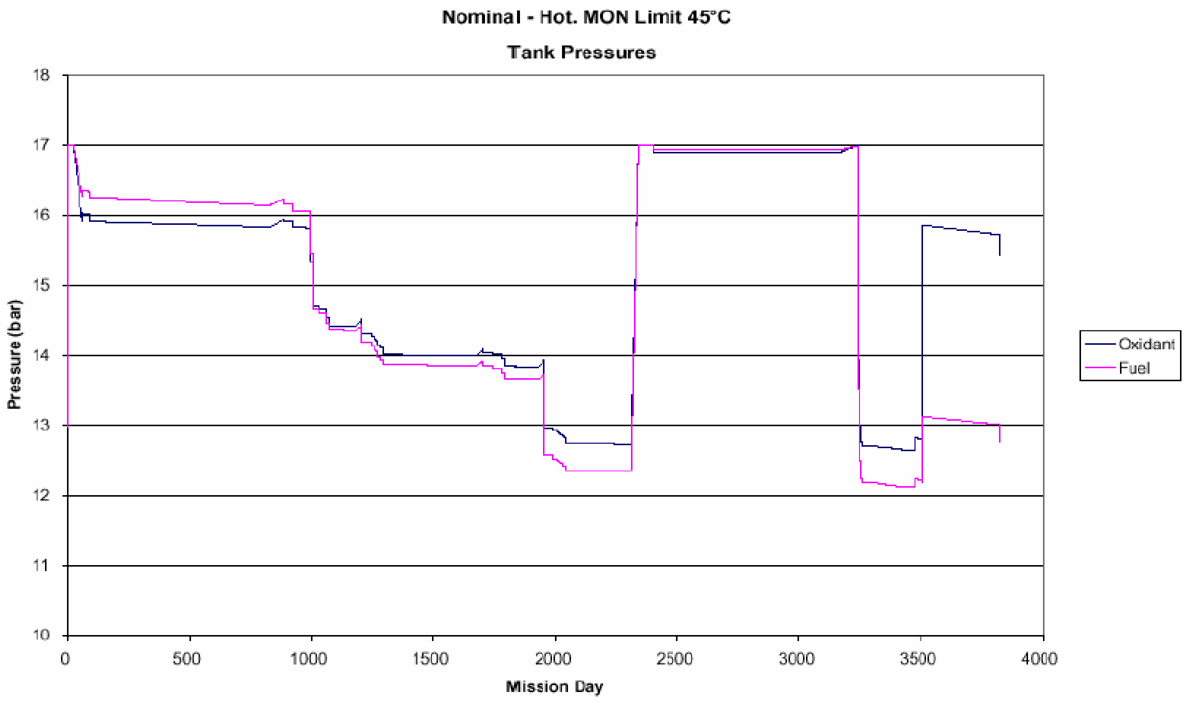


Figure 5-105: Predicted Pressure Evolution – Hot Case, with launch correction

5.4.3. Structure Subsystem

5.4.3.1. Design Overview

The Rosetta structure consists of two modules, the Bus Support Module (BSM) and the Payload Support Module (PSM) which have been designed to be handled separately to facillitate parallel integration activities in light of the tight schedule constraints of the Rosetta program. The PSM includes the Lander Interface Panel (LIP) which is removable to facillitate the Lander integration.

The Bus Support Module **(BSM)** accommodates most of the platform and Avionic equipment.

The BSM structure consists of the Central tube, the Internal deck, the +Y/-Y shear webs, the +X shear web, the –x shear webs (Lander webs), and the lander support shelf. These elements form the spinal structure

In addition to spinal structure parts the BSM module includes the panels below the internal deck on y sides and on – x side, and the three panels forming the whole +X wall. Two access doors on -X side and four upper thruster panels belong to the BSM.

Sixteen internal struts are applied to support unit I/F's and panels and to control the global behaviour of the structure. The BSM structure is shown in Figure 2-11 and the BSM structure elements are identified in Table 5-54

ref. to 2-11	PT id	Panel
1	B11AA	Central tube
2	B11AB B11AB01 B11AB02 B11AB03	Internal deck +x/+y panel +x/-y panel -x panel
3	B11AE10	BSM +x panel, upper
4	B11AE20	BSM +x panel, middle
5	B11AE30	BSM +x panel, lower
6	B11AF	BSM –x panel
7	B11AC	BSM +y panel
8	B11AD	BSM –y panel
9	B11AH	BSM +x web
10	B11AN	BSM –x webs
11	B11AL	BSM +y web
12	B11AM	BSM –y web
13	B11AS B11AS03 B11AS04	BSM Access doors BSM –X/-Y Access door BSM –X/+Y Access door
14	B11AP	BSM lander support shelf

Table 5-54: Bus Support Module items

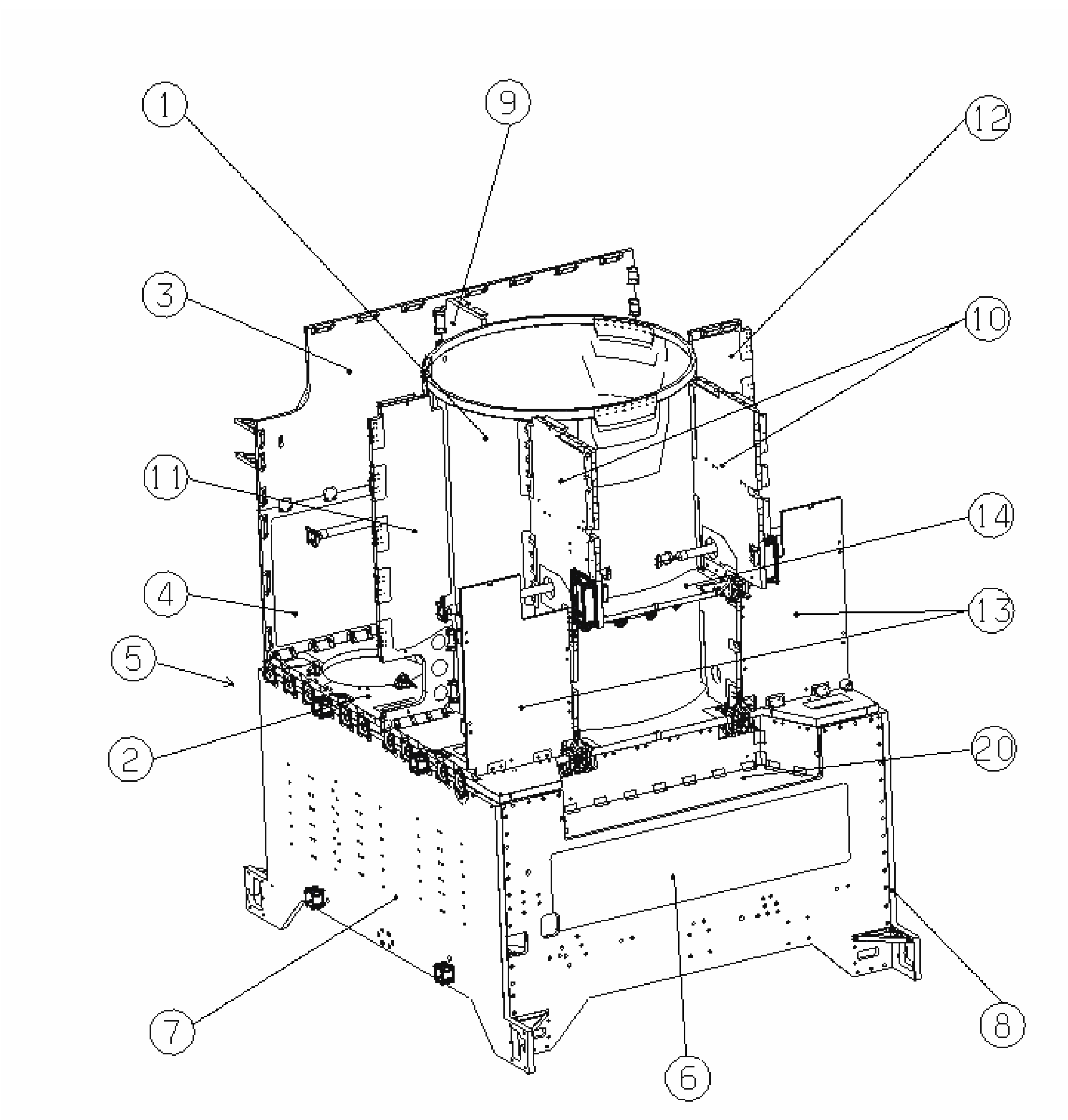


Figure 5-106: Bus Support Module Structure

The Payload Support Module (PSM) accommodates all science equipment.

The PSM structure consists of the PSM +z-panel, the PSM –x panel, the PSM +y/-y panels and the Lander Interface Panel (LIP) as described in Figure 5-107.

The PSM +Z-, -X, and ±Y-panels form a structure that can be handled as an independent module (PSM). The Lander Interface Panel is a separate part.

The structure panels are identified in Table 5-55.

Ref. to Figure 5-107	PT id	Panel
15	B11BA	PSM +z panel
16	B11BB	PSM -x panel
17	B11BC	PSM -y panel
18	B11BD	PSM +y panel
19	B11BF	Lander Interface Panel (LIP)
21		Thruster panels

Table 5-55: PSM Structure Panel

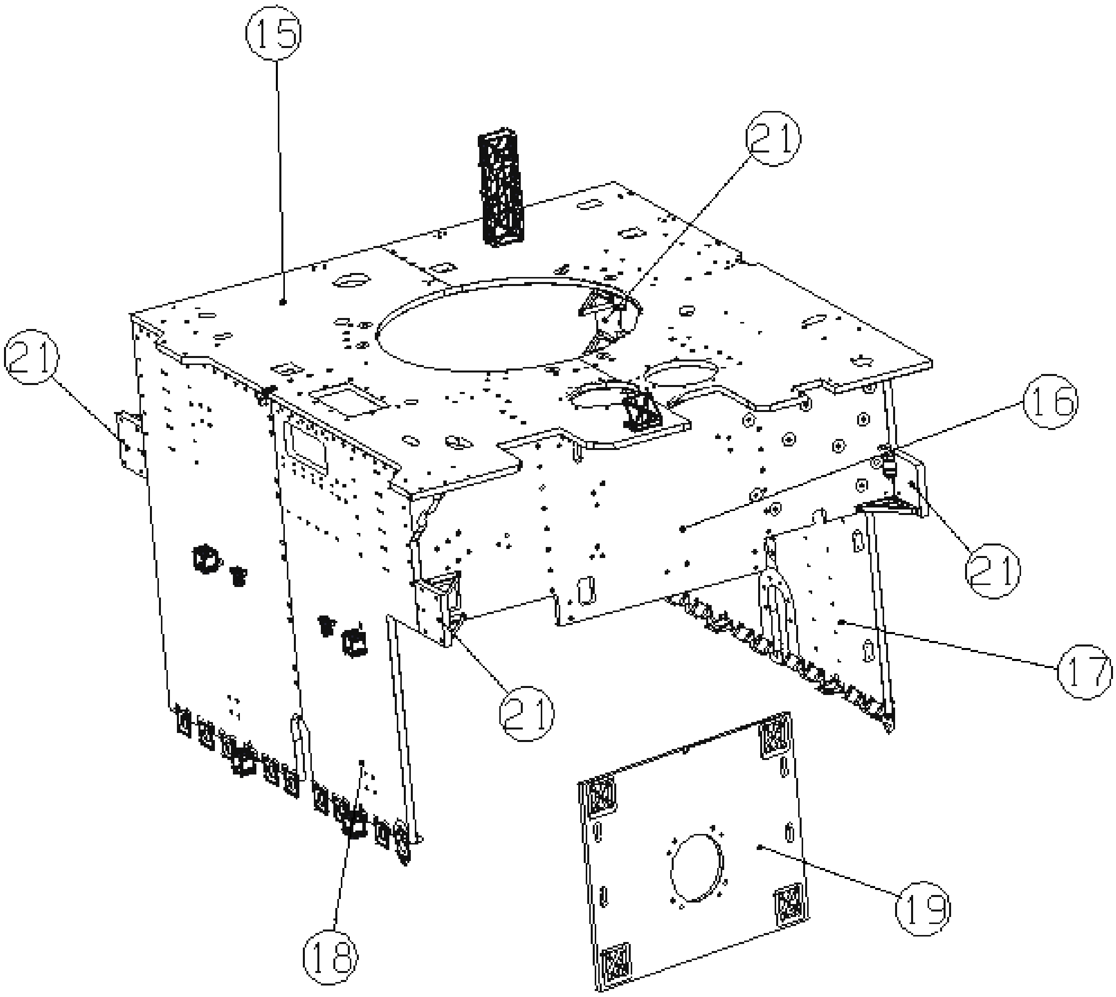


Figure 5-107: Payload Support Module Structure

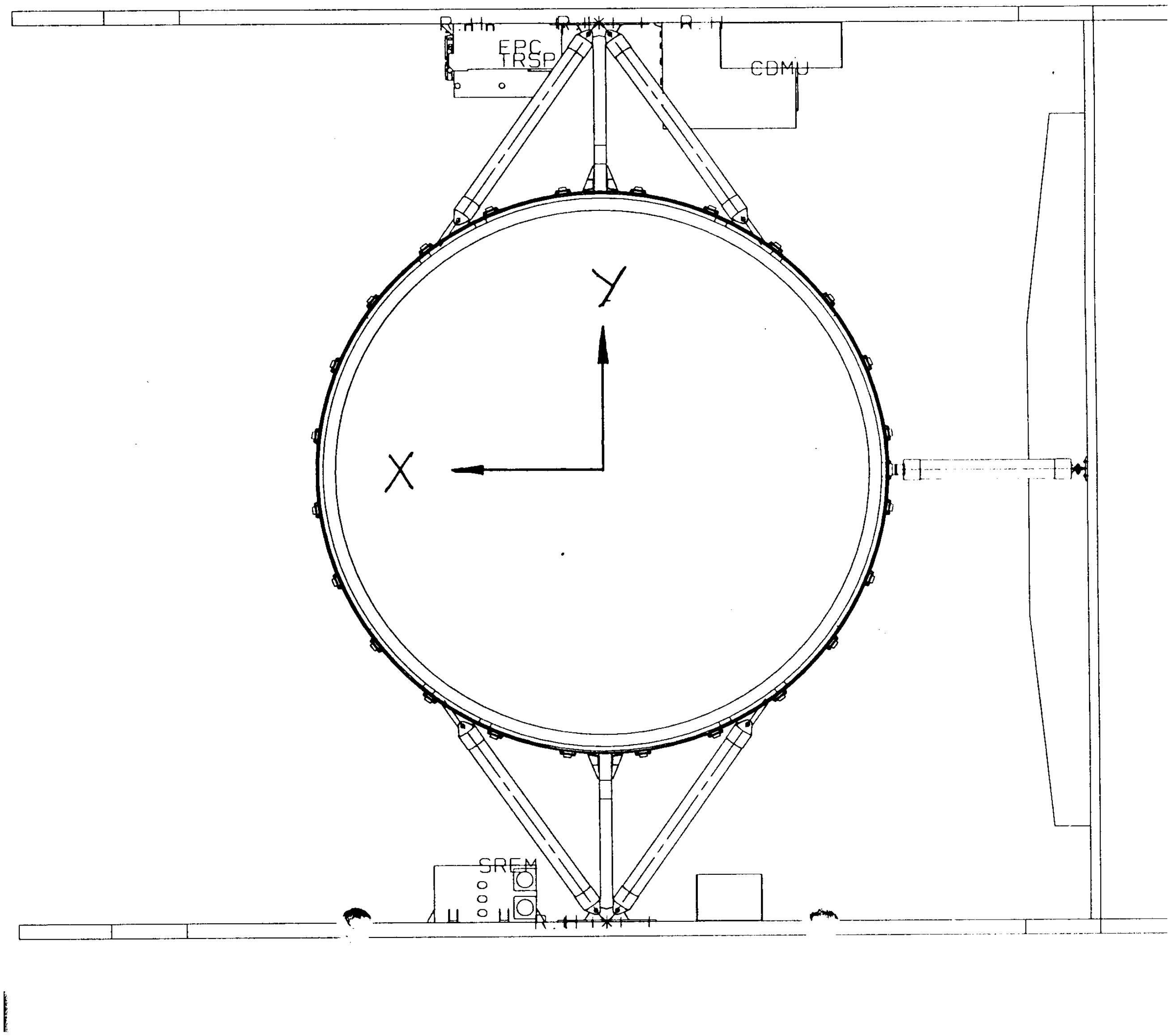


Figure 5-108: View of Additional Support Struts at base of spacecraft

5.4.4. Solar Array

The Rosetta solar array mechanical and thermal design is closely based on a proven rigid panel array design currently used on a number of Geostationary Earth orbit satellites. The electrical design also has heritage from the same proven arrays, but the photo voltaic cells are a new design in order to generate adequate power at the low light intensity and temperature experienced at the aphelion of the Rosetta mission.

Each wing (2 wings are needed for Rosetta) basically comprises 5 cell-bearing panels and a “yoke”, hinged together and to the interface bracket which mounts the array to a drive mechanism. During launch phase, the wing assembly is folded concertina-style and retained close to the spacecraft Y wall by 6 hold down devices. When release and deployment is required, redundant thermal “knives” are activated which thermally degrade a pre-tensioned Kevlar cable in each hold down. Upon fracture of all 6 hold-down cables, a system of springs, a damper mechanism, pre-tensioned cables and pulleys cause the yoke and panels to unfold in a controlled, manner until fully extended. At this time, latches engage at each hinge line to prevent the wing folding up during spacecraft manoeuvres. Flexible, flat cable assemblies transfer the generated power from the outer panels to a conventional harness on the yoke, and to connectors at the drive mechanism interface bracket. A sun sensor is mounted on the inboard edge of the 3rd panel to facilitate pointing of the solar cells towards the sun. When the array is stowed on the spacecraft body, the outer panel has its cells facing outwards, allowing power to be generated before full array deployment.

Each panel is a composite made of locally stiffened carbon fibre skins and aluminium honeycomb core. Carbon fibre edge members provide stiffness at edges where hinges are attached. Titanium alloy cylindrical fittings are assembled into the panels at the hold down positions to resist the clamping forces of the hold down cables during launch, and to ensure the required gap between the stowed panels so that they do not self-degrade during the launch vibration environment. The hold down brackets contain the thermal knife assemblies and attach the stowed array onto the spacecraft body by means of spacer brackets to ensure the correct offset of the array from the spacecraft. The yoke is made of carbon fibre filament wound tubes. These are attached to the main hinge which mounts the entire array to the drive mechanism on the spacecraft. This hinge also supports the eddy-current deployment damper assembly and the connectors used to transfer power from the array to the spacecraft. Snubber brackets ensure that the yoke is partly restrained by the spacecraft body in order to relieve the loading on the hinges on the first panel. The hinges are of aluminium alloy with a stainless steel shaft and low-friction material between the moving surfaces.

The solar cells are a Silicon LILT design, isolated from the panels by a Kapton layer. There are 2314 cells per panel , giving a coverage density of 88.2% allowing for implementation of ESD protection and blocking diodes (mounted to the rear of the panel). The cells are in 26 strings of 89 cells wired in series using silver wires and soldered connections. The harness is enclosed in a braided shield to protect against ESD. The maximum power generation per panel is 580W at 1AU. Thermistors allow to monitor the temperature of critical zones of the panels. Redundant microswitches are mounted on the main yoke hinge to signal full deployment and latching of the array.

5.4.5. Mechanisms

5.4.5.1. SADM

The detailed design description for the SADM is provided in RO-KDA-DD-3001, an overview is given below.

5.4.5.1.1. SADM Design Overview

The Solar Array Drive Mechanism is based on a stepper motor driven pinion that drives the solar arrays through a crown wheel/shaft assembly. The shaft is supported by a pair of preloaded ball bearings. The power and signal harness is located centrally in the shaft and connected to a ±180° twist capsule. An optical encoder, located near the bearings, is utilised for position sensing.

The SADM stepper motor has a motor step angle of 30°. With an overall gear ratio of 2600:1 then the size of a single step of the solar array is 0.0115°. The motor has a large torque capability (about 83 Nm) since the same motor is also used for the Antenna Pointing mechanism.

The SADM can rotate by approx ±180°. There are end-stops to prevent the SADM rotating beyond this point. The SADM motor receives its instructions from the SADE.

The position of the SADM is obtained from an optical encoder. The encoder measures absolute position and provides 16 bit resolution. The telemetry lsb is therefore approximately 0.0055°. It can be noted that one motor step is approximately equal to 2 encoder bits.

The major components are listed below and shown in the exploded views Figure 5-109a, Figure 5-109, Figure 5-110 and Figure 5-111:

- Thermal Washer
- S/A connecting flange
- Main Bearing
- Inner Mandrel (shaft)
- Optical Encoder
- Stepper Motor
- EMC-shield
- Twist Capsule
- Base Plate
- Outer Shell (Housing)

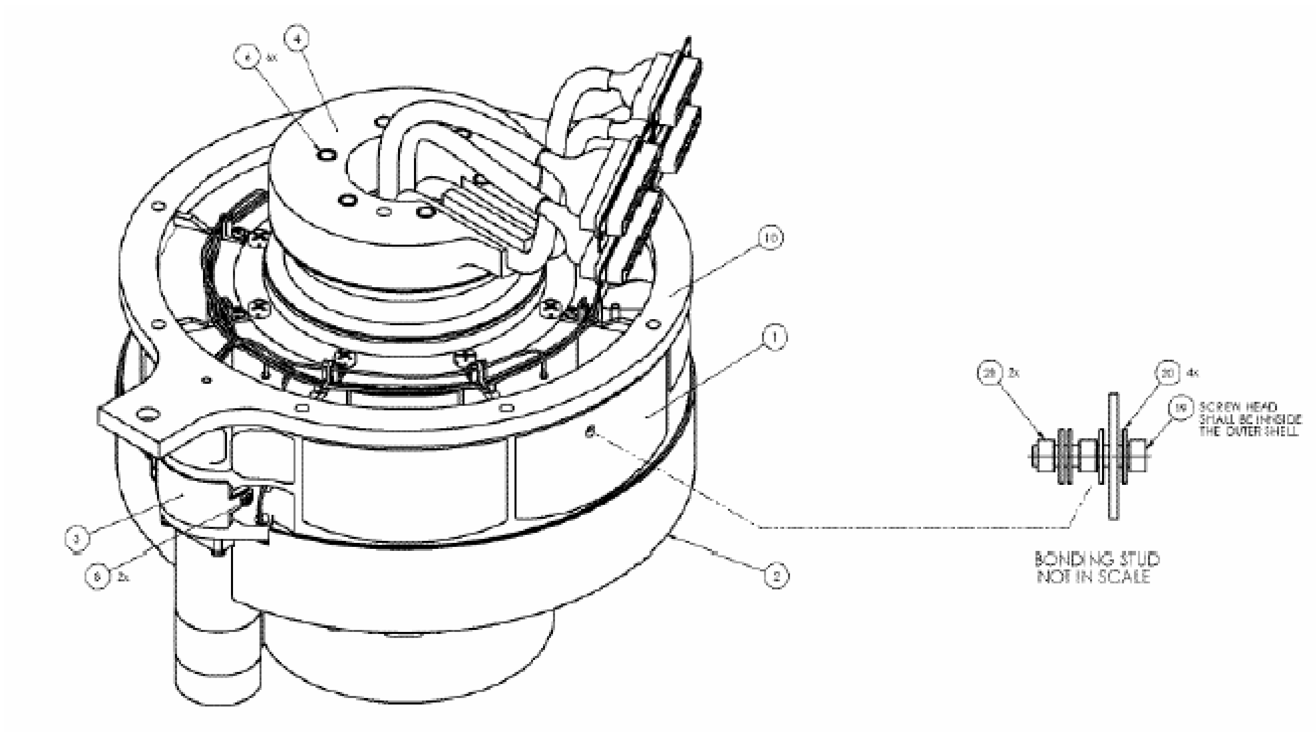


Figure 5-109a: Isometric view of SADM

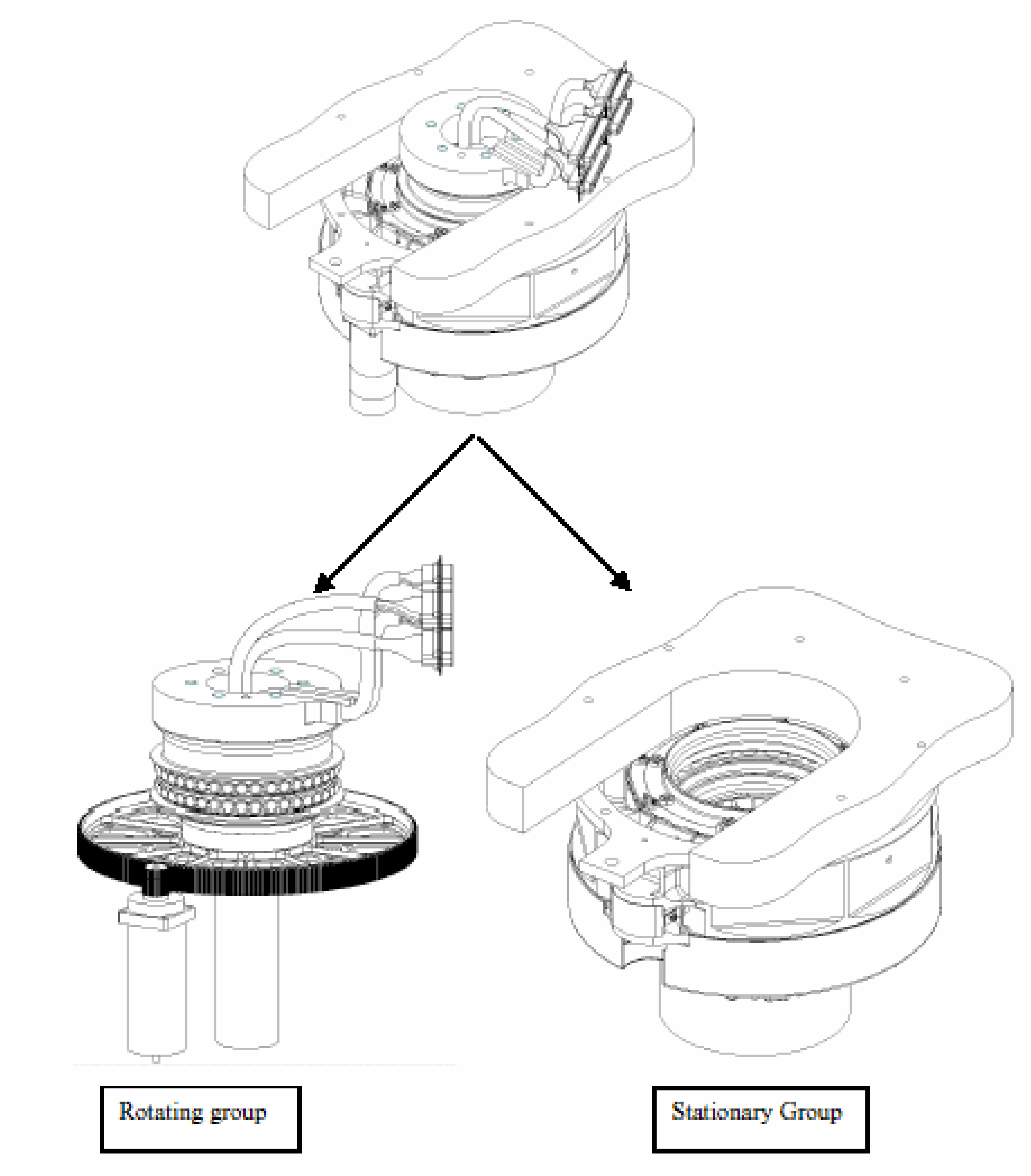


Figure 5-109: Rosetta SADM stationary and Rotating Groups

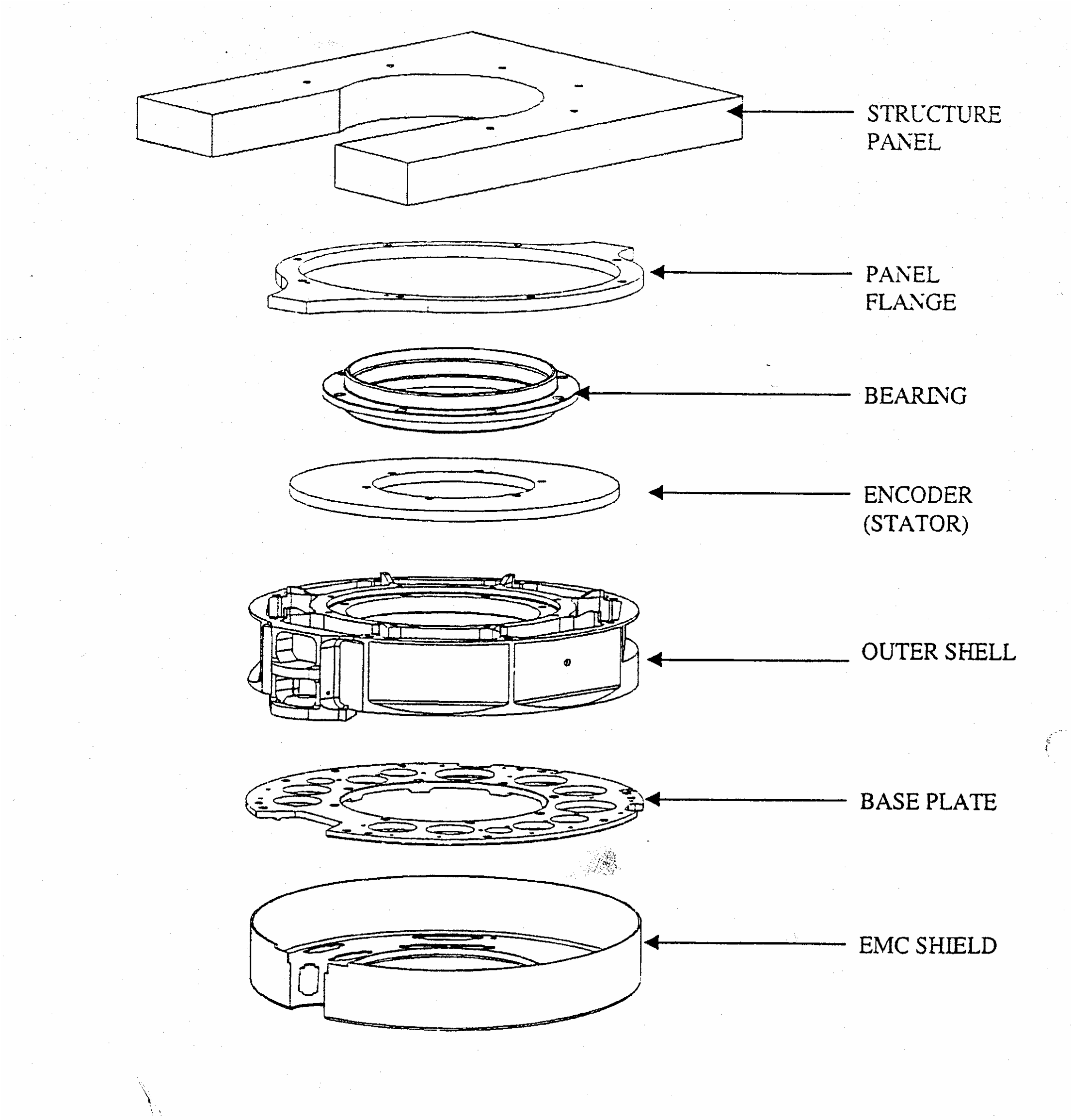


Figure 5-110: SADM Stationary Parts

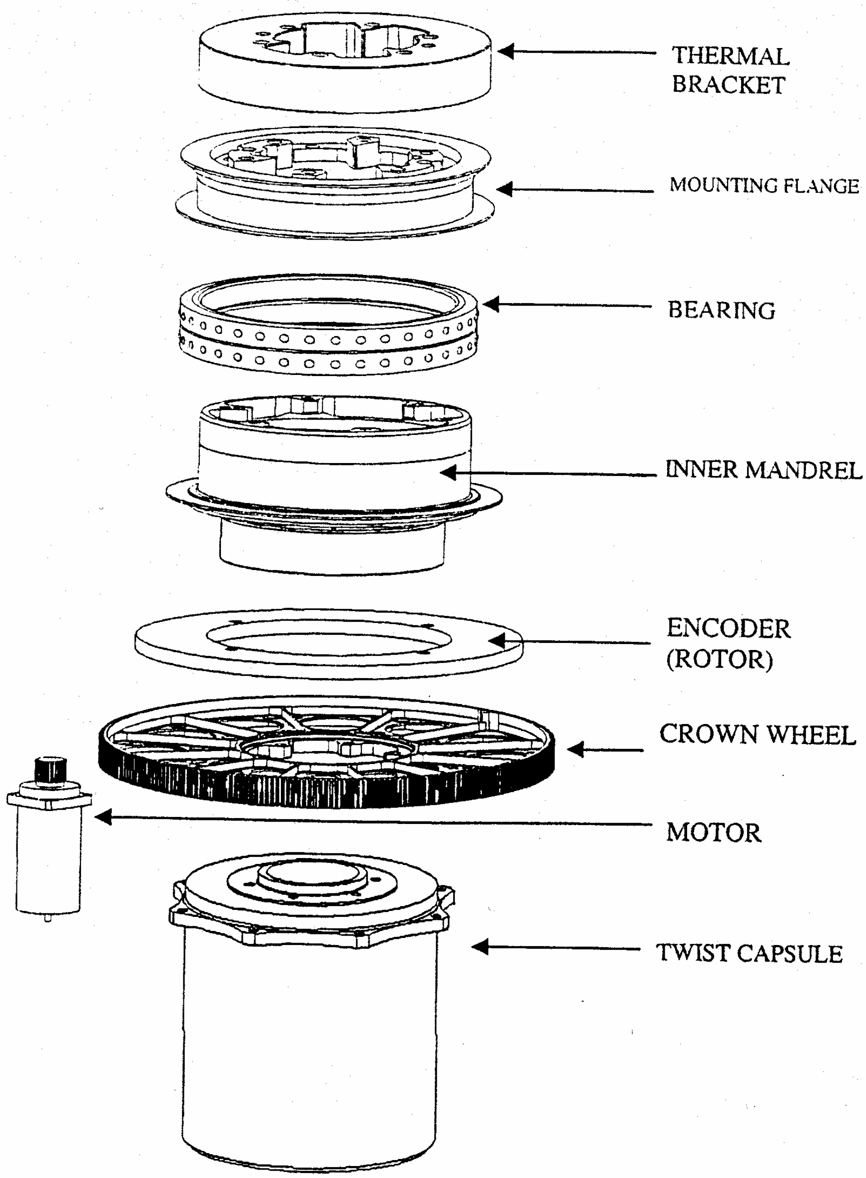


Figure 5-111: SADM Rotating Parts

5.4.5.1.2. Interfaces

There are two independent SADM units, each controlled from one SADE. All electronic functions are redundant. The SADE comprises two identical units, the nominal and redundant. All connectors on both SADE and SADM are D-SUB types.

Metallic backshells are required on the harness between SADE and SADM. Connector locations can be seen in Figure 5-109a.

The SADMs are attached to the +Y and –Y spacecraft walls using six M5 screws. The electrical interface to the spacecraft is located on the outside of the SADM, inside the spacecraft Y wall, while the electrical interface to the solar array is located on a connector bracket on the solar array hinge. The twist capsule transfers power and signals from the solar array to the spacecraft.

The SADE has several electrical interfaces, which include power, MACS bus, TM/TC, and thermistor interfaces. These are described in the SADE EICD

5.4.5.2. HGA Antenna Pointing Mechanism

See §5.4.6.4

5.4.5.3. HGA Antenna Holddown and Release Mechanism

See §5.4.6.3

5.4.5.4. Rosetta experiment booms

The detailed design for the Rosetta Experiment Booms is provided in RO-SEN-TN-3501, an overview is given below:

5.4.5.4.1. Boom Design Overview

The general functions of the Rosetta Experiment Booms are:

- to support the experiments in stowed configuration during launch.
- to deploy the boom in-orbit, to a defined position.
- to maintain this deployed configuration during the whole mission.

There are two different booms:

- Upper Payload Boom (UPL), which supports the Mutual Impedance Probe (MIP) and one Langmuir Probe (LAP).
- Lower Payload Boom (LPB), which supports the two Fluxgate Magnetometer (MAG 1 and MAG 2) and one Langmuir Probe (LAP).

The booms are located on the -X wall of the spacecraft. There location can be seen in Figure 5-112a. Figures 5-112b/c/d show the booms in stowed and deployed configurations respectively.

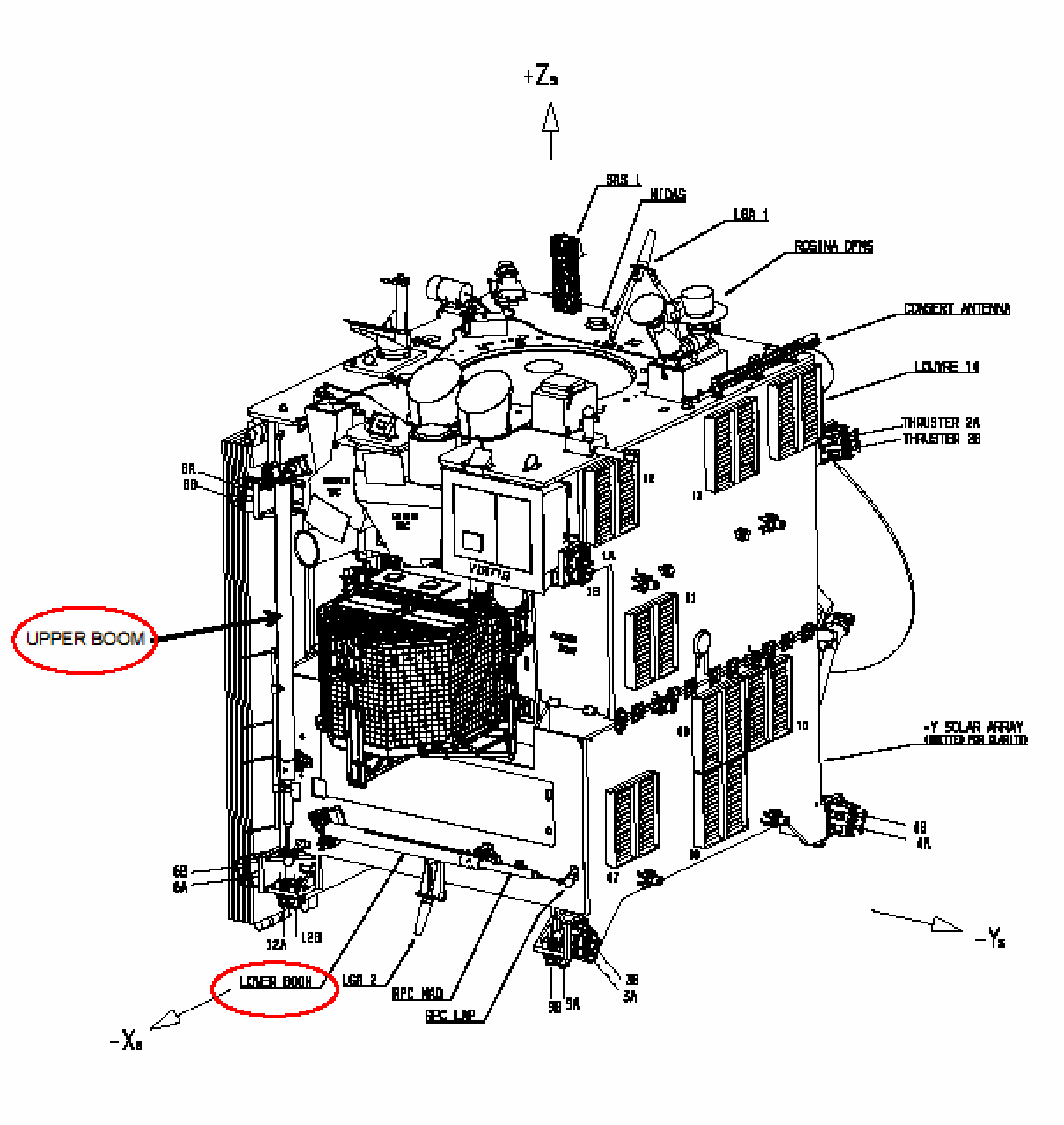


Figure 5-112a: Boom locations

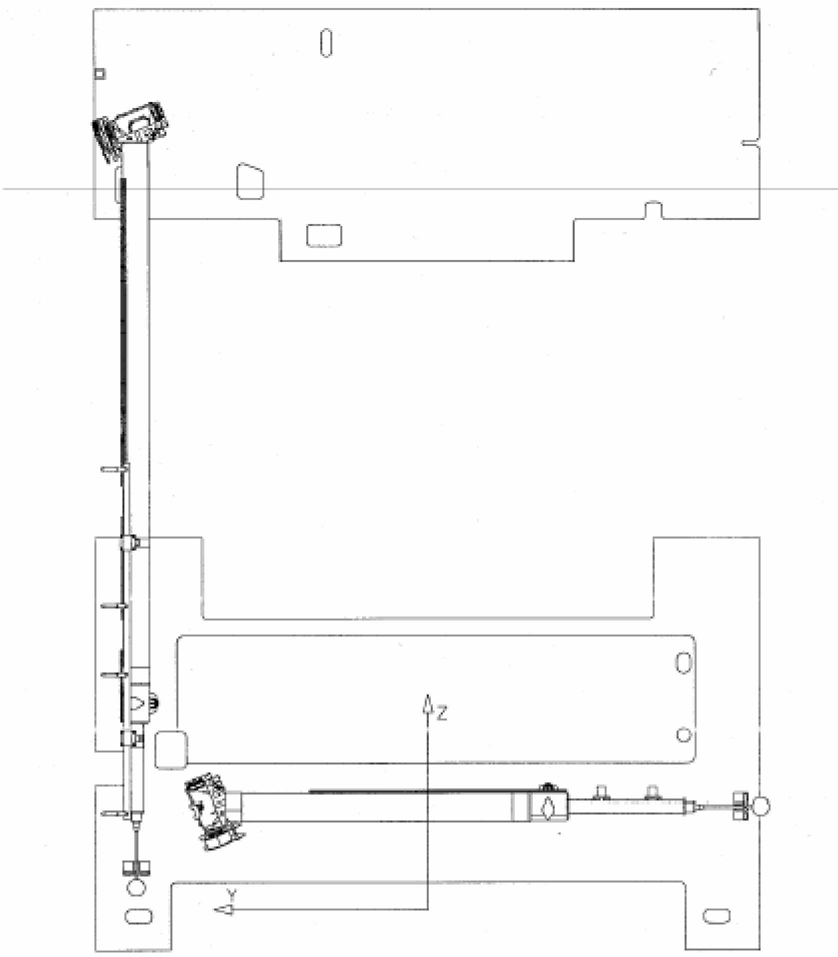


Figure 5-112b: Booms in stowed configuration

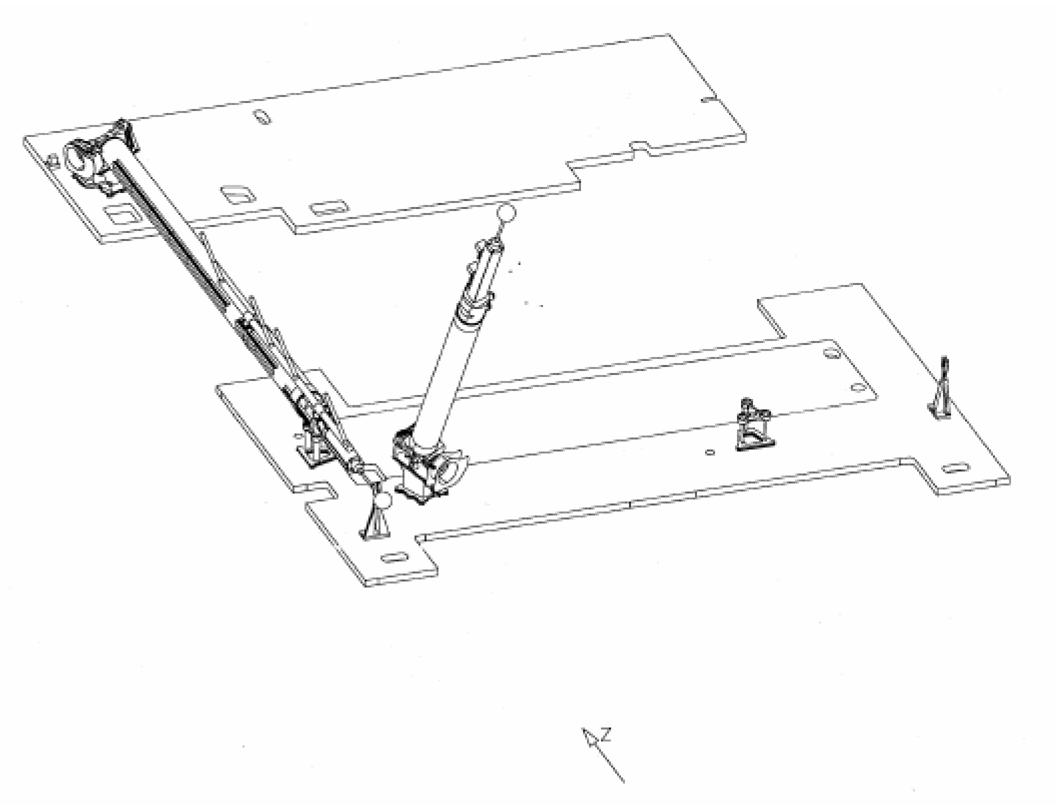


Figure 5-112c: Lower Boom deployed

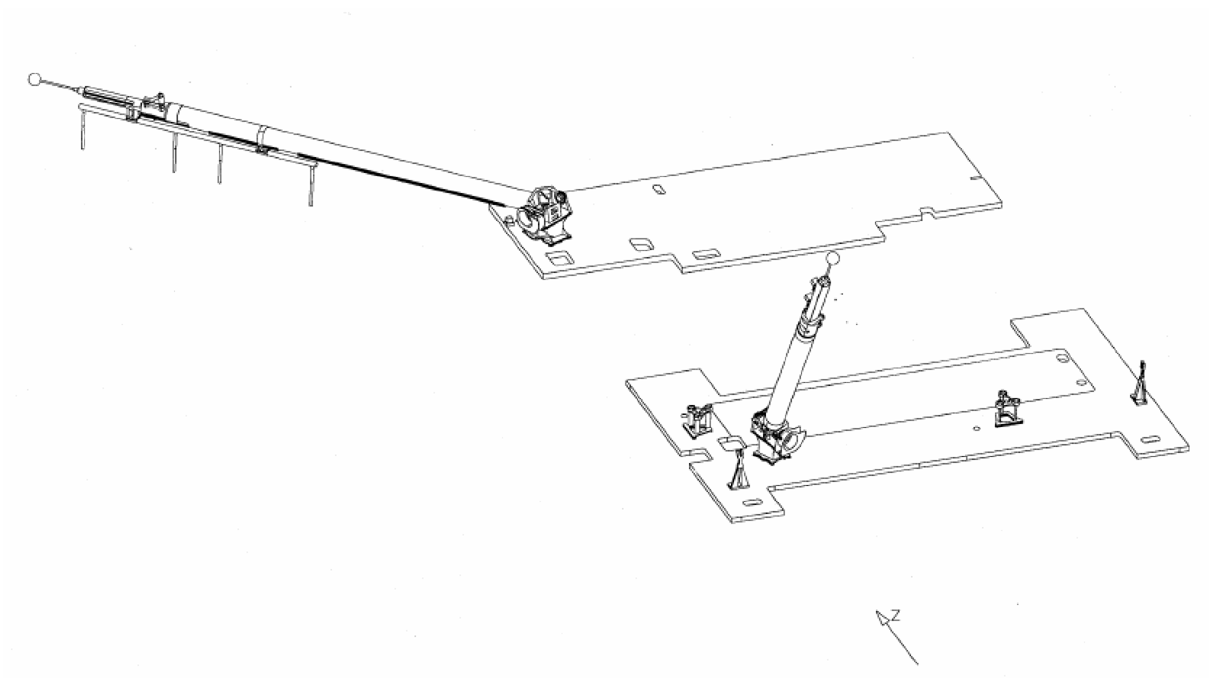


Figure 5-112d: Upper and Lower Boom deployed

Each experimental boom is composed of the following assemblies:

- Boom structure
- Hold down and release mechanism
- Deployment Mechanism
- Harness and accessories
- Thermal Hardware

The boom structure consists of a CFRP tube, with a hinge bonded to one end, and a hold down point bonded to the other. The experiments are attached to the structure by either a bracket bonded, or screwed to the tube.

The hold down and release mechanism prevents the boom from deploying during the launch phase, and allows it to be released when commanded by the ground. The release mechanism consists of a pyrotechnic separation nut, two initiator/ booster charges, and the hold down fitting.

The boom is deployed by means of a Motor Gear Unit (MGU). The MGU output shaft is connected to the boom through a flexible coupling. At the end of the deployment, the boom latches so that it remains securely locked in the deployed position. Figure 5-112 shows an isometric drawing of the deployment mechanism; a detailed design description of the deployment mechanism is given in RO-SEN-TN-3503.

The harness on each boom provides power and signal (i.e. telemetry / command) as necessary to the experiments, heaters, thermistors, microswitches and deployment motor.

The thermal hardware maintains the temperature of the boom within it’s operating limits.

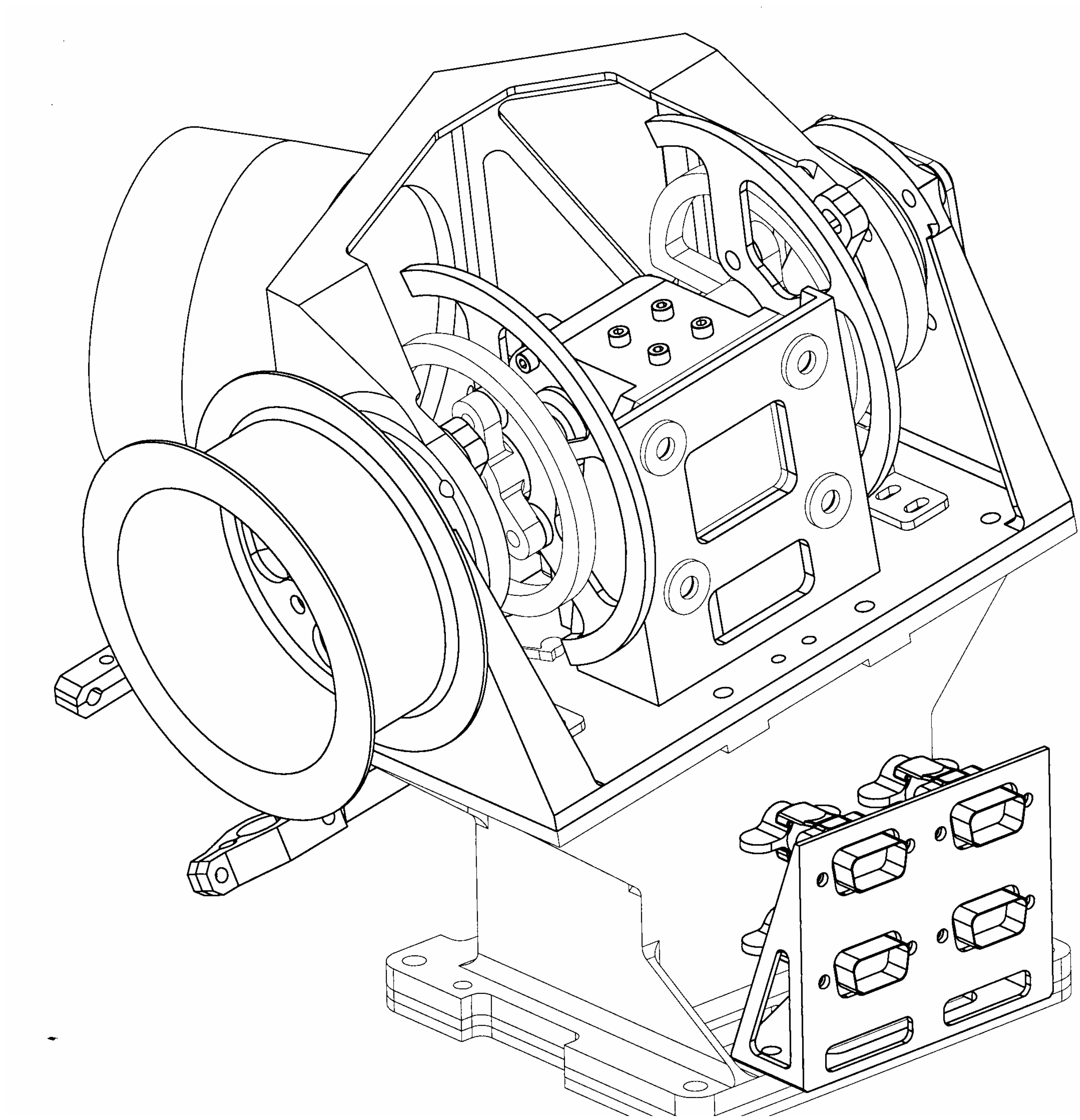


Figure 5-112: Boom deployment mechanism

5.4.5.4.2. Interfaces

Four connectors provide the electrical interfaces (power, and TM/TC) to each of the booms.

Thermal washers are used to decouple the boom from the SC structure and six MLI blankets are used to cover as much of the boom as possible. These blankets and washers try to maintain all parts and components within their allowable temperature range, and minimise the heat exchange with the SC platform. Heaters are used to keep the MGU above it's minimum qualification temperature before deployment, this is because it is not covered in MLI as it could interfere with the mechanism. These heaters will be switched off once the booms have been deployed, and latched.

5.4.5.5. Louvres

The louvre design, (see RO-SEN-TN-3001), consists of 8 pairs of VDA Kapton-taped aluminium blades, of dimension 52.7mm wide by 184mm long. The blades are supported by lengthwise shafts which rotate on Vespel end bearings. The blade shafts are rotated by spiral wound bimetal actuator springs. Each actuator spring operates independently for multiple redundancy. There is one actuator spring controlling each pair of blades. The actuator springs respond passively to changes in mounting surface temperature to rotate the blades either open or closed as required to maintain acceptable thermal control. When the underlying white paint radiator surface becomes relatively hot (e.g. during EOL full payload operations phases) then the bimetal springs expand and turn the louvre blades to the open position. This reveals the underlying white paint radiator surface which then radiates heat more efficiently to the cold space environment. Conversely, when the spacecraft and radiators are relatively cold then the springs contract, the louvre blades close and the white paint radiator surface is covered. The view factor from the radiators to space is then zero and heat losses from the spacecraft are minimised. Pin stops located on the outer side rails of the assembly constrain the louvre blades to rotation through a maximum range of 90°. Figure 5-113 shows a section through the blade mechanism.

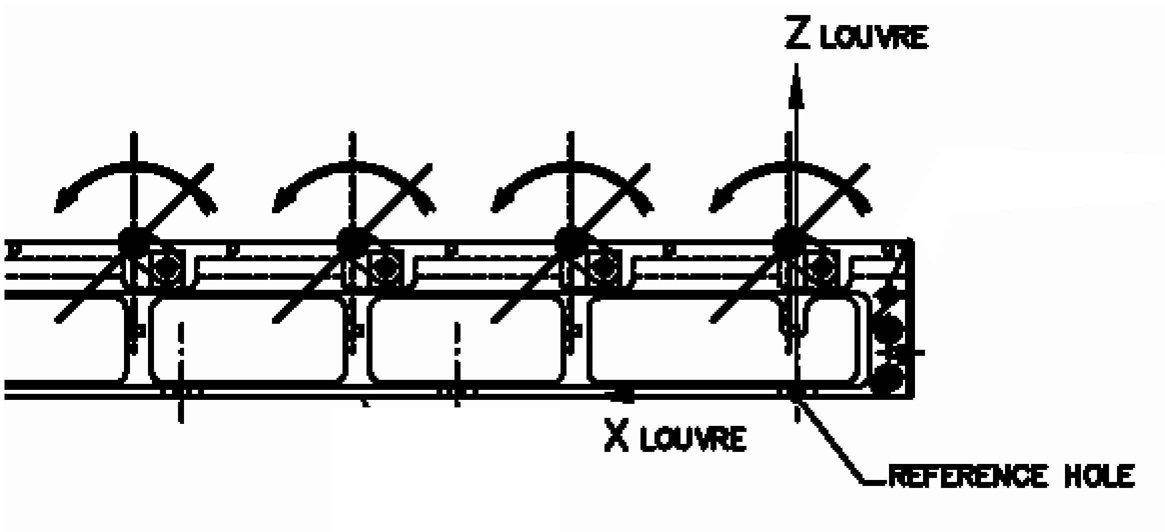


Figure 5-113: Details of Louvre Blades

5.4.5.6. Solar Array Holddown and Release Mechanism

5.4.5.6.1. Introduction

The holddown and release system uses a tie-down element (Kevlar cable) under high preload which will be degraded by heat of the thermal knife for release. Figure 5-114 shows a typical 5-panel holddown stack.

The minimum stack height covered/qualified within ARA Mk3 is 2 panels, the maximum number is 5 panels (as applied in the Rosetta design).

The interpanel gap in stowed configuration is 12 mm. This allows for ample freedom to route the harness and ensures enough dynamic clearance between the adjacent panels. The gap between the inner panel and the sidewall is nominally 70 mm, but can be extended by dedicated brackets underneath the holddowns up to 92.6 mm, this is the case for the Rosetta Solar Array.

The threaded cylindrical cup and cone parts (see run through the panel substrate. Both parts are made of titanium, thus improving compatibility with the thermal expansion of the Aramid restraint cable (section 5.4.5.6.2).

The first row of honeycomb cells around each titanium cup/cone cylinder is filled with SLE 3010 potting compound in order to create a good shear connection between the honeycomb core and the cylinder. The cups an cones are attached to the skin by means of EA 934, containing glass beads. These glass beads ensure parallelism between the cup/cone interface planes and the panel substrate skins.

The inner radius of the cups and cones is 40 mm. The cone angle of the cup/cones is 45”.

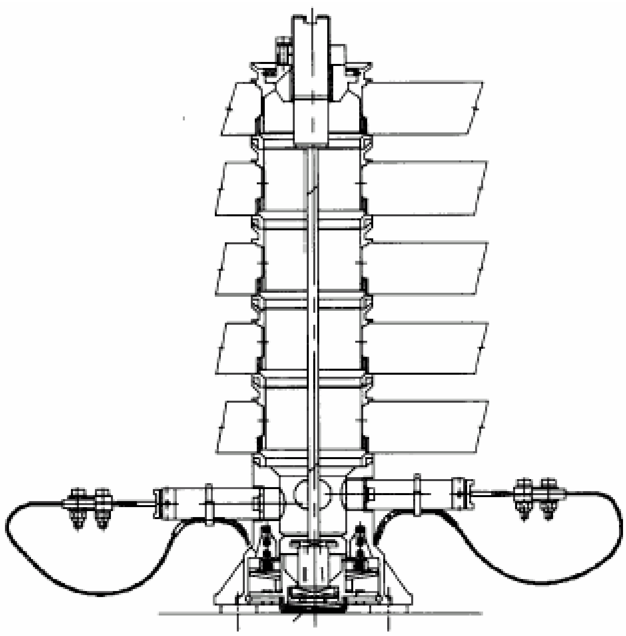


Figure 5-114: Holddown and Release Mechanism

This has two positive effects:

- the cup/cones are always self-releasing under an in-plane load. E.g., a difference in thermal expansion of the stowed panels never results in a release/deployment failure

- the combination of a relatively large radius of the cup/cones and a high preload in the holddown stack and the 45” angle prevents non linear behaviour of the holddown stack (‘canting’) under dynamic loading.

In order to prevent fretting/cold welding of the cups and cones, the contact surfaces on the cones are all covered with a Hauzer PVD Chrome-Nitride (ceramic) surface coating, whereas the cup contact surfaces are bare Titanium.

5.4.5.6.2. Thermal knife

The Aramid restraint cables are cut by means of thermal knives. Per holddown point 2 redundant knives are applied, opposite of each other and spaced sufficiently apart to avoid mechanical contact.

A knife assembly consists of a housing, mounted to the holddown S/C interface bracket, with a spring driven piston inside. The two straight piston legs are connected to a heater plate at one end and to the power lines connector at their other end.

It should be noted that the redundant knife is the one which is mounted closest to the restraint cable endfitting.

The power lines are attached to the ends of the piston legs by means of connectors. The power supply required to fire the thermal knives has the following I/F data:

- I/F voltage: 20 +/- 1.5 v

- max. inrush current: 1.4 A

- operational current: 0.95 A

- max. operating time: 60 set

- wiring: AWG24, twisted, shielded

There is no restriction on the interval between consecutive firings other than the spacecraft power supply capability. Although this is not a ‘hard’ requirement, there is a preferred firing order: if possible, the holddown points closest to the hinge line between yoke and inner panel shall be fired first. This off-loads the yoke snubbers and reduces the kick-off load on the damper.

5.4.5.6.3. Restraint Cable

In order to avoid canting induced by out-of-plane as well as in-plane accelerations in stowed configuration, the pretension of the single Aramid cable is 7 kN. In order to enable these high pre-loads, the diameter of the cable is approximately 4.5 mm.

The bottom part of the restraint cable is equipped with a bayonet shaped endfitting to ensure simple installation and retraction of the cable in the holddown stack of the stowed wing. The upper endfitting is internally and externally threaded. On the internal thread the tensioning tool can be attached. Both endfittings are attached to the Aramid tensioning cable by means of a conical wedge, or 'spike'. See Figure 5-115

Figure 5-115: Restraint Cable endfitting

5.4.5.6.4. Holddown bracket

The holddown bracket has a ∅ 60 mm bolt pattern and is attached to the spacecraft by 4xM5 Titanium bolts.

In the holddown bracket, a bayonet spring carrier is located, that serves to lock the restraint cable endfitting in its place. It also constrains a disk spring ('Belleville washer') and a compression spring. During the cutting process the tension in the restraint cable decreases. The disk spring maintains a minimum required pretension level in the restraint cable that is required to ensure a correct cutting behaviour of the thermal knife. The compression spring keeps the restraint cable in place in unloaded condition.

5.4.5.6.5. Tensioning mechanism

The mechanism to bring the restraint cable, and therefore the complete holddown stack, under tension, is located in the outer panel.

The tensioning mechanism consists of an end plate, on which a nut is torqued. First, a dedicated tensioning tool pulls out the top endfitting hydraulically, resulting in a tension in the holddown stack. At the correct load level, the nut is screwed over the external thread of the top endfitting of the restraint cable, down to the end plate, after which the tensioning tool is off-loaded and removed. The calibrated tool ensures a correct, reproducible pretension in the holddown and release mechanism.

5.4.5.7. Solar Array Deployment Mechanism

5.4.5.7.1. Introduction

The deployment mechanism is compatible with 22 mm thick substrate panels and an interpanel gap of 12 mm. The concept relies on spring-driven hinges. The spring characteristics are chosen such that the energy supply is enough for the full range up to 5 maximum sized panels, while maintaining the required deployment safety factors. In order to reduce the shock loads on the SADM and interpanel hinges, a damper is introduced in the deployment system.

5.4.5.7.2. Yoke

The V-yoke length is 1103 mm when measured from SADM hingeline to yoke/inner panel hingeline. The yoke length used within the ARAFOM 5-panel QM wing programme is identical.

The arms of the V-shaped yoke consist of M46J CFRP filament wound tubes (winding angle of 15” overall with additional 90” filaments to increase the buckling stability) with a circular cross section (inner diameter 43 mm; nominal wall thickness 0.9 mm) with reinforcements at the ends of the yoke tubes (wall thickness 1.44 mm). The thermal expansion coefficient is kept as close to zero as possible, in order to have favourable alignment behaviour, meeting the Rosetta requirements.

The yoke tubes are riveted as well as bonded to the SADM hinge and to the panel hinge attachment brackets. The flexprint panel is attached to these brackets by means of inserts.

Flexprints can be attached to the dedicated yoke flexprint panel (standard 3-layer M55/950-1 skin with local 5 layer reinforcements, edgemembers for flexprint and hinge attachment and 22 mm nominal honeycomb) running parallel to the panel hingeline edge. Depending on the I/F with the satellite (thruster locations), the flexprints can be attached in between the yoke tubes and/or on the outside. Therefore, the yoke flexprint panel extends outside of the hinges over the full length of and parallel with the panel edge. See also Figure 5-116

Yoke interface snubbers between the spacecraft sidewall and the yoke tubes reduce the load on the stowed panels.

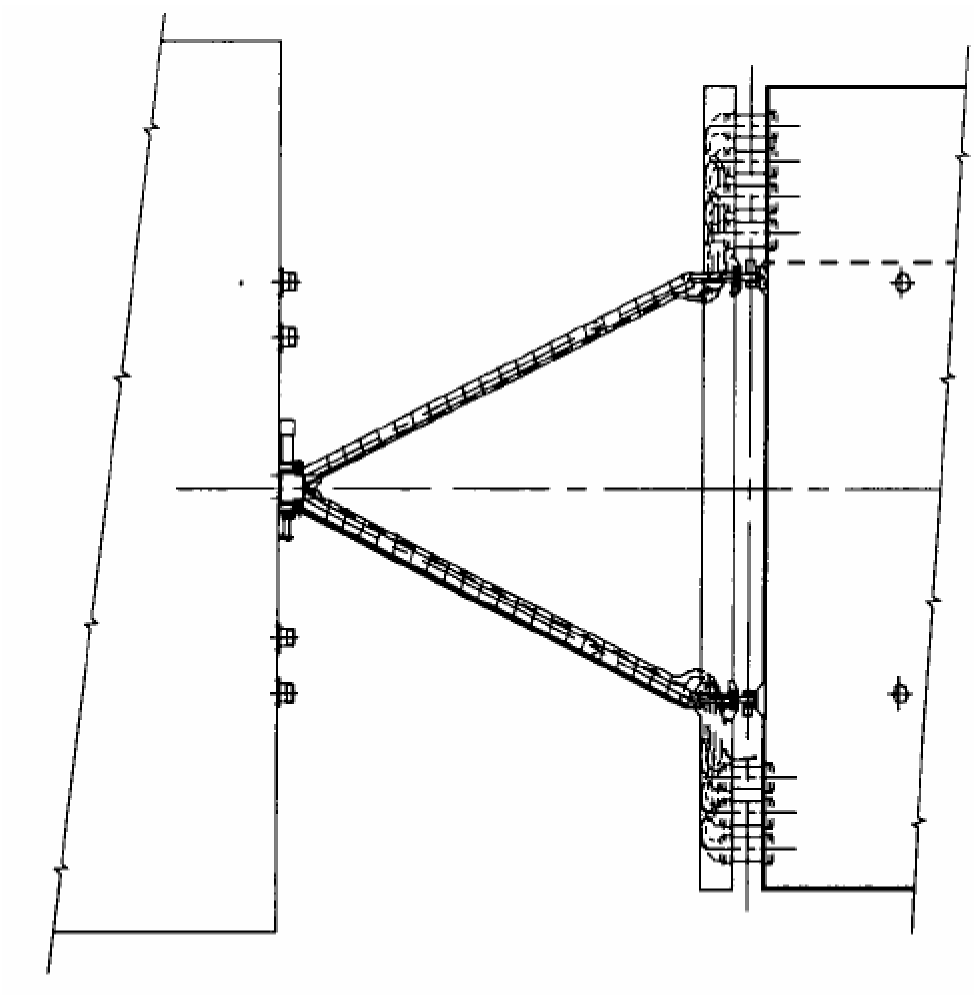


Figure 5-116: Yoke Configuration

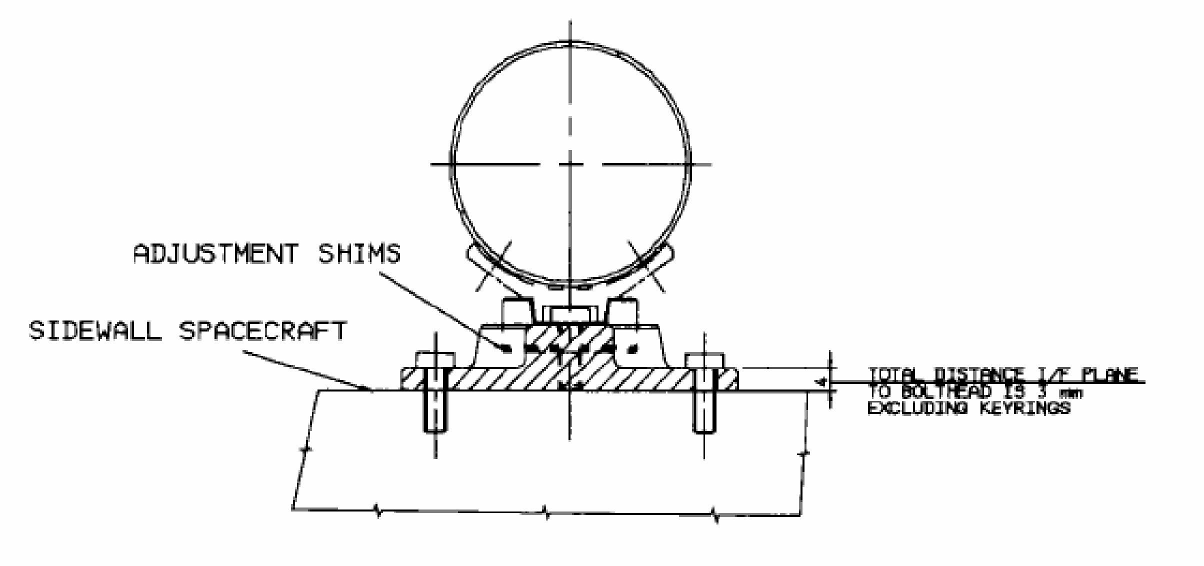


Figure 5-117: Yoke Snubber Configuration

5.4.5.7.3. Panel hinge

A hinge consists of the following parts:

- two hinge brackets, male and female, made of aluminium.
- hinge axis made of stainless steel.
- bearing, aluminium sleeve with teflon/glassfiber liner.
- adjustable stop for alignment in deployed configuration.
- spring operated titanium latch. The latch is a wedge-like device locking the hinge in deployed configuration and thus avoiding backlash. During deployment the latch runs over a circular cam, keeping the latch open.
- on each hingeline, in one of the hinges, the dedicated teflon washers are deleted in order to create axial play.

The interpanel hinges are equipped with dedicated springs to counter:

- retarding torque of the flexprints
- friction of the synchronisation system
- internal friction of the hinge bearing

The amount and type of flexprints and therefore their retarding torque is dependent on the number and size of panels and will also vary strongly per hingeline. Therefore the actuating torque that has to be produced by the hinges will also deviate strongly. Since one type of spring, covering the complete torque range, is not acceptable from either a mass or a strength point of view, the hinge design accommodates three different spring types.

The hinge spring is a circular ‘clock’ spring. The central spring end is directly attached to the hinge axis, whereas the outer end is connected to the male bracket. The adjustment can be fine-tuned, in order to introduce a pure torsion moment without any shear (that would increase hinge friction). Currently it is foreseen that the amount of torque, necessary to meet the requirements on safety factors against retarding torque, is sufficient within the current design.

The mechanical interface with the panel substrates consists of three close tolerance titanium bolts and pins, tightly clamping the hinge bracket in the panel edgemember. The close tolerance ensures correct alignment, whereas the friction due to the high clamping load gives a combination of low hysteresis and high strength to withstand the deployment shock loads. The holes are not in line, again in order to reduce hysteresis effects under bending loads. Shear webs are located in the brackets provide the necessary stiffness.

In order to allow for build misalignment in stowed configuration, the hinges are equipped with conical bearings, giving a large angular free play (±1°), while keeping the backlash (required to counter thermal mismatchof shaft and bracket) to a minimum (0.03 mm). This results in ZERO backlash in deployed configuration.

5.4.5.7.4. Synchro Mechanism

Because of the deployment damper, a stiff synchronisation system is applied. Without this high stiffness, the high actuation torque (driven by the high deployment safety factor) in combination with a high damping coefficient would cause a very non-synchronous deployment, resulting in unpredictable high deployment latch-up shocks at the interpanel hinges.

A slack compensator is provided in order to maintain a minimum cable tension in the synchro cables. The nominal tension is 10 N. These slack compensator consists of a spring that runs internally through the synchro cable braid. At the spring ends, the compensator is attached to the braid by means of EC2216.

During deployment the synchro cable tension will be much higher than 10 N which means that the spring bottoms and the cable itself takes the entire tension

5.4.5.7.5. SADM hinge

The SADM hinge consists of two hinged brackets providing attachment points for the SADM hinge torsion spring, the deployment damper, the yoke tubes, the SADM interface plate and the I/F connector bracket. One hinge axis serves as the incoming axis for the damper gearbox, while the other is used as feedthrough for the yoke harness. Four springs are applied in parallel in order to improve redundancy.

The ARA Mk3 design has a connector bracket attached to the SADM hinge. In the bracket the interface connectors are mounted and attached to the interface cable loom from the spacecraft. The Rosetta electrical and mechanical I/F definition changes the bracket with respect to the number of slots, 4 instead of 3, and the height of the bracket. This is enlarged in the direction of the spacecraft.

The hinge bracket, interfacing with the S/C SADM, has a pre-set bias of -2 or +2 degrees (standard ARA Mark3 design). The bracket is redesigned (in the same way as for XMM) for Rosetta in order to remove this bias.

5.4.5.7.6. Deployment damper

A deployment damper is included as standard in the ARA Mk3 design (and therefore in the Rosetta baseline) in order to reduce deployment shocks, while maintaining ample margins with respect to retarding torque's.

Thus, it allows for relaxation of the strength requirements due to deployment shock for the SADM and the interpanel hinges after deployment.

The damper is of the 'Eddy current' type. The damper design uses a four stage planetary gear head with a gear ratio of 1600. Furthermore eight Samarium Cobalt permanent magnets are equally spaced on both sides of a copper alloy disk to provide a constant magnetic field. All gears are made of 15-5 PH stainless steel heat treated to H1025 and are machined to AGMA Class 10.

Damping rates can be easily adjusted in the field by rotating the unit end ball, thereby misalligning magnets on either side of the eddy current disk. The input shaft has high torque capability. It transmits applied rotation motion to the first stage of the planetary gearing. It is positioned and supported by a pair of stainless steel ball bearings which are located within the input housing. The input shaft is machined from 15-5 PH stainless steel heat treated to H1025. The planet gears of the first two stages rotate on sintered bronze bearings impregnated with Bray Oil Company Type 8152 oil.

To provide bearing redundancy, each planet gear rotates on the outer diameter of a sleeve bearing, and each sleeve bearing rotates on the outer diameter of a planet carrier post. The third and fourth stage planet gears rotate on ball bearings. The ball bearing are made of 440C and lubricated with Braycote 8152 oil and Braycote Micronic 601 grease.

The damper/gearbox combination is mounted on one of the two axes of the SADM hinge. The outer diameter of the damper/gearbox housing drives the size of the gap (70 mm) between the inner panel and the satellite sidewall. For the 5-panel wing, this would then mean (in combination with the already mentioned panel thickness of 22 mm and an interpanel gap of 12 mm) that the height of the stowed panel package would become 229 mm (allowing 1 mm for cells, busbars and wiring on the outer panel surface) when measuring between the sidewall and the surface of the outer panel. However at hinge level synchro cable attachment parts result in a slightly higher stack height of 239 mm. Since the holddown spacers of 22.7 mm are added, the nominal height for the Rosetta wing has become 261.7 mm

The magnetic moment of the damper with the same damping coefficient setting as for Rosetta is <4E-4 Am'.

Due to the thermal extremes during the various mission phases, it may be required to extend the temperature range for survival (no leakage or loose parts, no damage to SADM hinge I/F) after functioning by an additional qualification test.

5.4.6. HGA Major Assembly Subsystem Design Description

5.4.6.1. General

The major function of the High Gain Antenna (HGA) is the transmission and receiving of data in the X and S bands between the Rosetta spacecraft and earth based stations. The High Gain Antenna Major Assembly (HGAMA) actively supports this functionality by:

- Securing stowage of the antenna during the launch phase and ensuring its subsequent deployment.
- Allowing accurate pointing of the antenna dish through controlled rotation about azimuth and elevation axes.
- Minimising RF transmission losses between the antenna and the spacecraft.

These objectives are accomplished by the assembly of Figure 5-118. The assembly can be broken down into four major subsystems:

- A Holddown and Release Mechanism (HRM) consisting of two tripod mounted units and a bracket mounted unit.
- An Antenna Pointing Mechanism (APM) consisting of two perpendicular drive units which steer rotation about azimuth and elevation axes. The APM is a subassembly that includes the mechanical components of the motor driven units (APM-M), their electronic control (APM-E), harness and the APM tripod support structure that anchors the APM to the spacecraft (APM Support Structure – APM-SS).
- A Cassegrain quasi-paraboloid High Gain Antenna (HGA) with dichroic subreflector and S and X band feeds.

- Radio Frequency (RF) ancillary equipment which includes rotary joints, waveguide and coaxial cable.

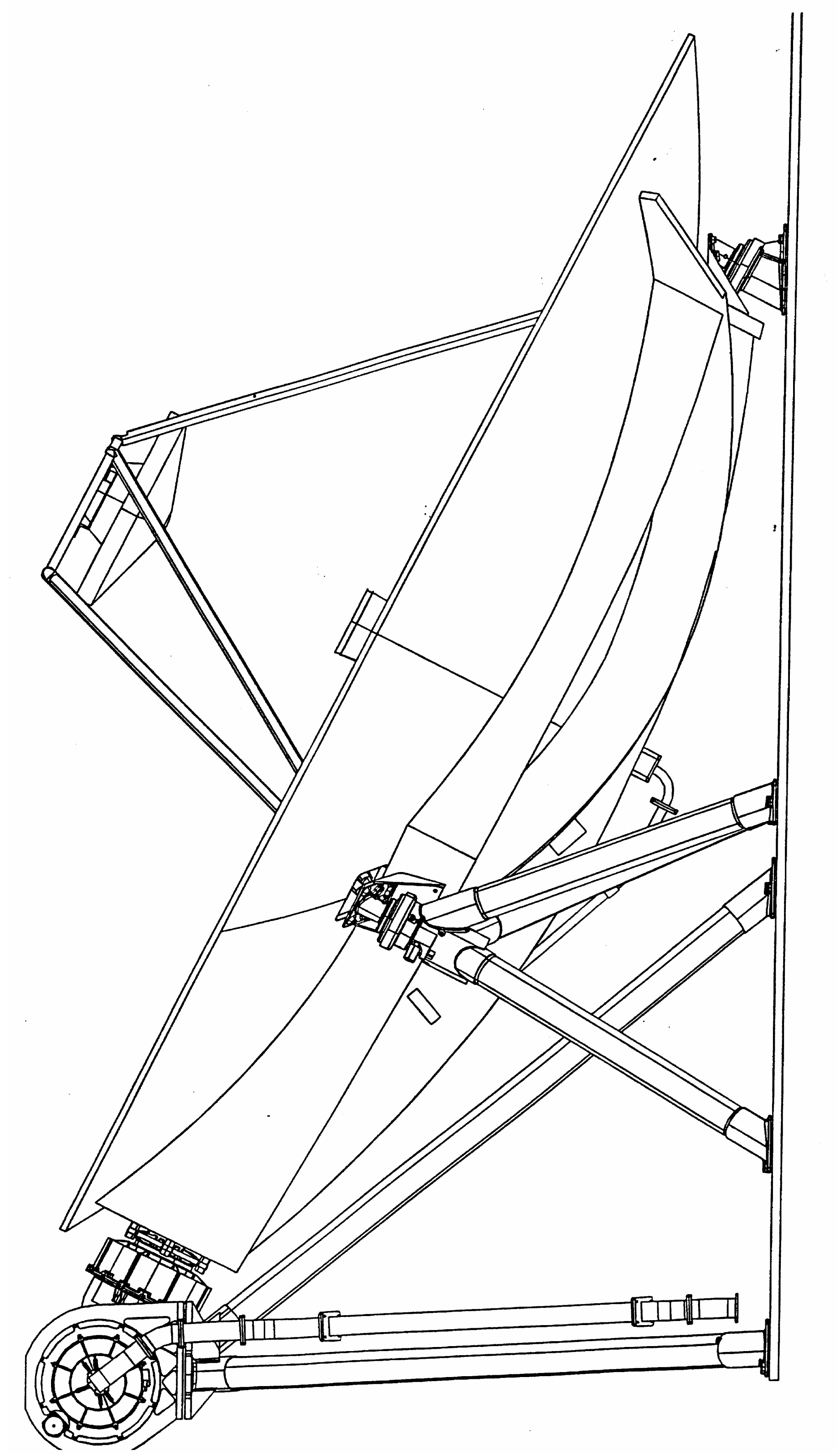


Figure 5-118: HGA Main Assembly

5.4.6.2. High Gain Antenna

The main functional requirement for the High Gain Antenna is the establishing of a stable communication link between earth based stations and the spacecraft for the lifetime of the mission.

The HGA is designed to transmit and receive in the S band at 2.11-2.12 GHz and at 2.29-2.30 GHz and to also transmit in the X band at 8.40-8.44 GHz (receive at 7.15 – 7.19 GHz). A detailed description of the antenna design and its performance can be found in the HGA design description. The following is a short description of the HGA design.

The HGA is a Cassegrain dual reflector system consisting of a main dish and a dichroic subreflector (Figure 5-119). The final shape of both main dish and subreflector has been optimised to maximise gain in the X band (for a small penalty in S band performance), by use of polynomial expansions and thus differs slightly from a perfect paraboloid shape for the main dish and the hyperboloid for the subreflector.

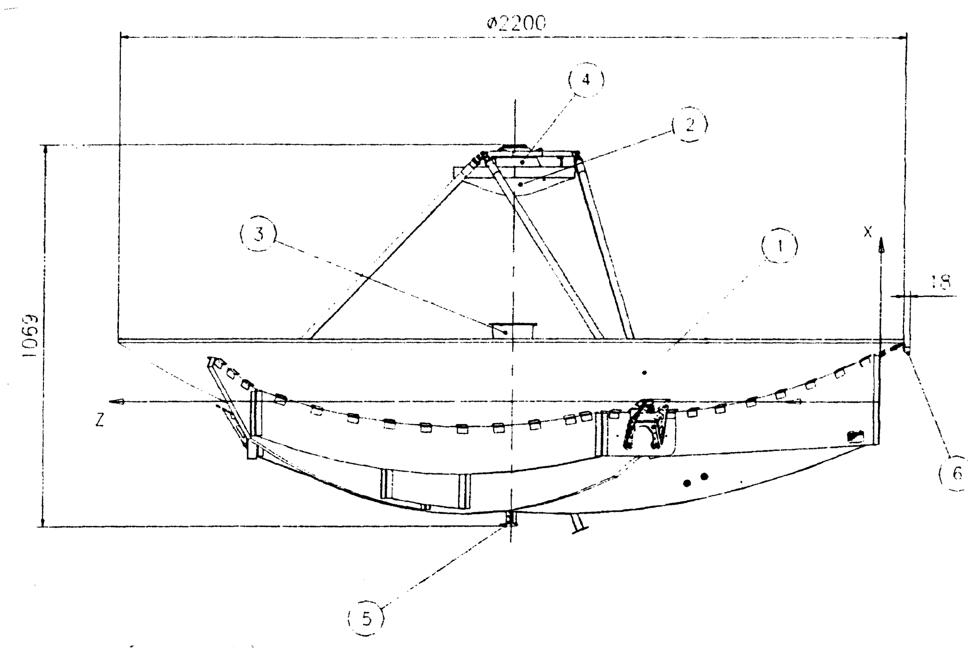


Figure 5-119: HGA Antenna

Main parts of the HGA Antenna:

- Main Reflector

- Dichroic Subreflector
- X-Band Feed
- S-Band Feed
- X-Band I/F
- Mirror Cube

The backing structure of the HGA is shown in Figure 5-120.

The main reflector is a ribbed sandwich laminate of 10.5 mm thickness and a projected diameter of 2200 mm. The sandwich structure consists of high modulus carbon fibre faces wound on a carbon fibre honeycomb core. Three aluminium brackets attached to the back ribs at a distance of 800 mm from the centreline form the interface to the HRM units and act as attachment points for the six carbon fibre struts which support the subreflector and the S band feed. A central hole in the main reflector allows mounting of the aluminium potter horn which acts as X band feed.

The subreflector is a dichroic construction which allows transmission of the S-band while reflecting waves in the X band region. It is made out of a Quartz Fibre Reinforced Plastic (QFRP) honeycomb reinforced sandwich with QFRP faces which have a copper grating. It is attached by six carbon fibre struts to the main dish. The S band feed is attached above it at the end of the struts and consists of a Patched Excited Cup element similar to the one used in the Artemis mission.

The HGA assembly is steered by the APM and maintained in the stowed configuration by the HRMs.

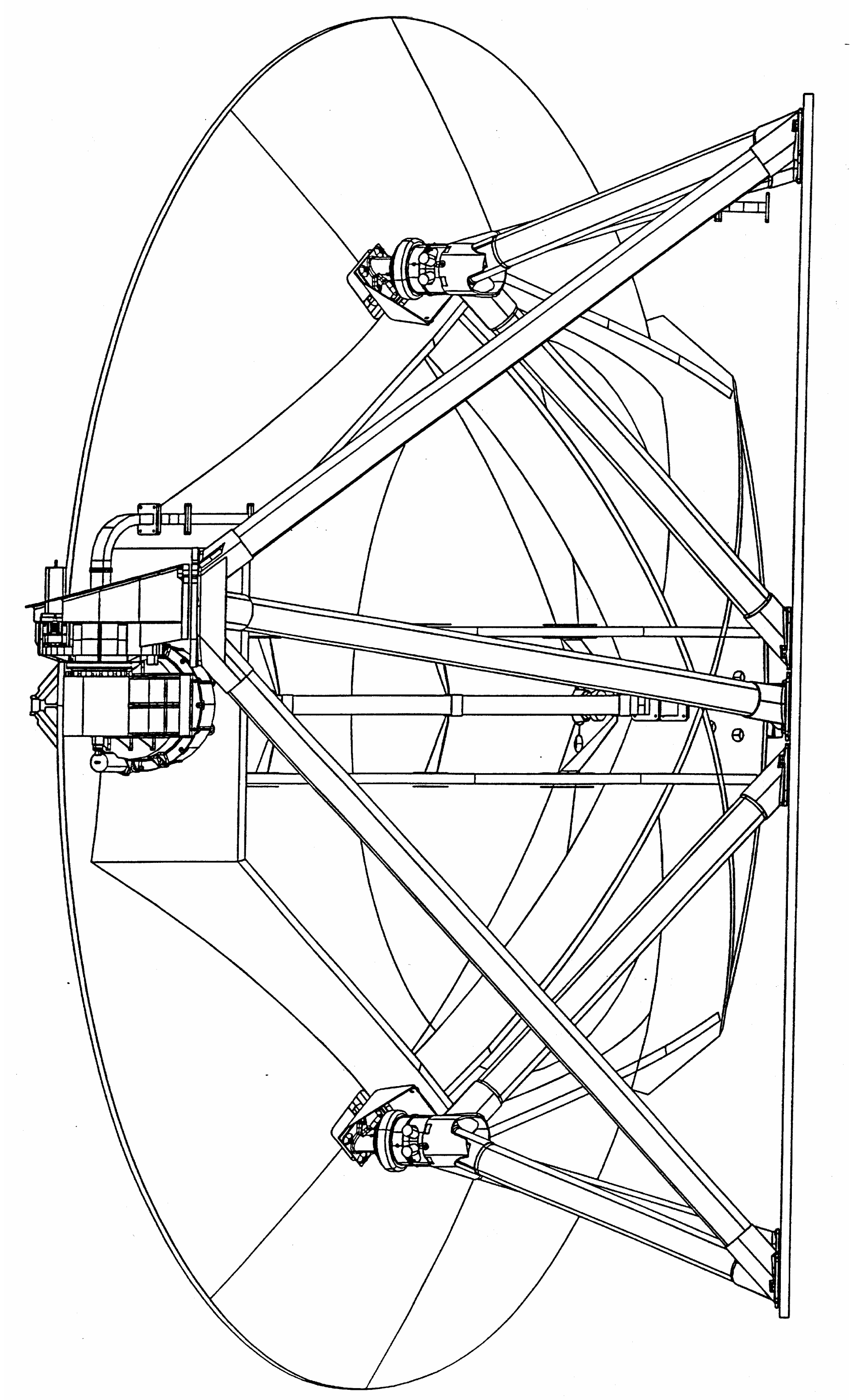


Figure 5-120: Assembly of HGA onto Support Structure Showing HGA Backing Structure

5.4.6.3. Holddown and Release Mechanism

The HRM has two main functions:

- Maintain the antenna in is stowed configuration during launch and ground operations.
- Release the antenna during the In-Orbit Commissioning phase after launch.

The HRM consists of three units, two of which are mounted on carbon fibre tripods and are located in the lower part of the spacecraft and a single bracket mounted unit which lies in the upper centreline of the S/C sidewall. The layout of the HRMs is symmetric about the sidewall centreline. (Figure 5-120). They are joined by aluminium brackets to the antenna ribs.

Each HRM consists of a bolt catcher unit, a separation nut unit and a support structure. The bolt catcher unit remains attached to the antenna after deployment. The separation nut and its support structure remain on the spacecraft sidewall. In order to accommodate the tolerances of the HGAMA at this internal interface a potting system using epoxy resin has been implemented. (Figure 5-121).

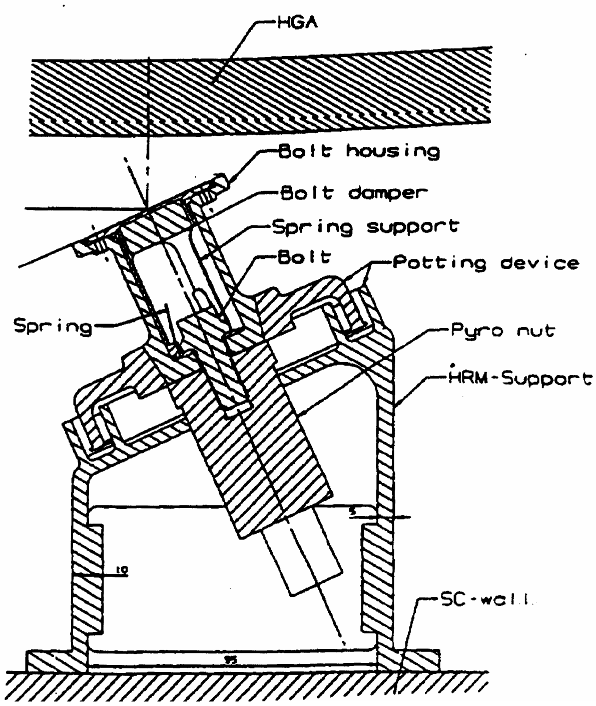


Figure 5-121: HRM Components

The bolt catcher unit forms the interface to the antenna bracket and consists of a removable lid to allow access to the bolt and replacement of the aluminium honeycomb damping material after testing and an aluminium cylinder with nested steel springs which holds the bolt after firing. The aluminium cylinder ends in a cone angle of 30° (Figure 5-121).

which fits into the aluminium lid of the separation nut housing. The bolt catcher is held in place by a titanium M10 bolt which threads into the separation nut. The interface to the separation nut housing is lubricated using molybdenum disulphide (MoS_2).

The separation nut housing consists of an aluminium lid which is glued into the potting flange of the support structure. The lid has a conical hole in its centre which accommodates the bolt catcher unit and which transfers all torsional and shear loads to the support structure so that the bolt is subject to pure tension. The separation nut is screwed into the lower side of the aluminium lid and activated by redundant initiators fixed to its lateral ports. A microswitch on the lid consisting of a conical pin and spring loaded piezoelectric sensor indicates successful release of the bolt catcher. A thermistor measures the housing temperature.

Whereas the bolt catcher and the separation nut housing are identical for the three HRM units their support structures differ. The HRM units located closed to the APM mast are mounted on to a carbon fibre tripod with legs of 40 mm outside diameter. The carbon fibre struts are glued to an aluminium fitting on the spacecraft sidewall end and to an aluminium node at the other end. The node consists of a machined aluminium part with holes that accommodate the carbon fiber struts and a removable potting flange. (Figure 5-122). The bolt catcher and separation nut assembly can be removed by unscrewing the potting flange.

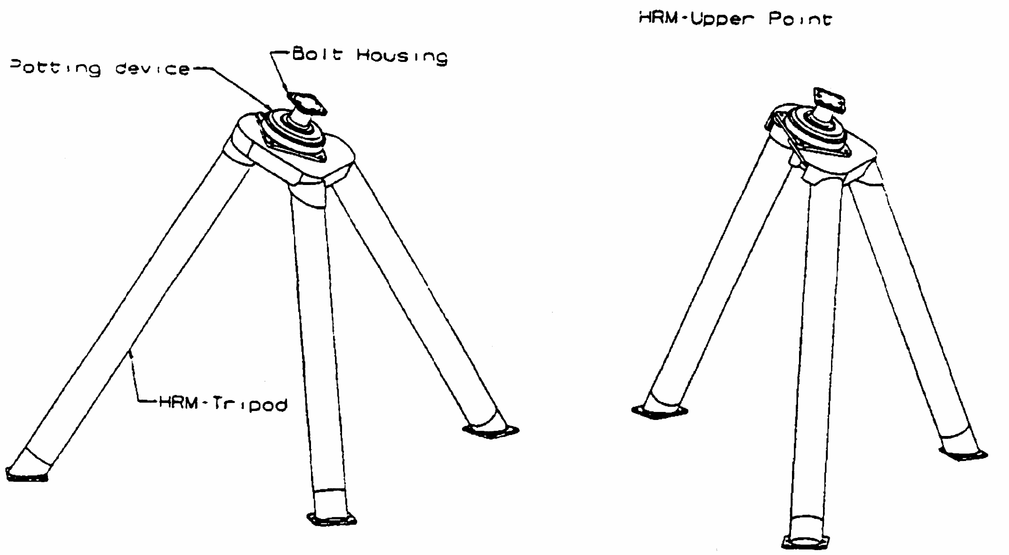


Figure 5-122: Tripod Mounted HRMs

The HRM unit furthest away from the APM mast is subject to the highest thermomechanical loads. It is therefore stiffer than the tripod mounted HRM units. This unit is mounted on an inverted U shaped aluminium bracket with ribs along its lower section (Figure 5-121). An oval hole in the sidewall allows placement of the separation nut and permits access to the ignitor cables. Since the potting flange forms a single unit with the bracket the entire unit must be removed in order to replace the separation nut.

Pyrotechnic initiators are used to activate the separation nuts. These initiators are capped and removable plugs are incorporated in the electrical design to avoid accidental firing during transport. An aluminium box with flippable lid which houses these plugs is located under the right (+X–located) tripod mounted HRM.

5.4.6.4. Antenna Pointing Mechanism

The main functions of the APM is to allow accurate and stable pointing of the antenna dish through controlled rotation about azimuth and elevation axes.

It consists of three main components:

- The motor drive units (APM-M).
- The electronic control of these units (APM-E).
- The support structure (APM-SS).

5.4.6.4.1. APM-M

The APM-M has two motor drive units: the azimuth and the elevation drive. Each motor drive unit consists of: a micro stepper motor with planetary gearhead and main gear stage, a feedback system which indicates the absolute position of the drive, a hollow shaft through which the waveguide is routed and a duplex ball bearing which ensures free rotation of the hollow shaft about the gear housing. Figure 5-123 shows the complete assembly.

The azimuth drive is placed above the elevation drive and interfaces to the HGA via a flanged steel shaft to which the rotary joint is anchored. This flanged hollow steel shaft, also known as output flange is bolted at its lower end into a 13:1 reduction single stage spur gear.

A duplex ball bearing is fixed to the steel shall by a fastening ring and is nested in a ribbed aluminium casing which houses the gear and its peripherals. The motor unit and an aluminium cable wrap which feeds flat band cable to the antenna are bolted unto this housing (Figure 5-124).

The operation of the APM-M is described in the component design description and therefore only briefly summarised here. The mating pinion of the spur gear is driven by a stepper motor which consists of a laminated stator and a rotor with redundant windings. The stepping of the motor is controlled by the electronic control unit (APM-E). The APM-M incorporates at the main gear stage an antibacklash mechanism in the form of a spring preloaded secondary pinion which sits on top of the drive pinion and eliminates backlash.

An optical encoder with a sensor unit fixed to the gear housing registers the absolute motion of the hollow shaft and sends this feedback to the electronic control unit. Electrical and mechanical ends stops in the form of microswitches and cam activated stops mounted on the gear housing hinder excessive rotation of the antenna.

Mechanical end stops have been embodied which restrict the motion of the HGAMA (after deployment) to an envelope which meets the system pointing requirement range but also prevent collision with other spacecraft elements.

The housing of the azimuth drive is bolted by a bracket to the output flange of the elevation drive. The elevation drive is identical to the azimuth drive with the exception of the aluminium housing, the output flange and the position of the end stops. Its housing is attached to the upper fitting of the APM support structure.

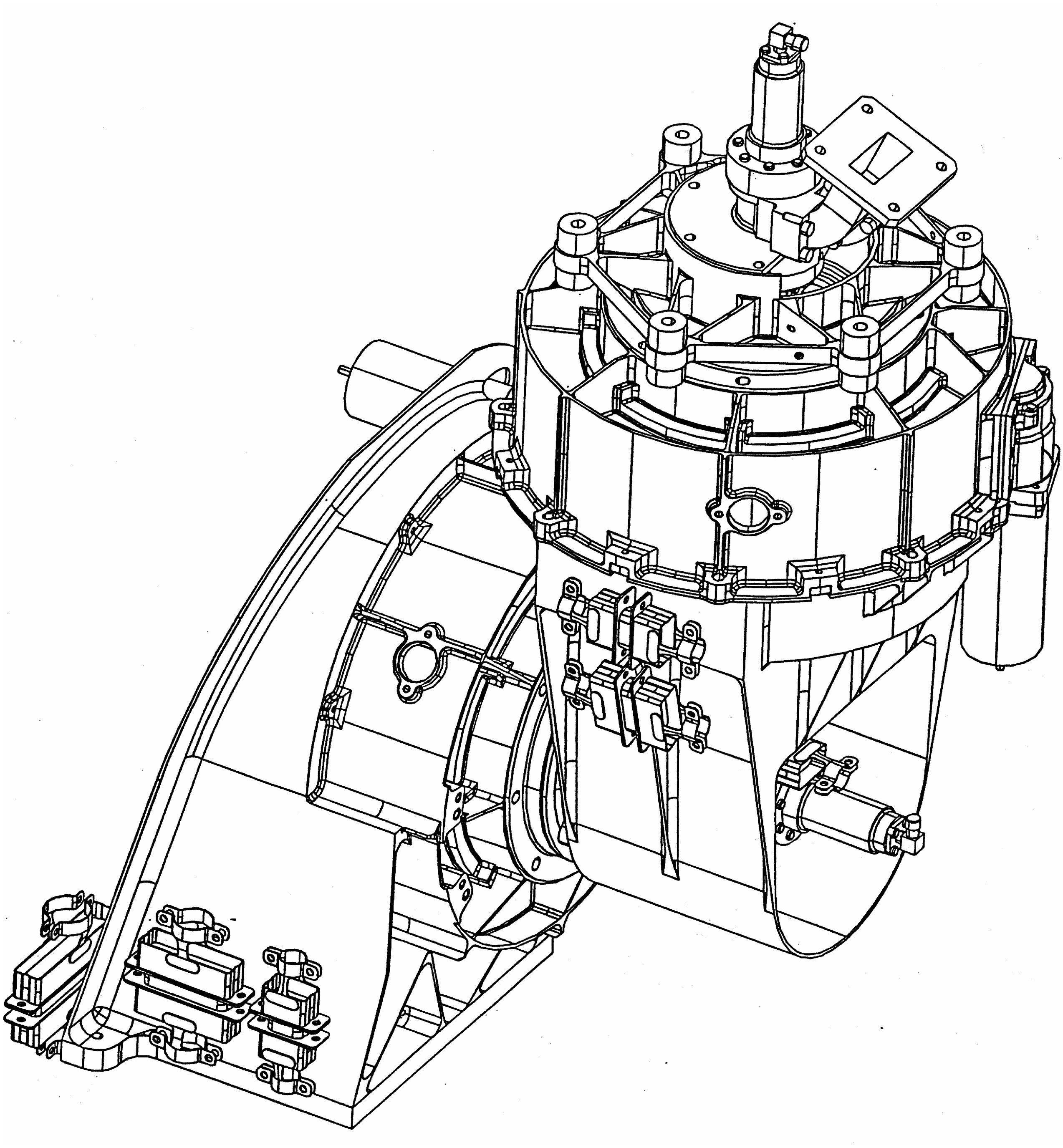


Figure 5-123: APM Assembly

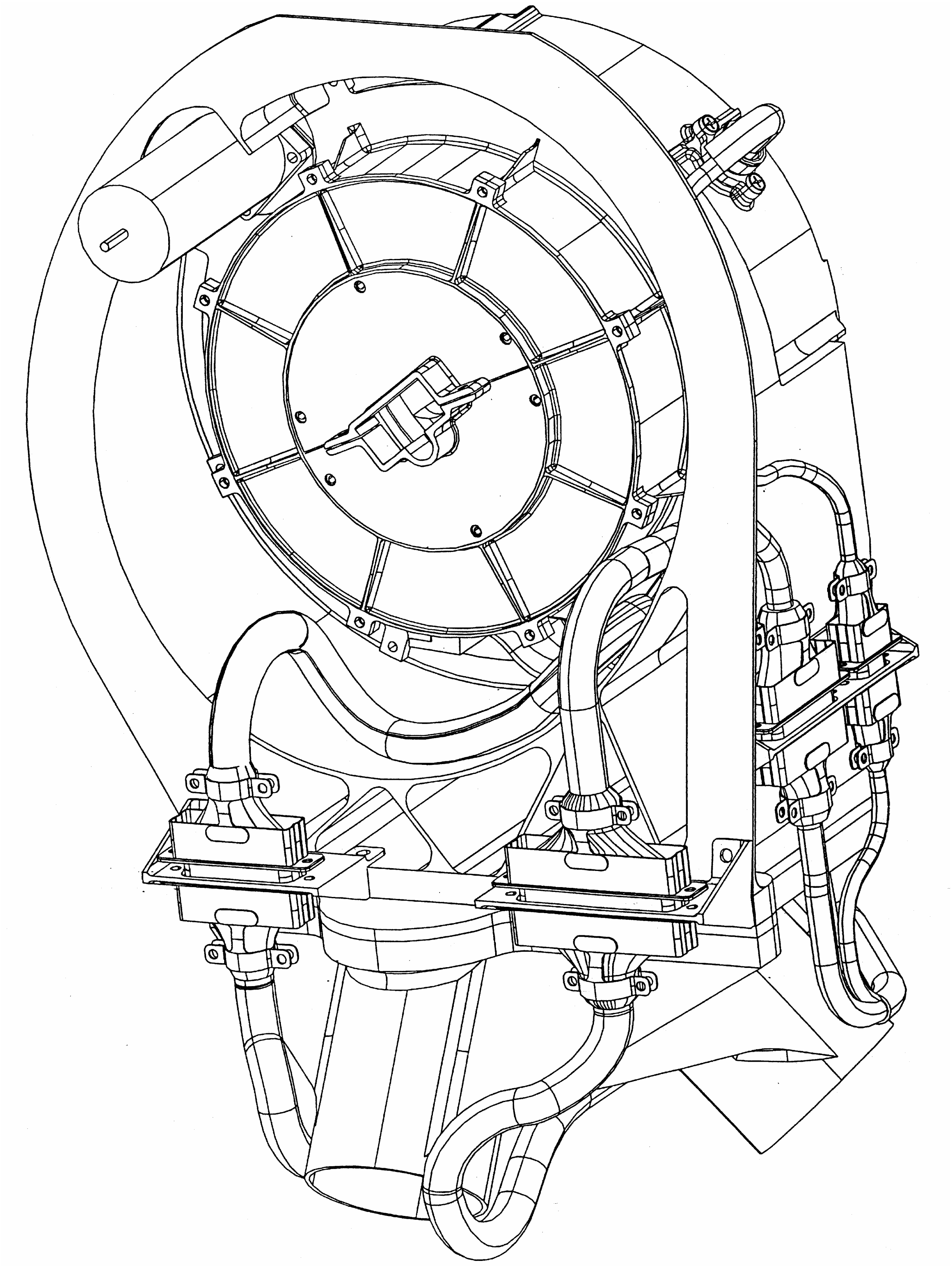


Figure 5-124: View Showing Cable Details Including Cable Wrap

5.4.6.4.2. Interfaces

The main interface between the APM and the RF equipment consists of the rotary joints and the freely rotating support integrated to the EDU cable drum structure. The axis of the rotary joints coincide with the EDU and ADU shafts.

The elevation drive unit is attached to the APM node which is adhesively bonded to the tripod. A shim plate is installed between the node and the EDU which allows alignment of the EDU axis with the spacecraft sidewall.

The APME is attached to the spacecraft wall by 11 M5 screws. The electrical interfaces with the APME include signal, MACS bus, and power, the connectors for which are on the surface of the APME. The signal interface includes the thermistor, encoder, and motor interfaces. The APME outer surface is painted with Alodine 1200 for thermal reasons.

The APME MACS bus interface is very similar to that used by the SADE, which can be found described in section 5.3.2.3.4.2.4 , and Table 5-12, Table 5-13, and Table 5-14. The difference is be address of the commands, but the structure is the same.

The APM SS, and APM-M is covered with MLI to prevent thermal gradients across the structure.

5.4.6.4.3. APM-E

For a description of the APM-E, see §5.3.2.3.5.

5.4.6.4.4. APM Support Structure APM-SS

The structural support for the APM consists of a carbon tripod structure (the support legs being manufactured from filament wound carbon struts) with titanium end fittings to attach to the ADM interface and aluminium end fittings to attach to the S/C interface. (See Figure 5-120).

The design has been optimised to reduce the thermoelastic induced pointing error.

5.4.6.5. RF Ancillary Equipment

The main function of the RF ancillary equipment is the transmission of signals in the S and X bands between the spacecraft and the high gain antenna with the lowest possible loss. It consists of three main elements:

- A waveguide
- Two rotary joints
- A coaxial cable

The waveguide consists of two segments for X band transmission and reception: the lower segment extends from the spacecraft sidewall to the elevation drive and the upper segment from the elevation rotary joint to the potter horn located in the centre of the high gain antenna. (Figure 5-125). The waveguide incorporates bellowed flanges at curvature points to allow for thermal expansion.

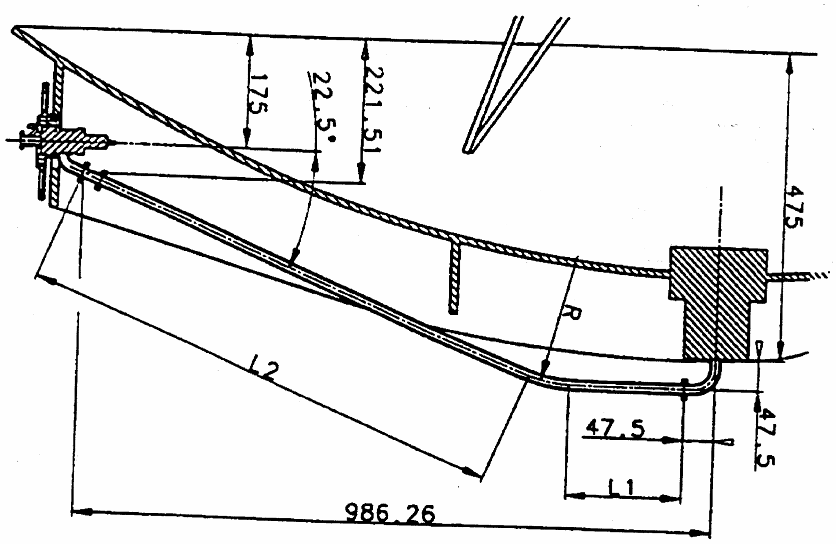


Figure 5-125: Upper Section of X-Band Waveguide

One rotary joint attached to the azimuth drive and an identical one attached to the elevation drive allow stress free rotation of the waveguide. The rotary joints have a rotating central flange and a static outer flange (Figure 5-126) which are attached to the waveguide so that unhindered rotation takes place about the centreline of the azimuth and elevation drives.

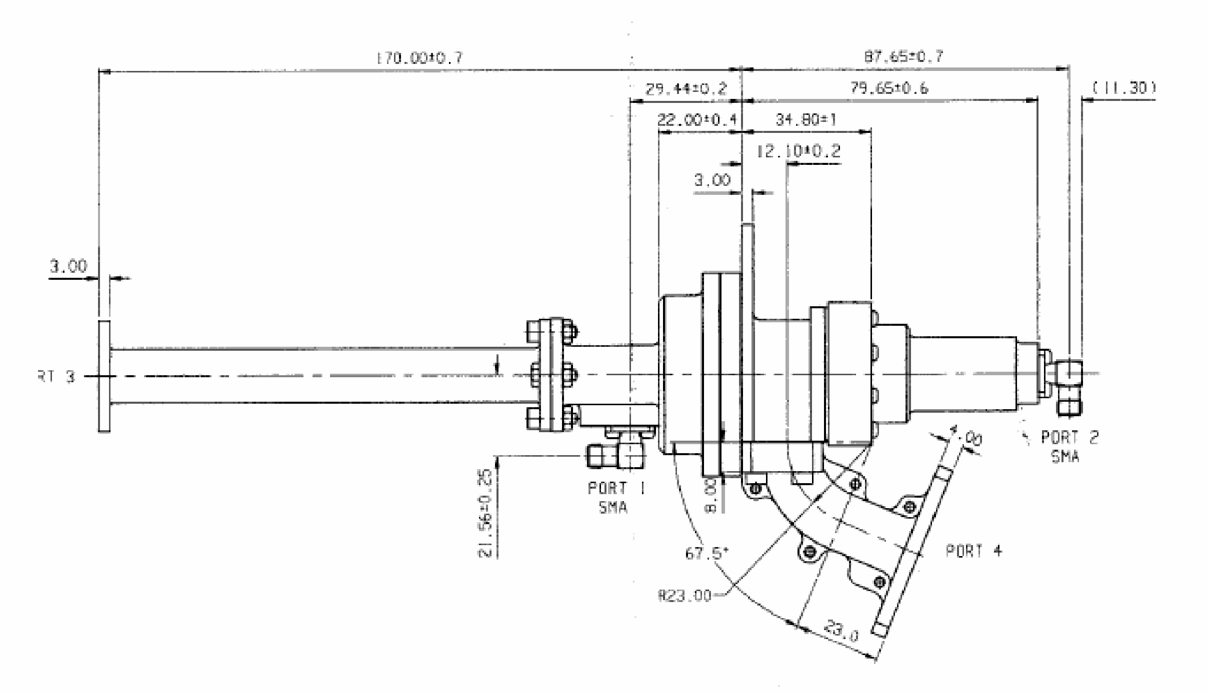


Figure 5-126: Rotary Joint

Figure 5-127 shows schematically the arrangement of the two rotary guides in the APM-M unit. The layout has changed from the one depicted in order to avoid the sharp E-bend of the waveguide.

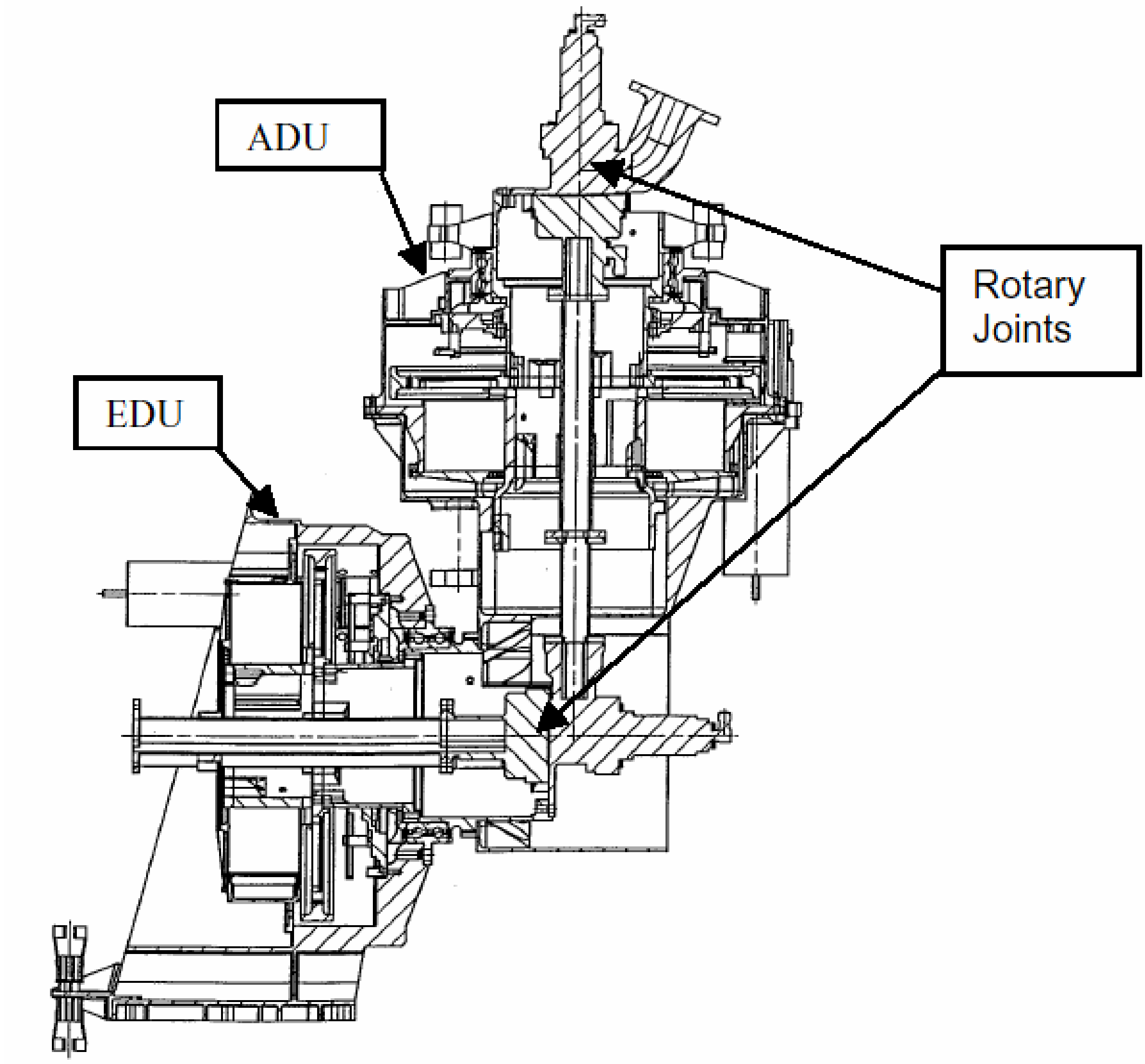


Figure 5-127: APM-M Cutout Showing Location of Rotary Joints

The coaxial cable is used for S-band transmission and is routed parallel to the waveguide up to the elevation drive from where it is routed to one of the subreflector struts and to the S-band feed at the top of the antenna (at the rear of the sub-reflector).

5.4.6.6. Thermal Protection

Except for the APM drives, which have heaters, the thermal protection of the HGAMA is a passive system consisting of Multiple Layer Insulation (MLI) blankets of differing thickness which decouple the system from the space environment. All other subsystems have been designed to operate within the temperature extremes of this passive environment thus obviating the need for active heaters. The heating elements of the drive units are placed as close as possible to the motor and are centrally controlled.

Thermal washers separate the exposed equipment (HGA) from the insulated equipment at the APM-HGA interface. The HRM units are exposed but their support structure is insulated. The back side of the antenna is also insulated.

A detailed description of the thermal loads and the functionality of insulators can be found in the Thermal Analysis Report.

5.4.6.7. Cable Harness

The HGAMA cable harness consists of separate unit harnesses for the HRM and the APM with the necessary connector interfaces mounted on the spacecraft. Except for the grounding cables and coaxial lines, all cables are twisted pairs.

The APM harness connects the motor units (azimuth and elevation), the encoder, thermistors, the RF coaxial line from the HGA to the spacecraft sidewall, the end-stop switches and grounding lines.

5.4.6.8. Interfaces

The X-Band feed interfaces with the Waveguide Interface Unit (WIU) via a waveguide.

The S-Band feed interfaces with the RF Distribution Unit (RFDU) via a coaxial cable.

The coaxial cable is fed to the S-band head along the carbon fibre struts, which support the S-band head, and subreflector, and the APM -Y strut; the cable is fastened using tie-downs. The cable ends as a flying lead with a male SMA connector.

The waveguide consists of three sections, the first interfaces with the SC sidewall on the APM +Y strut, and extends as far as the elevation drive unit. The second connects the elevation drive unit (EDU) rotary joint with the azimuth drive unit (ADU) rotary joint. The third section extends from the azimuth rotary joint to the potter horn located in the centre of the HGA. The waveguides incorporate bellowed sections to allowed for thermal expansion, and mechanical tolerances. The waveguide SC interface is square plain flange of thickness 4mm, the mating part is fixed with 4 bolts. The waveguide is type WR-112.

The figure below shows the lower (1st) and middle (2nd) waveguides.

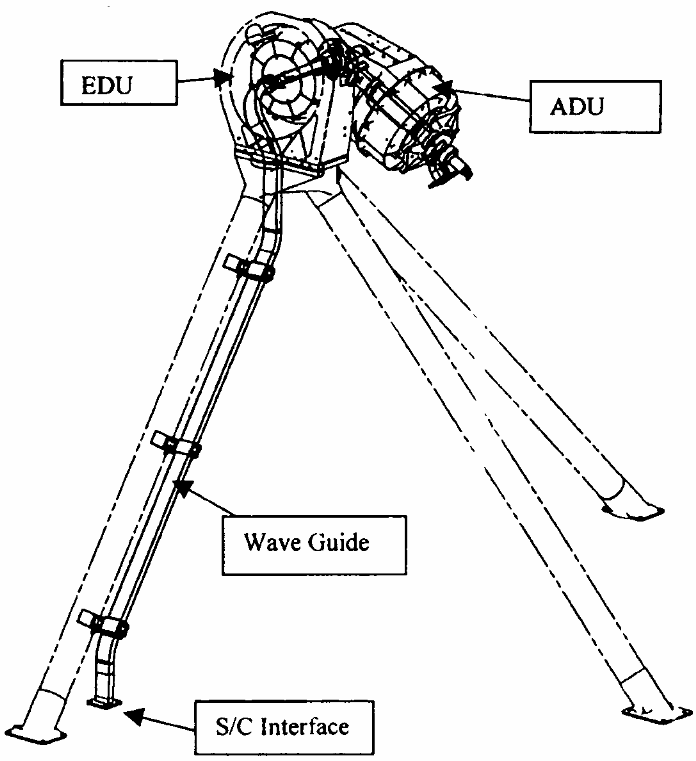


Figure 5-128: Lower section of X-Band waveguide

Rotary joints are fitted in the ADU, and EDU to allow rotation of the waveguides and coaxial cable, and allow transmission during movement of the antenna.

MLI is used to cover the back of the HGA, and the supporting structure. It will be fastened using clips.

The HGAMA structure is bolted to the +X SC wall.

6. EXPERIMENT DEFINITION

This section contains links to the top-level payload EID-Bs and Experiment User Manuals in folder “Payload Documentation”. The documentation is contained on CD 2 of the User Manual.

Instrument	Document Title	Doc Number	Issue
ALICE	ALICE EID-B	RO-EST-RS-3005	2
ALICE	ALICE User Manual	8225-EUM-01	rev 3
CONSERT	CONSERT EID-B	RO-EST-RS-3007	2
CONSERT	CONSERT Orbiter User Manual	RO-OCN-TN-3044	2.6
COSIMA	COSIMA EID-B	RO-EST-RS-3008	2
COSIMA	COSIMA User Manual	TBD	2.3
GIADA	GIADA EID-B	RO-EST-RS-3009	2
GIADA	GIADA User Manual	RO-GIA-MA-007	2
GIADA	Giada SW User Manual	RO-GIA-MA-009	1.3
LANDER	Lander EID-B	RO-EST-RS-3020	2
LANDER	Lander – ESS Processor Unit ADP	TBD	2
LANDER	Lander User Manual	RO-DLR-UM-3100	3
LANDER	Summary of Lander Configuration	RO-DSS-TN-1179	1
MIDAS	MIDAS EID-B	RO-EST-RS-3010	2
MIDAS	MIDAS User Manual	RO-MIR-PR-0030	2
MIRO	MIRO EID-B	RO-EST-RS-3011	2
MIRO	MIRO User Manual	RO-MIR-PR-0030	2
OSIRIS	OSIRIS EID-B	RO-EST-RS-3016	2
OSIRIS	OSIRIS User Manual	RO-RIS-MPAE-SP-025	1
ROSINA	ROSINA EID-B	RO-EST-RS-3013	2
ROSINA	ROSINA User Manual	RO-ROS-MAN-1009	3
RPC	RPC EID-B	RO-EST-RS-3012	2
RPC	RPC User Manual	RO-RPC-UM	Draft v.099
RSI	RSI EID-B	RO-EST-RS-3014	1
RSI	RSI User Manual	RO-RSI-IGM-MA-3081	2.3
VIRTIS	VIRTIS EID-B	RO-EST-RS-3015	2
VIRTIS	VIRTIS User Manual	RO-VIR-UM-001	2

7. APPENDIX 1 - SATELLITE BUILD STANDARD

See attached documents:

Document Title	DOCUMENT NUMBER	Issue
Satellite Configuration Status List	RO-DSS-CS-1001	5
Rosetta Product Tree	RO-DSS-PT-1001	6
Platform Configuration Status List	RO-MMB-CD-3101	4
Platform Configuration Status List	RO-MMB-LI-3117	3
Avionics Configuration Item Data List	RO-MMT-CD-2001	6
Software Configuration Status List For DMS SRR	RO-MMT-CS-2001	1
Software Configuration Status List For DMS ADR	RO-MMT-CS-2002	1
Software Configuration Status List For AOCMS SRR	RO-MMT-CS-2003	1

8. APPENDIX 2 – PLATFORM TM/TC DATASHEETS

The TM/TC datasheets are provided in HTM format, that can be read with a web-browser like Netscape or Internet Explorer. For each TC packet ~~(TC packets for the time being only)~~ a separate file is given in a form equivalent to the data sheets used for Mars Express. For the TM datasheets the content of the platform relevant Data Pool Groups are provided. The tables below list the packets respectively file names that can be accessed via hyperlinks.

Note, that HPC-commands are collected separately in the file HPC-CMDs.pdf.

8.1. PCU-Nominal TC Packets

Link to PDF-file: PCU-nominal.pdf

Name	Designation	Verif TM
ZPWM1000SWON	APR A1 ON, PCU-A	*none*
ZPWM1001SWON	APR A2 ON, PCU-A	*none*
ZPWM1002SWON	APR A3 ON, PCU-A	*none*
ZPWM1003SWON	APR B1 ON, PCU-A	*none*
ZPWM1004SWON	APR B2 ON, PCU-A	*none*
ZPWM1005SWON	APR B3 ON, PCU-A	*none*
ZPWM1006	BCR 1 CH CURR LEV 0, PCU-A	*none*
ZPWM1007	BCR 1 CH CURR LEV 1, PCU-A	*none*
ZPWM1008	BCR 1 EOC VOLT LEV 0, PCU-A	*none*
ZPWM1009	BCR 1 EOC VOLT LEV 1, PCU-A	*none*
ZPWM1010	BCR 1 EOC VOLT LEV 2, PCU-A	*none*
ZPWM1011	BCR 1 EOC VOLT LEV 3, PCU-A	*none*
ZPWM1012	BCR 1 EOC VOLT LEV 4, PCU-A	*none*
ZPWM1013	BCR 1 EOC VOLT LEV 5, PCU-A	*none*
ZPWM1014	BCR 1 EOC VOLT LEV 6, PCU-A	*none*
ZPWM1015	BCR 1 EOC VOLT LEV 7, PCU-A	*none*
ZPWM1016SWOF	BCR 1 OFF, PCU-A	*none*
ZPWM1017SWON	BCR 1 ON, PCU-A	*none*

Name	Designation	Verif TM
ZPWM1018	BCR 2 CH CURR LEV 0, PCU-A	*none*
ZPWM1019	BCR 2 CH CURR LEV 1, PCU-A	*none*
ZPWM1020	BCR 2 EOC VOLT LEV 0, PCU-A	*none*
ZPWM1021	BCR 2 EOC VOLT LEV 1, PCU-A	*none*
ZPWM1022	BCR 2 EOC VOLT LEV 2, PCU-A	*none*
ZPWM1023	BCR 2 EOC VOLT LEV 3, PCU-A	*none*
ZPWM1024	BCR 2 EOC VOLT LEV 4, PCU-A	*none*
ZPWM1025	BCR 2 EOC VOLT LEV 5, PCU-A	*none*
ZPWM1026	BCR 2 EOC VOLT LEV 6, PCU-A	*none*
ZPWM1027	BCR 2 EOC VOLT LEV 7, PCU-A	*none*
ZPWM1028SWOF	BCR 2 OFF, PCU-A	*none*
ZPWM1029SWON	BCR 2 ON, PCU-A	*none*
ZPWM1030	BCR 3 CH CURR LEV 0, PCU-A	*none*
ZPWM1031	BCR 3 CH CURR LEV 1, PCU-A	*none*
ZPWM1032	BCR 3 EOC VOLT LEV 0, PCU-A	*none*
ZPWM1033	BCR 3 EOC VOLT LEV 1, PCU-A	*none*
ZPWM1034	BCR 3 EOC VOLT LEV 2, PCU-A	*none*
ZPWM1035	BCR 3 EOC VOLT LEV 3, PCU-A	*none*
ZPWM1036	BCR 3 EOC VOLT LEV 4, PCU-A	*none*
ZPWM1037	BCR 3 EOC VOLT LEV 5, PCU-A	*none*
ZPWM1038	BCR 3 EOC VOLT LEV 6, PCU-A	*none*
ZPWM1039	BCR 3 EOC VOLT LEV 7, PCU-A	*none*
ZPWM1040SWOF	BCR 3 OFF, PCU-A	*none*
ZPWM1041SWON	BCR 3 ON, PCU-A	*none*
ZPWM1042SWOF	BDR 1 OFF, PCU-A	*none*
ZPWM1043SWOF	BDR 1 OFF ARM, PCU-A	*none*
ZPWM1044SWON	BDR 1 ON, PCU-A	*none*

Name	Designation	Verif TM
ZPWM1045SWOF	BDR 2 OFF, PCU-A	*none*
ZPWM1046SWOF	BDR 2 OFF ARM, PCU-A	*none*
ZPWM1047SWON	BDR 2 ON, PCU-A	*none*
ZPWM1048SWOF	BDR 3 OFF, PCU-A	*none*
ZPWM1049SWOF	BDR 3 OFF ARM, PCU-A	*none*
ZPWM1050SWON	BDR 3 ON, PCU-A	*none*
ZPWM1051SWOF	BDA 1 OFF, PCU-A	*none*
ZPWM1052SWOF	BDA 1 OFF ARM, PCU-A	*none*
ZPWM1053SWON	BDA 1 ON, PCU-A	*none*
ZPWM1054SWOF	BDA 2 OFF, PCU-A	*none*
ZPWM1055SWOF	BDA 2 OFF ARM, PCU-A	*none*
ZPWM1056SWON	BDA 2 ON, PCU-A	*none*
ZPWM1057SWOF	MB RECONN OFF, PCU-A	*none*
ZPWM1058SWON	MB RECONN ON, PCU-A	*none*
ZPWM1059	START TM READ, PCU-A	*none*
ZPWM1100SWOF	BDA 3 OFF, PCU-A	*none*
ZPWM1101SWOF	BDA 3 OFF ARM, PCU-A	*none*
ZPWM1102SWON	BDA 3 ON, PCU-A	*none*
ZPWM1103SWOF	BDA 4 OFF, PCU-A	*none*
ZPWM1104SWOF	BDA 4 OFF ARM, PCU-A	*none*
ZPWM1105SWON	BDA 4 ON, PCU-A	*none*
ZPWM1200	APR A1 SA VOLT LEV 0, MPPT DIS, PCU-A	*none*
ZPWM1201	APR A1 SA VOLT LEV 0, MPPT ENA, PCU-A	*none*
ZPWM1202	APR A1 SA VOLT LEV 1, MPPT DIS, PCU-A	*none*
ZPWM1203	APR A1 SA VOLT LEV 1, MPPT ENA, PCU-A	*none*
ZPWM1204	APR A1 SA VOLT LEV 2, MPPT DIS, PCU-A	*none*
ZPWM1205	APR A1 SA VOLT LEV 2, MPPT ENA, PCU-A	*none*

Name	Designation	Verif TM
ZPWM1206	APR A1 SA VOLT LEV 3, MPPT DIS, PCU-A	*none*
ZPWM1207	APR A1 SA VOLT LEV 3, MPPT ENA, PCU-A	*none*
ZPWM1208	APR A1 SA VOLT LEV 4, MPPT DIS, PCU-A	*none*
ZPWM1209	APR A1 SA VOLT LEV 4, MPPT ENA, PCU-A	*none*
ZPWM1210	APR A1 SA VOLT LEV 5, MPPT DIS, PCU-A	*none*
ZPWM1211	APR A1 SA VOLT LEV 5, MPPT ENA, PCU-A	*none*
ZPWM1212	APR A1 SA VOLT LEV 6, MPPT DIS, PCU-A	*none*
ZPWM1213	APR A1 SA VOLT LEV 6, MPPT ENA, PCU-A	*none*
ZPWM1214	APR A1 SA VOLT LEV 7, MPPT DIS, PCU-A	*none*
ZPWM1215	APR A1 SA VOLT LEV 7, MPPT ENA, PCU-A	*none*
ZPWM1216	APR A1 SA VOLT LEV ARM, PCU-A	*none*
ZPWM1217	APR A2 SA VOLT LEV 0, MPPT DIS, PCU-A	*none*
ZPWM1218	APR A2 SA VOLT LEV 0, MPPT ENA, PCU-A	*none*
ZPWM1219	APR A2 SA VOLT LEV 1, MPPT DIS, PCU-A	*none*
ZPWM1220	APR A2 SA VOLT LEV 1, MPPT ENA, PCU-A	*none*
ZPWM1221	APR A2 SA VOLT LEV 2, MPPT DIS, PCU-A	*none*
ZPWM1222	APR A2 SA VOLT LEV 2, MPPT ENA, PCU-A	*none*
ZPWM1223	APR A2 SA VOLT LEV 3, MPPT DIS, PCU-A	*none*
ZPWM1224	APR A2 SA VOLT LEV 3, MPPT ENA, PCU-A	*none*
ZPWM1225	APR A2 SA VOLT LEV 4, MPPT DIS, PCU-A	*none*
ZPWM1226	APR A2 SA VOLT LEV 4, MPPT ENA, PCU-A	*none*
ZPWM1227	APR A2 SA VOLT LEV 5, MPPT DIS, PCU-A	*none*
ZPWM1228	APR A2 SA VOLT LEV 5, MPPT ENA, PCU-A	*none*
ZPWM1229	APR A2 SA VOLT LEV 6, MPPT DIS, PCU-A	*none*
ZPWM1230	APR A2 SA VOLT LEV 6, MPPT ENA, PCU-A	*none*
ZPWM1231	APR A2 SA VOLT LEV 7, MPPT DIS, PCU-A	*none*
ZPWM1232	APR A2 SA VOLT LEV 7, MPPT ENA, PCU-A	*none*

Name	Designation	Verif TM
ZPWM1233	APR A2 SA VOLT LEV ARM, PCU-A	*none*
ZPWM1234	APR A3 SA VOLT LEV 0, MPPT DIS, PCU-A	*none*
ZPWM1235	APR A3 SA VOLT LEV 0, MPPT ENA, PCU-A	*none*
ZPWM1236	APR A3 SA VOLT LEV 1, MPPT DIS, PCU-A	*none*
ZPWM1237	APR A3 SA VOLT LEV 1, MPPT ENA, PCU-A	*none*
ZPWM1238	APR A3 SA VOLT LEV 2, MPPT DIS, PCU-A	*none*
ZPWM1239	APR A3 SA VOLT LEV 2, MPPT ENA, PCU-A	*none*
ZPWM1240	APR A3 SA VOLT LEV 3, MPPT DIS, PCU-A	*none*
ZPWM1241	APR A3 SA VOLT LEV 3, MPPT ENA, PCU-A	*none*
ZPWM1242	APR A3 SA VOLT LEV 4, MPPT DIS, PCU-A	*none*
ZPWM1243	APR A3 SA VOLT LEV 4, MPPT ENA, PCU-A	*none*
ZPWM1244	APR A3 SA VOLT LEV 5, MPPT DIS, PCU-A	*none*
ZPWM1245	APR A3 SA VOLT LEV 5, MPPT ENA, PCU-A	*none*
ZPWM1246	APR A3 SA VOLT LEV 6, MPPT DIS, PCU-A	*none*
ZPWM1247	APR A3 SA VOLT LEV 6, MPPT ENA, PCU-A	*none*
ZPWM1248	APR A3 SA VOLT LEV 7, MPPT DIS, PCU-A	*none*
ZPWM1249	APR A3 SA VOLT LEV 7, MPPT ENA, PCU-A	*none*
ZPWM1250	APR A3 SA VOLT LEV ARM, PCU-A	*none*
ZPWM1251	APR B1 SA VOLT LEV 0, MPPT DIS, PCU-A	*none*
ZPWM1252	APR B1 SA VOLT LEV 0, MPPT ENA, PCU-A	*none*
ZPWM1253	APR B1 SA VOLT LEV 1, MPPT DIS, PCU-A	*none*
ZPWM1254	APR B1 SA VOLT LEV 1, MPPT ENA, PCU-A	*none*
ZPWM1255	APR B1 SA VOLT LEV 2, MPPT DIS, PCU-A	*none*
ZPWM1256	APR B1 SA VOLT LEV 2, MPPT ENA, PCU-A	*none*
ZPWM1257	APR B1 SA VOLT LEV 3, MPPT DIS, PCU-A	*none*
ZPWM1258	APR B1 SA VOLT LEV 3, MPPT ENA, PCU-A	*none*
ZPWM1259	APR B1 SA VOLT LEV 4, MPPT DIS, PCU-A	*none*

Name	Designation	Verif TM
ZPWM1260	APR B1 SA VOLT LEV 4, MPPT ENA, PCU-A	*none*
ZPWM1261	APR B1 SA VOLT LEV 5, MPPT DIS, PCU-A	*none*
ZPWM1262	APR B1 SA VOLT LEV 5, MPPT ENA, PCU-A	*none*
ZPWM1263	APR B1 SA VOLT LEV 6, MPPT DIS, PCU-A	*none*
ZPWM1264	APR B1 SA VOLT LEV 6, MPPT ENA, PCU-A	*none*
ZPWM1265	APR B1 SA VOLT LEV 7, MPPT DIS, PCU-A	*none*
ZPWM1266	APR B1 SA VOLT LEV 7, MPPT ENA, PCU-A	*none*
ZPWM1267	APR B1 SA VOLT LEV ARM, PCU-A	*none*
ZPWM1268	APR B2 SA VOLT LEV 0, MPPT DIS, PCU-A	*none*
ZPWM1269	APR B2 SA VOLT LEV 0, MPPT ENA, PCU-A	*none*
ZPWM1270	APR B2 SA VOLT LEV 1, MPPT DIS, PCU-A	*none*
ZPWM1271	APR B2 SA VOLT LEV 1, MPPT ENA, PCU-A	*none*
ZPWM1272	APR B2 SA VOLT LEV 2, MPPT DIS, PCU-A	*none*
ZPWM1273	APR B2 SA VOLT LEV 2, MPPT ENA, PCU-A	*none*
ZPWM1274	APR B2 SA VOLT LEV 3, MPPT DIS, PCU-A	*none*
ZPWM1275	APR B2 SA VOLT LEV 3, MPPT ENA, PCU-A	*none*
ZPWM1276	APR B2 SA VOLT LEV 4, MPPT DIS, PCU-A	*none*
ZPWM1277	APR B2 SA VOLT LEV 4, MPPT ENA, PCU-A	*none*
ZPWM1278	APR B2 SA VOLT LEV 5, MPPT DIS, PCU-A	*none*
ZPWM1279	APR B2 SA VOLT LEV 5, MPPT ENA, PCU-A	*none*
ZPWM1280	APR B2 SA VOLT LEV 6, MPPT DIS, PCU-A	*none*
ZPWM1281	APR B2 SA VOLT LEV 6, MPPT ENA, PCU-A	*none*
ZPWM1282	APR B2 SA VOLT LEV 7, MPPT DIS, PCU-A	*none*
ZPWM1283	APR B2 SA VOLT LEV 7, MPPT ENA, PCU-A	*none*
ZPWM1284	APR B2 SA VOLT LEV ARM, PCU-A	*none*
ZPWM1285	APR B3 SA VOLT LEV 0, MPPT DIS, PCU-A	*none*
ZPWM1286	APR B3 SA VOLT LEV 0, MPPT ENA, PCU-A	*none*

Name	Designation	Verif TM
ZPWM1287	APR B3 SA VOLT LEV 1, MPPT DIS, PCU-A	*none*
ZPWM1288	APR B3 SA VOLT LEV 1, MPPT ENA, PCU-A	*none*
ZPWM1289	APR B3 SA VOLT LEV 2, MPPT DIS, PCU-A	*none*
ZPWM1290	APR B3 SA VOLT LEV 2, MPPT ENA, PCU-A	*none*
ZPWM1291	APR B3 SA VOLT LEV 3, MPPT DIS, PCU-A	*none*
ZPWM1292	APR B3 SA VOLT LEV 3, MPPT ENA, PCU-A	*none*
ZPWM1293	APR B3 SA VOLT LEV 4, MPPT DIS, PCU-A	*none*
ZPWM1294	APR B3 SA VOLT LEV 4, MPPT ENA, PCU-A	*none*
ZPWM1295	APR B3 SA VOLT LEV 5, MPPT DIS, PCU-A	*none*
ZPWM1296	APR B3 SA VOLT LEV 5, MPPT ENA, PCU-A	*none*
ZPWM1297	APR B3 SA VOLT LEV 6, MPPT DIS, PCU-A	*none*
ZPWM1298	APR B3 SA VOLT LEV 6, MPPT ENA, PCU-A	*none*
ZPWM1299	APR B3 SA VOLT LEV 7, MPPT DIS, PCU-A	*none*
ZPWM1300	APR B3 SA VOLT LEV 7, MPPT ENA, PCU-A	*none*
ZPWM1301	APR B3 SA VOLT LEV ARM, PCU-A	*none*
ZPWM1308	CM B MBR OFF, PCU-A	*none*
ZPWM1309	CM B MBR ON, PCU-A	*none*
ZPWM1991	Generic MLC PCU-A RTU-A Route of Cmd	*none*
ZPWM1993	Generic MLC PCU-A RTU-B Route of Cmd	*none*
ZPWM1999	Generic MLC for PCU-A	*none*

8.2. PCU-Redundant TC Packets

Link to PDF-file: PCU-redundant.pdf

Name	Designation	Verif TM
ZPWM4000SWON	APR A1 ON, PCU-B	*none*

Name	Designation	Verif TM
ZPWM4001SWON	APR A2 ON, PCU-B	*none*
ZPWM4002SWON	APR A3 ON, PCU-B	*none*
ZPWM4003SWON	APR B1 ON, PCU-B	*none*
ZPWM4004SWON	APR B2 ON, PCU-B	*none*
ZPWM4005SWON	APR B3 ON, PCU-B	*none*
ZPWM4006	BCR 1 CH CURR LEV 0, PCU-B	*none*
ZPWM4007	BCR 1 CH CURR LEV 1, PCU-B	*none*
ZPWM4008	BCR 1 EOC VOLT LEV 0, PCU-B	*none*
ZPWM4009	BCR 1 EOC VOLT LEV 1, PCU-B	*none*
ZPWM4010	BCR 1 EOC VOLT LEV 2, PCU-B	*none*
ZPWM4011	BCR 1 EOC VOLT LEV 3, PCU-B	*none*
ZPWM4012	BCR 1 EOC VOLT LEV 4, PCU-B	*none*
ZPWM4013	BCR 1 EOC VOLT LEV 5, PCU-B	*none*
ZPWM4014	BCR 1 EOC VOLT LEV 6, PCU-B	*none*
ZPWM4015	BCR 1 EOC VOLT LEV 7, PCU-B	*none*
ZPWM4016SWOF	BCR 1 OFF, PCU-B	*none*
ZPWM4017SWON	BCR 1 ON, PCU-B	*none*
ZPWM4018	BCR 2 CH CURR LEV 0, PCU-B	*none*
ZPWM4019	BCR 2 CH CURR LEV 1, PCU-B	*none*
ZPWM4020	BCR 2 EOC VOLT LEV 0, PCU-B	*none*
ZPWM4021	BCR 2 EOC VOLT LEV 1, PCU-B	*none*
ZPWM4022	BCR 2 EOC VOLT LEV 2, PCU-B	*none*
ZPWM4023	BCR 2 EOC VOLT LEV 3, PCU-B	*none*
ZPWM4024	BCR 2 EOC VOLT LEV 4, PCU-B	*none*

Name	Designation	Verif TM
ZPWM4025	BCR 2 EOC VOLT LEV 5, PCU-B	*none*
ZPWM4026	BCR 2 EOC VOLT LEV 6, PCU-B	*none*
ZPWM4027	BCR 2 EOC VOLT LEV 7, PCU-B	*none*
ZPWM4028SWOF	BCR 2 OFF, PCU-B	*none*
ZPWM4029SWON	BCR 2 ON, PCU-B	*none*
ZPWM4030	BCR 3 CH CURR LEV 0, PCU-B	*none*
ZPWM4031	BCR 3 CH CURR LEV 1, PCU-B	*none*
ZPWM4032	BCR 3 EOC VOLT LEV 0, PCU-B	*none*
ZPWM4033	BCR 3 EOC VOLT LEV 1, PCU-B	*none*
ZPWM4034	BCR 3 EOC VOLT LEV 2, PCU-B	*none*
ZPWM4035	BCR 3 EOC VOLT LEV 3, PCU-B	*none*
ZPWM4036	BCR 3 EOC VOLT LEV 4, PCU-B	*none*
ZPWM4037	BCR 3 EOC VOLT LEV 5, PCU-B	*none*
ZPWM4038	BCR 3 EOC VOLT LEV 6, PCU-B	*none*
ZPWM4039	BCR 3 EOC VOLT LEV 7, PCU-B	*none*
ZPWM4040SWOF	BCR 3 OFF, PCU-B	*none*
ZPWM4041SWON	BCR 3 ON, PCU-B	*none*
ZPWM4042SWOF	BDR 1 OFF, PCU-B	*none*
ZPWM4043SWOF	BDR 1 OFF ARM, PCU-B	*none*
ZPWM4044SWON	BDR 1 ON, PCU-B	*none*
ZPWM4045SWOF	BDR 2 OFF, PCU-B	*none*
ZPWM4046SWOF	BDR 2 OFF ARM, PCU-B	*none*
ZPWM4047SWON	BDR 2 ON, PCU-B	*none*
ZPWM4048SWOF	BDR 3 OFF, PCU-B	*none*

Name	Designation	Verif TM
ZPWM4049SWOF	BDR 3 OFF ARM, PCU-B	*none*
ZPWM4050SWON	BDR 3 ON, PCU-B	*none*
ZPWM4051SWOF	BDA 1 OFF, PCU-B	*none*
ZPWM4052SWOF	BDA 1 OFF ARM, PCU-B	*none*
ZPWM4053SWON	BDA 1 ON, PCU-B	*none*
ZPWM4054SWOF	BDA 2 OFF, PCU-B	*none*
ZPWM4055SWOF	BDA 2 OFF ARM, PCU-B	*none*
ZPWM4056SWON	BDA 2 ON, PCU-B	*none*
ZPWM4057SWOF	MB RECONN OFF, PCU-B	*none*
ZPWM4058SWON	MB RECONN ON, PCU-B	*none*
ZPWM4059	START TM READ, PCU-B	*none*
ZPWM4100SWOF	BDA 3 OFF, PCU-B	*none*
ZPWM4101SWOF	BDA 3 OFF ARM, PCU-B	*none*
ZPWM4102SWON	BDA 3 ON, PCU-B	*none*
ZPWM4103SWOF	BDA 4 OFF, PCU-B	*none*
ZPWM4104SWOF	BDA 4 OFF ARM, PCU-B	*none*
ZPWM4105SWON	BDA 4 ON, PCU-B	*none*
ZPWM4200	APR A1 SA VOLT LEV 0, MPPT DIS, PCU-B	*none*
ZPWM4201	APR A1 SA VOLT LEV 0, MPPT ENA, PCU-B	*none*
ZPWM4202	APR A1 SA VOLT LEV 1, MPPT DIS, PCU-B	*none*
ZPWM4203	APR A1 SA VOLT LEV 1, MPPT ENA, PCU-B	*none*
ZPWM4204	APR A1 SA VOLT LEV 2, MPPT DIS, PCU-B	*none*
ZPWM4205	APR A1 SA VOLT LEV 2, MPPT ENA, PCU-B	*none*
ZPWM4206	APR A1 SA VOLT LEV 3, MPPT DIS, PCU-B	*none*

Name	Designation	Verif TM
ZPWM4207	APR A1 SA VOLT LEV 3, MPPT ENA, PCU-B	*none*
ZPWM4208	APR A1 SA VOLT LEV 4, MPPT DIS, PCU-B	*none*
ZPWM4209	APR A1 SA VOLT LEV 4, MPPT ENA, PCU-B	*none*
ZPWM4210	APR A1 SA VOLT LEV 5, MPPT DIS, PCU-B	*none*
ZPWM4211	APR A1 SA VOLT LEV 5, MPPT ENA, PCU-B	*none*
ZPWM4212	APR A1 SA VOLT LEV 6, MPPT DIS, PCU-B	*none*
ZPWM4213	APR A1 SA VOLT LEV 6, MPPT ENA, PCU-B	*none*
ZPWM4214	APR A1 SA VOLT LEV 7, MPPT DIS, PCU-B	*none*
ZPWM4215	APR A1 SA VOLT LEV 7, MPPT ENA, PCU-B	*none*
ZPWM4216	APR A1 SA VOLT LEV ARM, PCU-B	*none*
ZPWM4217	APR A2 SA VOLT LEV 0, MPPT DIS, PCU-B	*none*
ZPWM4218	APR A2 SA VOLT LEV 0, MPPT ENA, PCU-B	*none*
ZPWM4219	APR A2 SA VOLT LEV 1, MPPT DIS, PCU-B	*none*
ZPWM4220	APR A2 SA VOLT LEV 1, MPPT ENA, PCU-B	*none*
ZPWM4221	APR A2 SA VOLT LEV 2, MPPT DIS, PCU-B	*none*
ZPWM4222	APR A2 SA VOLT LEV 2, MPPT ENA, PCU-B	*none*
ZPWM4223	APR A2 SA VOLT LEV 3, MPPT DIS, PCU-B	*none*
ZPWM4224	APR A2 SA VOLT LEV 3, MPPT ENA, PCU-B	*none*
ZPWM4225	APR A2 SA VOLT LEV 4, MPPT DIS, PCU-B	*none*
ZPWM4226	APR A2 SA VOLT LEV 4, MPPT ENA, PCU-B	*none*
ZPWM4227	APR A2 SA VOLT LEV 5, MPPT DIS, PCU-B	*none*
ZPWM4228	APR A2 SA VOLT LEV 5, MPPT ENA, PCU-B	*none*
ZPWM4229	APR A2 SA VOLT LEV 6, MPPT DIS, PCU-B	*none*
ZPWM4230	APR A2 SA VOLT LEV 6, MPPT ENA, PCU-B	*none*

Name	Designation	Verif TM
ZPWM4231	APR A2 SA VOLT LEV 7, MPPT DIS, PCU-B	*none*
ZPWM4232	APR A2 SA VOLT LEV 7, MPPT ENA, PCU-B	*none*
ZPWM4233	APR A2 SA VOLT LEV ARM, PCU-B	*none*
ZPWM4234	APR A3 SA VOLT LEV 0, MPPT DIS, PCU-B	*none*
ZPWM4235	APR A3 SA VOLT LEV 0, MPPT ENA, PCU-B	*none*
ZPWM4236	APR A3 SA VOLT LEV 1, MPPT DIS, PCU-B	*none*
ZPWM4237	APR A3 SA VOLT LEV 1, MPPT ENA, PCU-B	*none*
ZPWM4238	APR A3 SA VOLT LEV 2, MPPT DIS, PCU-B	*none*
ZPWM4239	APR A3 SA VOLT LEV 2, MPPT ENA, PCU-B	*none*
ZPWM4240	APR A3 SA VOLT LEV 3, MPPT DIS, PCU-B	*none*
ZPWM4241	APR A3 SA VOLT LEV 3, MPPT ENA, PCU-B	*none*
ZPWM4242	APR A3 SA VOLT LEV 4, MPPT DIS, PCU-B	*none*
ZPWM4243	APR A3 SA VOLT LEV 4, MPPT ENA, PCU-B	*none*
ZPWM4244	APR A3 SA VOLT LEV 5, MPPT DIS, PCU-B	*none*
ZPWM4245	APR A3 SA VOLT LEV 5, MPPT ENA, PCU-B	*none*
ZPWM4246	APR A3 SA VOLT LEV 6, MPPT DIS, PCU-B	*none*
ZPWM4247	APR A3 SA VOLT LEV 6, MPPT ENA, PCU-B	*none*
ZPWM4248	APR A3 SA VOLT LEV 7, MPPT DIS, PCU-B	*none*
ZPWM4249	APR A3 SA VOLT LEV 7, MPPT ENA, PCU-B	*none*
ZPWM4250	APR A3 SA VOLT LEV ARM, PCU-B	*none*
ZPWM4251	APR B1 SA VOLT LEV 0, MPPT DIS, PCU-B	*none*
ZPWM4252	APR B1 SA VOLT LEV 0, MPPT ENA, PCU-B	*none*
ZPWM4253	APR B1 SA VOLT LEV 1, MPPT DIS, PCU-B	*none*
ZPWM4254	APR B1 SA VOLT LEV 1, MPPT ENA, PCU-B	*none*

Name	Designation	Verif TM
ZPWM4255	APR B1 SA VOLT LEV 2, MPPT DIS, PCU-B	*none*
ZPWM4256	APR B1 SA VOLT LEV 2, MPPT ENA, PCU-B	*none*
ZPWM4257	APR B1 SA VOLT LEV 3, MPPT DIS, PCU-B	*none*
ZPWM4258	APR B1 SA VOLT LEV 3, MPPT ENA, PCU-B	*none*
ZPWM4259	APR B1 SA VOLT LEV 4, MPPT DIS, PCU-B	*none*
ZPWM4260	APR B1 SA VOLT LEV 4, MPPT ENA, PCU-B	*none*
ZPWM4261	APR B1 SA VOLT LEV 5, MPPT DIS, PCU-B	*none*
ZPWM4262	APR B1 SA VOLT LEV 5, MPPT ENA, PCU-B	*none*
ZPWM4263	APR B1 SA VOLT LEV 6, MPPT DIS, PCU-B	*none*
ZPWM4264	APR B1 SA VOLT LEV 6, MPPT ENA, PCU-B	*none*
ZPWM4265	APR B1 SA VOLT LEV 7, MPPT DIS, PCU-B	*none*
ZPWM4266	APR B1 SA VOLT LEV 7, MPPT ENA, PCU-B	*none*
ZPWM4267	APR B1 SA VOLT LEV ARM, PCU-B	*none*
ZPWM4268	APR B2 SA VOLT LEV 0, MPPT DIS, PCU-B	*none*
ZPWM4269	APR B2 SA VOLT LEV 0, MPPT ENA, PCU-B	*none*
ZPWM4270	APR B2 SA VOLT LEV 1, MPPT DIS, PCU-B	*none*
ZPWM4271	APR B2 SA VOLT LEV 1, MPPT ENA, PCU-B	*none*
ZPWM4272	APR B2 SA VOLT LEV 2, MPPT DIS, PCU-B	*none*
ZPWM4273	APR B2 SA VOLT LEV 2, MPPT ENA, PCU-B	*none*
ZPWM4274	APR B2 SA VOLT LEV 3, MPPT DIS, PCU-B	*none*
ZPWM4275	APR B2 SA VOLT LEV 3, MPPT ENA, PCU-B	*none*
ZPWM4276	APR B2 SA VOLT LEV 4, MPPT DIS, PCU-B	*none*
ZPWM4277	APR B2 SA VOLT LEV 4, MPPT ENA, PCU-B	*none*
ZPWM4278	APR B2 SA VOLT LEV 5, MPPT DIS, PCU-B	*none*

Name	Designation	Verif TM
ZPWM4279	APR B2 SA VOLT LEV 5, MPPT ENA, PCU-B	*none*
ZPWM4280	APR B2 SA VOLT LEV 6, MPPT DIS, PCU-B	*none*
ZPWM4281	APR B2 SA VOLT LEV 6, MPPT ENA, PCU-B	*none*
ZPWM4282	APR B2 SA VOLT LEV 7, MPPT DIS, PCU-B	*none*
ZPWM4283	APR B2 SA VOLT LEV 7, MPPT ENA, PCU-B	*none*
ZPWM4284	APR B2 SA VOLT LEV ARM, PCU-B	*none*
ZPWM4285	APR B3 SA VOLT LEV 0, MPPT DIS, PCU-B	*none*
ZPWM4286	APR B3 SA VOLT LEV 0, MPPT ENA, PCU-B	*none*
ZPWM4287	APR B3 SA VOLT LEV 1, MPPT DIS, PCU-B	*none*
ZPWM4288	APR B3 SA VOLT LEV 1, MPPT ENA, PCU-B	*none*
ZPWM4289	APR B3 SA VOLT LEV 2, MPPT DIS, PCU-B	*none*
ZPWM4290	APR B3 SA VOLT LEV 2, MPPT ENA, PCU-B	*none*
ZPWM4291	APR B3 SA VOLT LEV 3, MPPT DIS, PCU-B	*none*
ZPWM4292	APR B3 SA VOLT LEV 3, MPPT ENA, PCU-B	*none*
ZPWM4293	APR B3 SA VOLT LEV 4, MPPT DIS, PCU-B	*none*
ZPWM4294	APR B3 SA VOLT LEV 4, MPPT ENA, PCU-B	*none*
ZPWM4295	APR B3 SA VOLT LEV 5, MPPT DIS, PCU-B	*none*
ZPWM4296	APR B3 SA VOLT LEV 5, MPPT ENA, PCU-B	*none*
ZPWM4297	APR B3 SA VOLT LEV 6, MPPT DIS, PCU-B	*none*
ZPWM4298	APR B3 SA VOLT LEV 6, MPPT ENA, PCU-B	*none*
ZPWM4299	APR B3 SA VOLT LEV 7, MPPT DIS, PCU-B	*none*
ZPWM4300	APR B3 SA VOLT LEV 7, MPPT ENA, PCU-B	*none*
ZPWM4301	APR B3 SA VOLT LEV ARM, PCU-B	*none*
ZPWM4308	CM B MBR OFF, PCU-B	*none*

Name	Designation	Verif TM
ZPWM4309	CM B MBR ON, PCU-B	*none*
ZPWM4991	Generic MLC PCU-B RTU-A Route of Cmd	*none*
ZPWM4993	Generic MLC PCU-B RTU-B Route of Cmd	*none*
ZPWM4999	Generic MLC for PCU-B	*none*

8.3. SS-PDU (nominal) TC Packets

Link to PDF-file: SS-PDU-nominal.pdf

Name	Designation	Verif TM
ZPWM2010	UPDATE ALL TM, PDU-S/S-A	*none*
ZPWM2011	UPDATE SWITCH TM, PDU-S/S-A	*none*
ZPWM2012SWON	TM POWER ON, PDU-S/S-A	*none*
ZPWM2013SWOF	TM POWER OFF, PDU-S/S-A	*none*
ZPWM2014	TMpyro S/S-PDU, PDU-S/S-A	*none*
ZPWM2015	RESET PYRO BUFFERS, PDU-S/S-A	*none*
ZPWM2016	START CONTINUOUS, PDU-S/S-A	*none*
ZPWM2017SWON	TWTA A, LCL 1A ON, PDU-S/S-A	NPWA2360
ZPWM2018SWOF	TWTA A, LCL 1A OFF, PDU-S/S-A	NPWA2360
ZPWM2019SWON	TX A, LCL 2A ON, PDU-S/S-A	NPWA2360
ZPWM2020SWOF	TX A, LCL 2A OFF, PDU-S/S-A	NPWA2360
ZPWM2021SWON	AIU-RCS 1, LCL 3A ON, PDU-S/S-A	NPWA2370
ZPWM2022SWOF	AIU-RCS 1, LCL 3A OFF, PDU-S/S-A	NPWA2370
ZPWM2023SWON	NAVCAM/STR1, LCL 4A ON, PDU-S/S-A	NPWA2370
ZPWM2024SWOF	NAVCAM/STR1, LCL 4A OFF, PDU-S/S-A	NPWA2370
ZPWM2025SWON	GYROS&ACC1, LCL 5A ON, PDU-S/S-A	NPWA2380
ZPWM2026SWOF	GYROS&ACC1, LCL 5A OFF, PDU-S/S-A	NPWA2380
ZPWM2027SWON	SADE A, LCL 6A ON, PDU-S/S-A	NPWA2380
ZPWM2028SWOF	SADE A, LCL 6A OFF, PDU-S/S-A	NPWA2380
ZPWM2029SWON	SSMM 1, LCL 7A ON, PDU-S/S-A	NPWA2390
ZPWM2030SWOF	SSMM 1, LCL 7A OFF, PDU-S/S-A	NPWA2390

Name	Designation	Verif TM
ZPWM2031SWON	RTU S/S PS1, LCL 8A ON, PDU-S/S-A	NPWA2390
ZPWM2032SWOF	RTU S/S PS1, LCL 8A OFF, PDU-S/S-A	NPWA2390
ZPWM2033SWON	RTU P/L PS1, LCL 9A ON, PDU-S/S-A	NPWA2400
ZPWM2034SWOF	RTU P/L PS1, LCL 9A OFF, PDU-S/S-A	NPWA2400
ZPWM2035SWON	USO A, LCL 10A ON, PDU-S/S-A	NPWA2400
ZPWM2036SWOF	USO A, LCL 10A OFF, PDU-S/S-A	NPWA2400
ZPWM2037SWON	AIU PS 1, LCL 11A ON, PDU-S/S-A	NPWA2410
ZPWM2038SWOF	AIU PS 1, LCL 11A OFF, PDU-S/S-A	NPWA2410
ZPWM2039SWON	PRESS TRANS A, LCL 12A ON, PDU-S/S-A	NPWA2410
ZPWM2040SWOF	PRESS TRANS A, LCL 12A OFF, PDU-S/S-A	NPWA2410
ZPWM2041SWON	WDE HTR 1, LCL 13A ON, PDU-S/S-A	NPWA2420
ZPWM2042SWOF	WDE HTR 1, LCL 13A OFF, PDU-S/S-A	NPWA2420
ZPWM2043SWON	WDE HTR 3, LCL 14A ON, PDU-S/S-A	NPWA2420
ZPWM2044SWOF	WDE HTR 3, LCL 14A OFF, PDU-S/S-A	NPWA2420
ZPWM2045SWON	LBM/VIRTDECH, LCL 15A ON, PDU-S/S-A	NPWA2440
ZPWM2046SWOF	LBM/VIRTDECH, LCL 15A OFF, PDU-S/S-A	NPWA2440
ZPWM2047SWON	UBMP/+Z/-ZTNKG, LCL 16A ON, PDU-S/S-A	NPWA2440
ZPWM2048SWOF	UBMP/+Z/-ZTNKG, LCL 16A OFF, PDU-S/S-A	NPWA2440
ZPWM2049SWON	VIRTIS, LCL 17A ON, PDU-S/S-A	NPWA2450
ZPWM2050SWOF	VIRTIS, LCL 17A OFF, PDU-S/S-A	NPWA2450
ZPWM2051SWON	RW1&2, LCL 18A ON, PDU-S/S-A	NPWA2450
ZPWM2052SWOF	RW1&2, LCL 18A OFF, PDU-S/S-A	NPWA2450
ZPWM2053SWON	STR1-2/NAVC1-2, LCL 19A ON, PDU-S/S-A	NPWA2340

Name	Designation	Verif TM
ZPWM2054SWOF	STR1-2/NAVC1-2, LCL 19A OFF, PDU-S/S-A	NPWA2340
ZPWM2055SWON	BATT 1-3, LCL 20A ON, PDU-S/S-A	NPWA2340
ZPWM2056SWOF	BATT 1-3, LCL 20A OFF, PDU-S/S-A	NPWA2340
ZPWM2057SWON	SADM+Y/SADM -Y, LCL 21A ON, PDU-S/S-A	NPWA2350
ZPWM2058SWOF	SADM+Y/SADM -Y, LCL 21A OFF, PDU-S/S-A	NPWA2350
ZPWM2059SWON	OSIR CCD+STR, LCL 22A ON, PDU-S/S-A	NPWA2350
ZPWM2060SWOF	OSIR CCD+STR, LCL 22A OFF, PDU-S/S-A	NPWA2350
ZPWM2061SWON	WDE1, LCL 23A ON, PDU-S/S-A	NPWA2280
ZPWM2062SWOF	WDE1, LCL 23A OFF, PDU-S/S-A	NPWA2280
ZPWM2063SWON	SPARE, LCL 24A ON, PDU-S/S-A	NPWA2280
ZPWM2064SWOF	SPARE, LCL 24A OFF, PDU-S/S-A	NPWA2280
ZPWM2065SWON	GYROS&ACC3, LCL 25A ON, PDU-S/S-A	NPWA2290
ZPWM2066SWOF	GYROS&ACC3, LCL 25A OFF, PDU-S/S-A	NPWA2290
ZPWM2067SWON	SPARE, LCL 26A ON, PDU-S/S-A	NPWA2290
ZPWM2068SWOF	SPARE, LCL 26A OFF, PDU-S/S-A	NPWA2290
ZPWM2069SWON	APME A, LCL 27A ON, PDU-S/S-A	NPWA2300
ZPWM2070SWOF	APME A, LCL 27A OFF, PDU-S/S-A	NPWA2300
ZPWM2071SWON	SPARE, LCL 28A ON, PDU-S/S-A	NPWA2300
ZPWM2072SWOF	SPARE, LCL 28A OFF, PDU-S/S-A	NPWA2300
ZPWM2073SWON	SPARE, LCL 29A ON, PDU-S/S-A	NPWA2310
ZPWM2074SWOF	SPARE, LCL 29A OFF, PDU-S/S-A	NPWA2310
ZPWM2075SWON	WDE 3, LCL 30A ON, PDU-S/S-A	NPWA2520
ZPWM2076SWOF	WDE 3, LCL 30A OFF, PDU-S/S-A	NPWA2520

Name	Designation	Verif TM
ZPWM2077	TWTA A, SEL LCL 1A CURR. PROF-A	*none*
ZPWM2078	TX A, SEL LCL 2A CURR. PROF-A	*none*
ZPWM2079	AIU-RCS 1, SEL LCL 3A CURR. PROF-A	*none*
ZPWM2080	NAVCAM/STR 1, SEL LCL 4A CURR. PROF-A	*none*
ZPWM2081	GYROS&ACC 1, SEL LCL 5A CURR. PROF-A	*none*
ZPWM2082	SADE A, SEL LCL 6A CURR. PROF-A	*none*
ZPWM2083	SSMM 1, SEL LCL 7A CURR. PROF-A	*none*
ZPWM2084	RTU S/S PS 1, SEL LCL 8A CURR. PROF-A	*none*
ZPWM2085	RTU P/L PS 1, SEL LCL 9A CURR. PROF-A	*none*
ZPWM2086	USO A, SEL LCL 10A CURR. PROF-A	*none*
ZPWM2087	AIU PS 1, SEL LCL 11A CURR. PROF-A	*none*
ZPWM2088	PRESS TRANS A, SEL LCL 12A CURR. PROF-A	*none*
ZPWM2089	WDE HTR 1, SEL LCL 13A CURR. PROF-A	*none*
ZPWM2090	WDE HTR 3, SEL LCL 14A CURR. PROF-A	*none*
ZPWM2091	LBM/VIRTDECH, SEL LCL 15A CURR. PROF-A	*none*
ZPWM2092	UBMP/+Z/-ZTNKG, SEL LCL 16A CURR. PROF-A	*none*
ZPWM2093	VIRTIS, SEL LCL 17A CURR. PROF-A	*none*
ZPWM2094	RW1&2, SEL LCL 18A CURR. PROF-A	*none*
ZPWM2095	STR1-2/NAVC1-2, SEL LCL 19A CURR. PROF-A	*none*
ZPWM2096	BATT 1-3, SEL LCL 20A CURR. PROF-A	*none*
ZPWM2097	SADM+Y/SADM -Y, SEL LCL 21A CURR. PROF-A	*none*
ZPWM2098	OSIR CCD+STR, SEL LCL 22A CURR. PROF-A	*none*
ZPWM2099	WDE1, SEL LCL 23A CURR. PROF-A	*none*

Name	Designation	Verif TM
ZPWM2100	SPARE, SEL LCL 24A CURR. PROF-A	*none*
ZPWM2101	GYROS&ACC 3, SEL LCL 25A CURR. PROF-A	*none*
ZPWM2102	SPARE, SEL LCL 26A CURR. PROF-A	*none*
ZPWM2103	APME A, SEL LCL 27A CURR. PROF-A	*none*
ZPWM2104	SPARE, SEL LCL 28A CURR. PROF-A	*none*
ZPWM2105	SPARE, SEL LCL 29A CURR. PROF-A	*none*
ZPWM2106	WDE 3, SEL LCL 30A CURR. PROF-A	*none*
ZPWM2107SWON	LOWER BOOM MOTOR, PWR SW 1A ON-A	*none*
ZPWM2108SWOF	LOWER BOOM MOTOR, PWR SW 1A OFF-A	*none*
ZPWM2109SWON	VIRTIS DECONT, HTR SW 2A ON-A	*none*
ZPWM2110SWOF	VIRTIS DECONT, HTR SW 2A OFF-A	*none*
ZPWM2111SWON	SPARE, HTR SW 3A ON-A	*none*
ZPWM2112SWOF	SPARE, HTR SW 3A OFF-A	*none*
ZPWM2113SWON	SPARE, HTR SW 4A ON-A	*none*
ZPWM2114SWOF	SPARE, HTR SW 4A OFF-A	*none*
ZPWM2115SWON	SPARE, HTR SW 5A ON-A	*none*
ZPWM2116SWOF	SPARE, HTR SW 5A OFF-A	*none*
ZPWM2117SWON	UPPER BOOM MOTOR, PWR SW 6A ON-A	*none*
ZPWM2118SWOF	UPPER BOOM MOTOR, PWR SW 6A OFF-A	*none*
ZPWM2119SWON	Z+ TANK GAUGE, HTR SW 7A ON-A	*none*
ZPWM2120SWOF	Z+ TANK GAUGE, HTR SW 7A OFF-A	*none*
ZPWM2121SWON	Z- TANK GAUGE, HTR SW 8A ON-A	*none*
ZPWM2122SWOF	Z- TANK GAUGE, HTR SW 8A OFF-A	*none*

Name	Designation	Verif TM
ZPWM2123SWON	VIRTIS CCD, HTR SW 9A ON-A	*none*
ZPWM2124SWOF	VIRTIS CCD, HTR SW 9A OFF-A	*none*
ZPWM2125SWON	SPARE, HTR SW 10A ON-A	*none*
ZPWM2126SWOF	SPARE, HTR SW 10A OFF-A	*none*
ZPWM2127SWON	SPARE, HTR SW 11A ON-A	*none*
ZPWM2128SWOF	SPARE, HTR SW 11A OFF-A	*none*
ZPWM2129SWON	SPARE, HTR SW 12A ON-A	*none*
ZPWM2130SWOF	SPARE, HTR SW 12A OFF-A	*none*
ZPWM2131SWON	RW 1, HTR SW 13A ON-A	*none*
ZPWM2132SWOF	RW 1, HTR SW 13A OFF-A	*none*
ZPWM2133SWON	RW 2, HTR SW 14A ON-A	*none*
ZPWM2134SWOF	RW 2, HTR SW 14A OFF-A	*none*
ZPWM2135SWON	RW 3 (NC), HTR SW 15A ON-A	*none*
ZPWM2136SWOF	RW 3 (NC), HTR SW 15A OFF-A	*none*
ZPWM2137SWON	RW 4 (NC), HTR SW 16A ON-A	*none*
ZPWM2138SWOF	RW 4 (NC), HTR SW 16A OFF-A	*none*
ZPWM2139SWON	STR 1, HTR SW 17A ON-A	*none*
ZPWM2140SWOF	STR 1, HTR SW 17A OFF-A	*none*
ZPWM2141SWON	STR 2, HTR SW 18A ON-A	*none*
ZPWM2142SWOF	STR 2, HTR SW 18A OFF-A	*none*
ZPWM2143SWON	NAVCAM 1, HTR SW 19A ON-A	*none*
ZPWM2144SWOF	NAVCAM 1, HTR SW 19A OFF-A	*none*
ZPWM2145SWON	NAVCAM 2, HTR SW 20A ON-A	*none*

Name	Designation	Verif TM
ZPWM2146SWOF	NAVCAM 2, HTR SW 20A OFF-A	*none*
ZPWM2147SWON	BATT 1, HTR SW 21A ON-A	*none*
ZPWM2148SWOF	BATT 1, HTR SW 21A OFF-A	*none*
ZPWM2149SWON	BATT 3, HTR SW 22A ON-A	*none*
ZPWM2150SWOF	BATT 3, HTR SW 22A OFF-A	*none*
ZPWM2151SWON	SPARE, HTR SW 23A ON-A	*none*
ZPWM2152SWOF	SPARE, HTR SW 23A OFF-A	*none*
ZPWM2153SWON	BATT 2, HTR SW 24A ON-A	*none*
ZPWM2154SWOF	BATT 2, HTR SW 24A OFF-A	*none*
ZPWM2155SWON	SPARE, HTR SW 25A ON-A	*none*
ZPWM2156SWOF	SPARE, HTR SW 25A OFF-A	*none*
ZPWM2157SWON	SPARE, HTR SW 26A ON-A	*none*
ZPWM2158SWOF	SPARE, HTR SW 26A OFF-A	*none*
ZPWM2159SWON	SADM +Y CASE/SHAFT, HTR SW 27A ON-A	*none*
ZPWM2160SWOF	SADM +Y CASE/SHAFT, HTR SW 27A OFF-A	*none*
ZPWM2161SWON	SADM -Y CASE/SHAFT, HTR SW 28A ON-A	*none*
ZPWM2162SWOF	SADM -Y CASE/SHAFT, HTR SW 28A OFF-A	*none*
ZPWM2163SWON	OSIRIS NAC+WAC CCD, HTR SW 29A ON-A	*none*
ZPWM2164SWOF	OSIRIS NAC+WAC CCD, HTR SW 29A OFF-A	*none*
ZPWM2165SWON	OSIRIS NAC+WAC STRUCT, HTR SW 30A ON-A	*none*
ZPWM2166SWOF	OSIRIS NAC+WAC STRUCT, HTR SW 30A OFF-A	*none*
ZPWM2167SWON	SPARE, HTR SW 31A ON-A	*none*
ZPWM2168SWOF	SPARE, HTR SW 31A OFF-A	*none*

Name	Designation	Verif TM
ZPWM2169SWON	SPARE, HTR SW 32A ON-A	*none*
ZPWM2170SWOF	SPARE, HTR SW 32A OFF-A	*none*
ZPWM2173SWON	TK 1A ON, PDU-S/S-A	*none*
ZPWM2174SWOF	TK 1A OFF, PDU-S/S-A	*none*
ZPWM2175SWON	TK 2A ON, PDU-S/S-A	*none*
ZPWM2176SWOF	TK 2A OFF, PDU-S/S-A	*none*
ZPWM2177SWON	TK 3A ON, PDU-S/S-A	*none*
ZPWM2178SWOF	TK 3A OFF, PDU-S/S-A	*none*
ZPWM2179SWON	TK 4A ON, PDU-S/S-A	*none*
ZPWM2180SWOF	TK 4A OFF, PDU-S/S-A	*none*
ZPWM2181SWON	TK 5A ON, PDU-S/S-A	*none*
ZPWM2182SWOF	TK 5A OFF, PDU-S/S-A	*none*
ZPWM2183SWON	TK 6A ON, PDU-S/S-A	*none*
ZPWM2184SWOF	TK 6A OFF, PDU-S/S-A	*none*
ZPWM2185SWON	TK 7A ON, PDU-S/S-A	*none*
ZPWM2186SWOF	TK 7A OFF, PDU-S/S-A	*none*
ZPWM2187SWON	TK 8A ON, PDU-S/S-A	*none*
ZPWM2188SWOF	TK 8A OFF, PDU-S/S-A	*none*
ZPWM2189SWON	TK 9A ON, PDU-S/S-A	*none*
ZPWM2190SWOF	TK 9A OFF, PDU-S/S-A	*none*
ZPWM2191SWON	TK 10A ON, PDU-S/S-A	*none*
ZPWM2192SWOF	TK 10A OFF, PDU-S/S-A	*none*
ZPWM2193SWON	TK 11A ON, PDU-S/S-A	*none*

Name	Designation	Verif TM
ZPWM2194SWOF	TK 11A OFF, PDU-S/S-A	*none*
ZPWM2195SWON	TK 12A ON, PDU-S/S-A	*none*
ZPWM2196SWOF	TK 12A OFF, PDU-S/S-A	*none*
ZPWM2197SWON	TK ARM A ON, PDU-S/S-A	*none*
ZPWM2198SWOF	TK ARM A OFF, PDU-S/S-A	*none*
ZPWM2199SWON	TK FIRE A ON, PDU-S/S-A	NPWA2550
ZPWM2200SWOF	TK FIRE A OFF, PDU-S/S-A	NPWA2550
ZPWM2201SWON	V23-N2O4 TLFV, PARM1 PYRO1A ON-A	*none*
ZPWM2202SWON	V24-N2O4 TLFV, PARM1 PYRO2A ON-A	*none*
ZPWM2203SWON	V25-MMH TLFV, PARM1 PYRO3A ON-A	*none*
ZPWM2204SWON	V26-MMH TLFV, PARM1 PYRO4A ON-A	*none*
ZPWM2205SWON	V02-HE 1 PV, PARM1 PYRO5A ON-A	*none*
ZPWM2206SWON	V32-HE 1 PV, PARM1 PYRO6A ON-A	*none*
ZPWM2207SWON	V12-N2O4 1 PV, PARM1 PYRO7A ON-A	*none*
ZPWM2208SWON	V13-N2O4 1 PV, PARM1 PYRO8A ON-A	*none*
ZPWM2209SWON	V18-MMH 1 PV, PARM1 PYRO9A ON-A	*none*
ZPWM2210SWON	V19-MMH 1 PV, PARM1 PYRO10A ON-A	*none*
ZPWM2211SWOF	V23-N2O4 TLFV, PARM1 PYRO1A OFF-A	*none*
ZPWM2212SWOF	V24-N2O4 TLFV, PARM1 PYRO2A OFF-A	*none*
ZPWM2213SWOF	V25-MMH TLFV, PARM1 PYRO3A OFF-A	*none*
ZPWM2214SWOF	V26-MMH TLFV, PARM1 PYRO4A OFF-A	*none*
ZPWM2215SWOF	V02-HE 1 PV, PARM1 PYRO5A OFF-A	*none*
ZPWM2216SWOF	V32-HE 1 PV, PARM1 PYRO6A OFF-A	*none*

Name	Designation	Verif TM
ZPWM2217SWOF	V12-N2O4 1 PV, PARM1 PYRO7A OFF-A	*none*
ZPWM2218SWOF	V13-N2O4 1 PV, PARM1 PYRO8A OFF-A	*none*
ZPWM2219SWOF	V18-MMH 1 PV, PARM1 PYRO9A OFF-A	*none*
ZPWM2220SWOF	V19-MMH 1 PV, PARM1 PYRO10A OFF-A	*none*
ZPWM2221SWON	V03-HE 2 PV, PARM2 PYRO1A ON-A	*none*
ZPWM2222SWON	V04-HE 2 PV, PARM2 PYRO2A ON-A	*none*
ZPWM2223SWON	V14-N2O4 2 PV, PARM2 PYRO3A ON-A	*none*
ZPWM2224SWON	V15-N2O4 2 PV, PARM2 PYRO4A ON-A	*none*
ZPWM2225SWON	V20-MMH 2 PV, PARM2 PYRO5A ON-A	*none*
ZPWM2226SWON	V21-MMH 2 PV, PARM2 PYRO6A ON-A	*none*
ZPWM2227SWOF	V03-HE 2 PV, PARM2 PYRO1A OFF-A	*none*
ZPWM2228SWOF	V04-HE 2 PV, PARM2 PYRO2A OFF-A	*none*
ZPWM2229SWOF	V14-N2O4 2 PV, PARM2 PYRO3A OFF-A	*none*
ZPWM2230SWOF	V15-N2O4 2 PV, PARM2 PYRO4A OFF-A	*none*
ZPWM2231SWOF	V20-MMH 2 PV, PARM2 PYRO5A OFF-A	*none*
ZPWM2232SWOF	V21-MMH 2 PV, PARM2 PYRO6A OFF-A	*none*
ZPWM2233SWON	V01-HE 1 IV, PARM3 PYRO1A ON-A	*none*
ZPWM2234SWON	V31-HE 1 IV, PARM3 PYRO2A ON-A	*none*
ZPWM2235SWON	V11-N2O4 1 PIV, PARM3 PYRO3A ON-A	*none*
ZPWM2236SWON	V27-N2O4 1 PIV, PARM3 PYRO4A ON-A	*none*
ZPWM2237SWON	V17-MMH 1 PIV, PARM3 PYRO5A ON-A	*none*
ZPWM2238SWON	V28-MMH 1 PIV,PARM3 PYRO6A ON-A	*none*
ZPWM2239SWON	HGA HDRM 1, PARM3 PYRO7A ON-A	*none*

Name	Designation	Verif TM
ZPWM2240SWON	HGA HDRM 2, PARM3 PYRO8A ON-A	*none*
ZPWM2241SWON	HGA HDRM 3, PARM3 PYRO9A ON-A	*none*
ZPWM2242SWOF	V01-HE 1 IV, PARM3 PYRO1A OFF-A	*none*
ZPWM2243SWOF	V31-HE 1 IV, PARM3 PYRO2A OFF-A	*none*
ZPWM2244SWOF	V11-N2O4 1 PIV, PARM3 PYRO3A OFF-A	*none*
ZPWM2245SWOF	V27-N2O4 1 PIV, PARM3 PYRO4A OFF-A	*none*
ZPWM2246SWOF	V17-MMH 1 PIV, PARM3 PYRO5A OFF-A	*none*
ZPWM2247SWOF	V28-MMH 1 PIV,PARM3 PYRO6A OFF-A	*none*
ZPWM2248SWOF	HGA HDRM 1, PARM3 PYRO7A OFF-A	*none*
ZPWM2249SWOF	HGA HDRM 2, PARM3 PYRO8A OFF-A	*none*
ZPWM2250SWOF	HGA HDRM 3, PARM3 PYRO9A OFF-A	*none*
ZPWM2251SWON	V05-PR 1 HP IV, PARM4 PYRO1A ON-A	*none*
ZPWM2252SWON	V06-PR 1 LP IV, PARM4 PYRO2A ON-A	*none*
ZPWM2253SWON	V07-PR 2 HP PV, PARM4 PYRO3A ON-A	*none*
ZPWM2254SWON	V08-PR 2 HP PV, PARM4 PYRO4A ON-A	*none*
ZPWM2255SWON	V09-PR 2 LP OV, PARM4 PYRO5A ON-A	*none*
ZPWM2256SWON	V10-PR 2 LP OV, PARM4 PYRO6A ON-A	*none*
ZPWM2257SWOF	V05-PR 1 HP IV, PARM4 PYRO1A OFF-A	*none*
ZPWM2258SWOF	V06-PR 1 LP IV, PARM4 PYRO2A OFF-A	*none*
ZPWM2259SWOF	V07-PR 2 HP PV, PARM4 PYRO3A OFF-A	*none*
ZPWM2260SWOF	V08-PR 2 HP PV, PARM4 PYRO4A OFF-A	*none*
ZPWM2261SWOF	V09-PR 2 LP OV, PARM4 PYRO5A OFF-A	*none*
ZPWM2262SWOF	V10-PR 2 LP OV, PARM4 PYRO6A OFF-A	*none*

Name	Designation	Verif TM
ZPWM2263SWON	V16-N2O4 LP IV, PARM5 PYRO1A ON-A	*none*
ZPWM2264SWON	V22-MMH LP IV, PARM5 PYRO2A ON-A	*none*
ZPWM2265SWON	V29-N2O4 LP IV, PARM5 PYRO3A ON-A	*none*
ZPWM2266SWON	V30-MMH LP IV, PARM5 PYRO4A ON-A	*none*
ZPWM2267SWOF	V16-N2O4 LP IV, PARM5 PYRO1A OFF-A	*none*
ZPWM2268SWOF	V22-MMH LP IV, PARM5 PYRO2A OFF-A	*none*
ZPWM2269SWOF	V29-N2O4 LP IV, PARM5 PYRO3A OFF-A	*none*
ZPWM2270SWOF	V30-MMH LP IV, PARM5 PYRO4A OFF-A	*none*
ZPWM2271SWON	PYRO ARM 1A ON, PDU-S/S-A	*none*
ZPWM2272SWON	PYRO ARM 2A ON, PDU-S/S-A	*none*
ZPWM2273SWON	PYRO ARM 3A ON, PDU-S/S-A	*none*
ZPWM2274SWON	PYRO ARM 4A ON, PDU-S/S-A	*none*
ZPWM2275SWON	PYRO ARM 5A ON, PDU-S/S-A	*none*
ZPWM2276SWOF	PYRO ARM 1A OFF, PDU-S/S-A	*none*
ZPWM2277SWOF	PYRO ARM 2A OFF, PDU-S/S-A	*none*
ZPWM2278SWOF	PYRO ARM 3A OFF, PDU-S/S-A	*none*
ZPWM2279SWOF	PYRO ARM 4A OFF, PDU-S/S-A	*none*
ZPWM2280SWOF	PYRO ARM 5A OFF, PDU-S/S-A	*none*
ZPWM2281SWON	PYRO POWER BAT1 A ON, PDU-S/S-A	*none*
ZPWM2282SWON	PYRO POWER BAT2 A ON, PDU-S/S-A	*none*
ZPWM2283SWON	PYRO POWER BUS A ON, PDU-S/S-A	*none*
ZPWM2284SWOF	PYRO POWER BAT1 A OFF, PDU-S/S-A	*none*
ZPWM2285SWOF	PYRO POWER BAT2 A OFF, PDU-S/S-A	*none*

Name	Designation	Verif TM
ZPWM2286SWOF	PYRO POWER BUS A OFF, PDU-S/S-A	*none*
ZPWM2287	PYRO FIRE A, PDU-S/S-A	NPWA2030
ZPWM2288SWON	TWTA B, LCL 1B ON, PDU-S/S-A	NPWA2680
ZPWM2289SWOF	TWTA B, LCL 1B OFF, PDU-S/S-A	NPWA2680
ZPWM2290SWON	TX B, LCL 2B ON, PDU-S/S-A	NPWA2680
ZPWM2291SWOF	TX B, LCL 2B OFF, PDU-S/S-A	NPWA2680
ZPWM2292SWON	AIU-RCS 2, LCL 3B ON, PDU-S/S-A	NPWA2690
ZPWM2293SWOF	AIU-RCS 2, LCL 3B OFF, PDU-S/S-A	NPWA2690
ZPWM2294SWON	NAVCAM/STR2, LCL 4B ON, PDU-S/S-A	NPWA2690
ZPWM2295SWOF	NAVCAM/STR2, LCL 4B OFF, PDU-S/S-A	NPWA2690
ZPWM2296SWON	GYROS&ACC2, LCL 5B ON, PDU-S/S-A	NPWA2700
ZPWM2297SWOF	GYROS&ACC2, LCL 5B OFF, PDU-S/S-A	NPWA2700
ZPWM2298SWON	SADE B, LCL 6B ON, PDU-S/S-A	NPWA2700
ZPWM2299SWOF	SADE B, LCL 6B OFF, PDU-S/S-A	NPWA2700
ZPWM2300SWON	SSMM 2, LCL 7B ON, PDU-S/S-A	NPWA2710
ZPWM2301SWOF	SSMM 2, LCL 7B OFF, PDU-S/S-A	NPWA2710
ZPWM2302SWON	RTU S/S PS2, LCL 8B ON, PDU-S/S-A	NPWA2710
ZPWM2303SWOF	RTU S/S PS2, LCL 8B OFF, PDU-S/S-A	NPWA2710
ZPWM2304SWON	RTU P/L PS2, LCL 9B ON, PDU-S/S-A	NPWA2720
ZPWM2305SWOF	RTU P/L PS2, LCL 9B OFF, PDU-S/S-A	NPWA2720
ZPWM2306SWON	USO B, LCL 10B ON, PDU-S/S-A	NPWA2720
ZPWM2307SWOF	USO B, LCL 10B OFF, PDU-S/S-A	NPWA2720
ZPWM2308SWON	AIU PS 2, LCL 11B ON, PDU-S/S-A	NPWA2730

Name	Designation	Verif TM
ZPWM2309SWOF	AIU PS 2, LCL 11B OFF, PDU-S/S-A	NPWA2730
ZPWM2310SWON	PRESS TRANS B, LCL 12B ON, PDU-S/S-A	NPWA2730
ZPWM2311SWOF	PRESS TRANS B, LCL 12B OFF, PDU-S/S-A	NPWA2730
ZPWM2312SWON	WDE HTR 2, LCL 13B ON, PDU-S/S-A	NPWA2740
ZPWM2313SWOF	WDE HTR 2, LCL 13B OFF, PDU-S/S-A	NPWA2740
ZPWM2314SWON	WDE HTR 4, LCL 14B ON, PDU-S/S-A	NPWA2740
ZPWM2315SWOF	WDE HTR 4, LCL 14B OFF, PDU-S/S-A	NPWA2740
ZPWM2316SWON	LBM/VIRTDECH, LCL 15B ON, PDU-S/S-A	NPWA2760
ZPWM2317SWOF	LBM/VIRTDECH, LCL 15B OFF, PDU-S/S-A	NPWA2760
ZPWM2318SWON	UBMP/+Z/-ZTNKG, LCL 16B ON, PDU-S/S-A	NPWA2760
ZPWM2319SWOF	UBMP/+Z/-ZTNKG, LCL 16B OFF, PDU-S/S-A	NPWA2760
ZPWM2320SWON	VIRTIS, LCL 17B ON, PDU-S/S-A	NPWA2770
ZPWM2321SWOF	VIRTIS, LCL 17B OFF, PDU-S/S-A	NPWA2770
ZPWM2322SWON	RW1&2, LCL 18B ON, PDU-S/S-A	NPWA2770
ZPWM2323SWOF	RW1&2, LCL 18B OFF, PDU-S/S-A	NPWA2770
ZPWM2324SWON	STR1-2/NAVC1-2, LCL 19B ON, PDU-S/S-A	NPWA2660
ZPWM2325SWOF	STR1-2/NAVC1-2, LCL 19B OFF, PDU-S/S-A	NPWA2660
ZPWM2326SWON	BATT 1-3, LCL 20B ON, PDU-S/S-A	NPWA2660
ZPWM2327SWOF	BATT 1-3, LCL 20B OFF, PDU-S/S-A	NPWA2660
ZPWM2328SWON	SADM+Y/SADM -Y, LCL 21B ON, PDU-S/S-A	NPWA2670
ZPWM2329SWOF	SADM+Y/SADM -Y, LCL 21B OFF, PDU-S/S-A	NPWA2670
ZPWM2330SWON	OSIR CCD+STR, LCL 22B ON, PDU-S/S-A	NPWA2670
ZPWM2331SWOF	OSIR CCD+STR, LCL 22B OFF, PDU-S/S-A	NPWA2670

Name	Designation	Verif TM
ZPWM2332SWON	WDE 2, LCL 23B ON, PDU-S/S-A	NPWA2600
ZPWM2333SWOF	WDE 2, LCL 23B OFF, PDU-S/S-A	NPWA2600
ZPWM2334SWON	SPARE, LCL 24B ON, PDU-S/S-A	NPWA2600
ZPWM2335SWOF	SPARE, LCL 24B OFF, PDU-S/S-A	NPWA2600
ZPWM2336SWON	SPARE, LCL 25B ON, PDU-S/S-A	NPWA2610
ZPWM2337SWOF	SPARE, LCL 25B OFF, PDU-S/S-A	NPWA2610
ZPWM2338SWON	SPARE, LCL 26B ON, PDU-S/S-A	NPWA2610
ZPWM2339SWOF	SPARE, LCL 26B OFF, PDU-S/S-A	NPWA2610
ZPWM2340SWON	APME B, LCL 27B ON, PDU-S/S-A	NPWA2620
ZPWM2341SWOF	APME B, LCL 27B OFF, PDU-S/S-A	NPWA2620
ZPWM2342SWON	SPARE, LCL 28B ON, PDU-S/S-A	NPWA2620
ZPWM2343SWOF	SPARE, LCL 28B OFF, PDU-S/S-A	NPWA2620
ZPWM2344SWON	SPARE, LCL 29B ON, PDU-S/S-A	NPWA2630
ZPWM2345SWOF	SPARE, LCL 29B OFF, PDU-S/S-A	NPWA2630
ZPWM2346SWON	WDE 4, LCL 30B ON, PDU-S/S-A	NPWA2840
ZPWM2347SWOF	WDE 4, LCL 30B OFF, PDU-S/S-A	NPWA2840
ZPWM2348	TWTA B, SEL LCL 1B CURR. PROF-A	*none*
ZPWM2349	TX B, SEL LCL 2B CURR. PROF-A	*none*
ZPWM2350	AIU-RCS 2, SEL LCL 3B CURR. PROF-A	*none*
ZPWM2351	NAVCAM/STR 2, SEL LCL 4B CURR. PROF-A	*none*
ZPWM2352	GYROS&ACC 2, SEL LCL 5B CURR. PROF-A	*none*
ZPWM2353	SADE B, SEL LCL 6B CURR. PROF-A	*none*
ZPWM2354	SSMM 2, SEL LCL 7B CURR. PROF-A	*none*

Name	Designation	Verif TM
ZPWM2355	RTU S/S PS 2, SEL LCL 8B CURR. PROF-A	*none*
ZPWM2356	RTU P/L PS 2, SEL LCL 9B CURR. PROF-A	*none*
ZPWM2357	USO B, SEL LCL 10B CURR. PROF-A	*none*
ZPWM2358	AIU PS 2, SEL LCL 11B CURR. PROF-A	*none*
ZPWM2359	PRESS TRANS B, SEL LCL 12B CURR. PROF-A	*none*
ZPWM2360	WDE HTR 2, SEL LCL 13B CURR. PROF-A	*none*
ZPWM2361	WDE HTR 4, SEL LCL 14B CURR. PROF-A	*none*
ZPWM2362	LBM/VIRTDECH, SEL LCL 15B CURR. PROF-A	*none*
ZPWM2363	UBMP/+Z/-ZTNKG, SEL LCL 16B CURR. PROF-A	*none*
ZPWM2364	VIRTIS, SEL LCL 17B CURR. PROF-A	*none*
ZPWM2365	RW1&2, SEL LCL 18B CURR. PROF-A	*none*
ZPWM2366	STR1-2/NAVC1-2, SEL LCL 19B CURR. PROF-A	*none*
ZPWM2367	BATT 1-3, SEL LCL 20B CURR. PROF-A	*none*
ZPWM2368	SADM+Y/SADM -Y, SEL LCL 21B CURR. PROF-A	*none*
ZPWM2369	OSIR CCD+STR, SEL LCL 22B CURR. PROF-A	*none*
ZPWM2370	WDE2, SEL LCL 23B CURR. PROF-A	*none*
ZPWM2371	SPARE, SEL LCL 24B CURR. PROF-A	*none*
ZPWM2372	SPARE, SEL LCL 25B CURR. PROF-A	*none*
ZPWM2373	SPARE, SEL LCL 26B CURR. PROF-A	*none*
ZPWM2374	APME B, SEL LCL 27B CURR. PROF-A	*none*
ZPWM2375	SPARE, SEL LCL 28B CURR. PROF-A	*none*
ZPWM2376	SPARE, SEL LCL 29B CURR. PROF-A	*none*
ZPWM2377	WDE 4, SEL LCL 30B CURR. PROF-A	*none*

Name	Designation	Verif TM
ZPWM2378SWON	LOWER BOOM MOTOR, PWR SW 1B ON-A	*none*
ZPWM2379SWOF	LOWER BOOM MOTOR, PWR SW 1B OFF-A	*none*
ZPWM2380SWON	VIRTIS DECONT, HTR SW 2B ON-A	*none*
ZPWM2381SWOF	VIRTIS DECONT, HTR SW 2B OFF-A	*none*
ZPWM2382SWON	SPARE, HTR SW 3B ON-A	*none*
ZPWM2383SWOF	SPARE, HTR SW 3B OFF-A	*none*
ZPWM2384SWON	SPARE, HTR SW 4B ON-A	*none*
ZPWM2385SWOF	SPARE, HTR SW 4B OFF-A	*none*
ZPWM2386SWON	SPARE, HTR SW 5B ON-A	*none*
ZPWM2387SWOF	SPARE, HTR SW 5B OFF-A	*none*
ZPWM2388SWON	UPPER BOOM MOTOR, PWR SW 6B ON-A	*none*
ZPWM2389SWOF	UPPER BOOM MOTOR, PWR SW 6B OFF-A	*none*
ZPWM2390SWON	Z+ TANK GAUGE, HTR SW 7B ON-A	*none*
ZPWM2391SWOF	Z+ TANK GAUGE, HTR SW 7B OFF-A	*none*
ZPWM2392SWON	Z- TANK GAUGE, HTR SW 8B ON-A	*none*
ZPWM2393SWOF	Z- TANK GAUGE, HTR SW 8B OFF-A	*none*
ZPWM2394SWON	VIRTIS CCD, HTR SW 9B ON-A	*none*
ZPWM2395SWOF	VIRTIS CCD, HTR SW 9B OFF-A	*none*
ZPWM2396SWON	SPARE, HTR SW 10B ON-A	*none*
ZPWM2397SWOF	SPARE, HTR SW 10B OFF-A	*none*
ZPWM2398SWON	SPARE, HTR SW 11B ON-A	*none*
ZPWM2399SWOF	SPARE, HTR SW 11B OFF-A	*none*
ZPWM2400SWON	SPARE, HTR SW 12B ON-A	*none*

Name	Designation	Verif TM
ZPWM2401SWOF	SPARE, HTR SW 12B OFF-A	*none*
ZPWM2402SWON	RW 1, HTR SW 13B ON-A	*none*
ZPWM2403SWOF	RW 1, HTR SW 13B OFF-A	*none*
ZPWM2404SWON	RW 2, HTR SW 14B ON-A	*none*
ZPWM2405SWOF	RW 2, HTR SW 14B OFF-A	*none*
ZPWM2406SWON	RW 3 (NC), HTR SW 15B ON-A	*none*
ZPWM2407SWOF	RW 3 (NC), HTR SW 15B OFF-A	*none*
ZPWM2408SWON	RW 4 (NC), HTR SW 16B ON-A	*none*
ZPWM2409SWOF	RW 4 (NC), HTR SW 16B OFF-A	*none*
ZPWM2410SWON	STR 1, HTR SW 17B ON-A	*none*
ZPWM2411SWOF	STR 1, HTR SW 17B OFF-A	*none*
ZPWM2412SWON	STR 2, HTR SW 18B ON-A	*none*
ZPWM2413SWOF	STR 2, HTR SW 18B OFF-A	*none*
ZPWM2414SWON	NAVCAM 1, HTR SW 19B ON-A	*none*
ZPWM2415SWOF	NAVCAM 1, HTR SW 19B OFF-A	*none*
ZPWM2416SWON	NAVCAM 2, HTR SW 20B ON-A	*none*
ZPWM2417SWOF	NAVCAM 2, HTR SW 20B OFF-A	*none*
ZPWM2418SWON	BATT 1, HTR SW 21B ON-A	*none*
ZPWM2419SWOF	BATT 1, HTR SW 21B OFF-A	*none*
ZPWM2420SWON	BATT 3, HTR SW 22B ON-A	*none*
ZPWM2421SWOF	BATT 3, HTR SW 22B OFF-A	*none*
ZPWM2422SWON	SPARE, HTR SW 23B ON-A	*none*
ZPWM2423SWOF	SPARE, HTR SW 23B OFF-A	*none*

Name	Designation	Verif TM
ZPWM2424SWON	BATT 2, HTR SW 24B ON-A	*none*
ZPWM2425SWOF	BATT 2, HTR SW 24B OFF-A	*none*
ZPWM2426SWON	SPARE, HTR SW 25B ON-A	*none*
ZPWM2427SWOF	SPARE, HTR SW 25B OFF-A	*none*
ZPWM2428SWON	SPARE, HTR SW 26B ON-A	*none*
ZPWM2429SWOF	SPARE, HTR SW 26B OFF-A	*none*
ZPWM2430SWON	SADM +Y CASE/SHAFT, HTR SW 27B ON-A	*none*
ZPWM2431SWOF	SADM +Y CASE/SHAFT, HTR SW 27B OFF-A	*none*
ZPWM2432SWON	SADM -Y CASE/SHAFT, HTR SW 28B ON-A	*none*
ZPWM2433SWOF	SADM -Y CASE/SHAFT, HTR SW 28B OFF-A	*none*
ZPWM2434SWON	OSIRIS NAC+WAC CCD, HTR SW 29B ON-A	*none*
ZPWM2435SWOF	OSIRIS NAC+WAC CCD, HTR SW 29B OFF-A	*none*
ZPWM2436SWON	OSIRIS NAC+WAC STRUCT, HTR SW 30B ON-A	*none*
ZPWM2437SWOF	OSIRIS NAC+WAC STRUCT, HTR SW 30B OFF-A	*none*
ZPWM2438SWON	SPARE, HTR SW 31B ON-A	*none*
ZPWM2439SWOF	SPARE, HTR SW 31B OFF-A	*none*
ZPWM2440SWON	SPARE, HTR SW 32B ON-A	*none*
ZPWM2441SWOF	SPARE, HTR SW 32B OFF-A	*none*
ZPWM2444SWON	TK1B ON, PDU-S/S-A	*none*
ZPWM2445SWOF	TK1B OFF, PDU-S/S-A	*none*
ZPWM2446SWON	TK2B ON, PDU-S/S-A	*none*
ZPWM2447SWOF	TK2B OFF, PDU-S/S-A	*none*
ZPWM2448SWON	TK3B ON, PDU-S/S-A	*none*

Name	Designation	Verif TM
ZPWM2449SWOF	TK3B OFF, PDU-S/S-A	*none*
ZPWM2450SWON	TK4B ON, PDU-S/S-A	*none*
ZPWM2451SWOF	TK4B OFF, PDU-S/S-A	*none*
ZPWM2452SWON	TK5B ON, PDU-S/S-A	*none*
ZPWM2453SWOF	TK5B OFF, PDU-S/S-A	*none*
ZPWM2454SWON	TK6B ON, PDU-S/S-A	*none*
ZPWM2455SWOF	TK6B OFF, PDU-S/S-A	*none*
ZPWM2456SWON	TK7B ON, PDU-S/S-A	*none*
ZPWM2457SWOF	TK7B OFF, PDU-S/S-A	*none*
ZPWM2458SWON	TK8B ON, PDU-S/S-A	*none*
ZPWM2459SWOF	TK8B OFF, PDU-S/S-A	*none*
ZPWM2460SWON	TK9B ON, PDU-S/S-A	*none*
ZPWM2461SWOF	TK9B OFF, PDU-S/S-A	*none*
ZPWM2462SWON	TK10B ON, PDU-S/S-A	*none*
ZPWM2463SWOF	TK10B OFF, PDU-S/S-A	*none*
ZPWM2464SWON	TK11B ON, PDU-S/S-A	*none*
ZPWM2465SWOF	TK11B OFF, PDU-S/S-A	*none*
ZPWM2466SWON	TK12B ON, PDU-S/S-A	*none*
ZPWM2467SWOF	TK12B OFF, PDU-S/S-A	*none*
ZPWM2468SWON	TK ARM B ON, PDU-S/S-A	*none*
ZPWM2469SWOF	TK ARM B OFF, PDU-S/S-A	*none*
ZPWM2470SWON	TK FIRE B ON, PDU-S/S-A	NPWA2870
ZPWM2471SWOF	TK FIRE B OFF, PDU-S/S-A	NPWA2870

Name	Designation	Verif TM
ZPWM2472SWON	V23-N2O4 TLFV, PARM1 PYRO1B ON-A	*none*
ZPWM2473SWON	V24-N2O4 TLFV, PARM1 PYRO2B ON-A	*none*
ZPWM2474SWON	V25-MMH TLFV, PARM1 PYRO3B ON-A	*none*
ZPWM2475SWON	V26-MMH TLFV, PARM1 PYRO4B ON-A	*none*
ZPWM2476SWON	V02-HE 1 PV, PARM1 PYRO5B ON-A	*none*
ZPWM2477SWON	V32-HE 1 PV, PARM1 PYRO6B ON-A	*none*
ZPWM2478SWON	V12-N2O4 1 PV, PARM1 PYRO7B ON-A	*none*
ZPWM2479SWON	V13-N2O4 1 PV, PARM1 PYRO8B ON-A	*none*
ZPWM2480SWON	V18-MMH 1 PV, PARM1 PYRO9B ON-A	*none*
ZPWM2481SWON	V19-MMH 1 PV, PARM1 PYRO10B ON-A	*none*
ZPWM2482SWOF	V23-N2O4 TLFV, PARM1 PYRO1B OFF-A	*none*
ZPWM2483SWOF	V24-N2O4 TLFV, PARM1 PYRO2B OFF-A	*none*
ZPWM2484SWOF	V25-MMH TLFV, PARM1 PYRO3B OFF-A	*none*
ZPWM2485SWOF	V26-MMH TLFV, PARM1 PYRO4B OFF-A	*none*
ZPWM2486SWOF	V02-HE 1 PV, PARM1 PYRO5B OFF-A	*none*
ZPWM2487SWOF	V32-HE 1 PV, PARM1 PYRO6B OFF-A	*none*
ZPWM2488SWOF	V12-N2O4 1 PV, PARM1 PYRO7B OFF-A	*none*
ZPWM2489SWOF	V13-N2O4 1 PV, PARM1 PYRO8B OFF-A	*none*
ZPWM2490SWOF	V18-MMH 1 PV, PARM1 PYRO9B OFF-A	*none*
ZPWM2491SWOF	V19-MMH 1 PV, PARM1 PYRO10B OFF-A	*none*
ZPWM2492SWON	V03-HE 2 PV, PARM2 PYRO1B ON-A	*none*
ZPWM2493SWON	V04-HE 2 PV, PARM2 PYRO2B ON-A	*none*
ZPWM2494SWON	V14-N2O4 2 PV, PARM2 PYRO3B ON-A	*none*

Name	Designation	Verif TM
ZPWM2495SWON	V15-N2O4 2 PV, PARM2 PYRO4B ON-A	*none*
ZPWM2496SWON	V20-MMH 2 PV, PARM2 PYRO5B ON-A	*none*
ZPWM2497SWON	V21-MMH 2 PV, PARM2 PYRO6B ON-A	*none*
ZPWM2498SWOF	V03-HE 2 PV, PARM2 PYRO1B OFF-A	*none*
ZPWM2499SWOF	V04-HE 2 PV, PARM2 PYRO2B OFF-A	*none*
ZPWM2500SWOF	V14-N2O4 2 PV, PARM2 PYRO3B OFF-A	*none*
ZPWM2501SWOF	V15-N2O4 2 PV, PARM2 PYRO4B OFF-A	*none*
ZPWM2502SWOF	V20-MMH 2 PV, PARM2 PYRO5B OFF-A	*none*
ZPWM2503SWOF	V21-MMH 2 PV, PARM2 PYRO6B OFF-A	*none*
ZPWM2504SWON	V01-HE 1 IV, PARM3 PYRO1B ON-A	*none*
ZPWM2505SWON	V31-HE 1 IV, PARM3 PYRO2B ON-A	*none*
ZPWM2506SWON	V11-N2O4 1 PIV, PARM3 PYRO3B ON-A	*none*
ZPWM2507SWON	V27-N2O4 1 PIV, PARM3 PYRO4B ON-A	*none*
ZPWM2508SWON	V17-MMH 1 PIV, PARM3 PYRO5B ON-A	*none*
ZPWM2509SWON	V28-MMH 1 PIV,PARM3 PYRO6B ON-A	*none*
ZPWM2510SWON	HGA HDRM 1, PARM3 PYRO7B ON-A	*none*
ZPWM2511SWON	HGA HDRM 2, PARM3 PYRO8B ON-A	*none*
ZPWM2512SWON	HGA HDRM 3, PARM3 PYRO9B ON-A	*none*
ZPWM2513SWOF	V01-HE 1 IV, PARM3 PYRO1B OFF-A	*none*
ZPWM2514SWOF	V31-HE 1 IV, PARM3 PYRO2B OFF-A	*none*
ZPWM2515SWOF	V11-N2O4 1 PIV, PARM3 PYRO3B OFF-A	*none*
ZPWM2516SWOF	V27-N2O4 1 PIV, PARM3 PYRO4B OFF-A	*none*
ZPWM2517SWOF	V17-MMH 1 PIV, PARM3 PYRO5B OFF-A	*none*

Name	Designation	Verif TM
ZPWM2518SWOF	V28-MMH 1 PIV,PARM3 PYRO6B OFF-A	*none*
ZPWM2519SWOF	HGA HDRM 1, PARM3 PYRO7B OFF-A	*none*
ZPWM2520SWOF	HGA HDRM 2, PARM3 PYRO8B OFF-A	*none*
ZPWM2521SWOF	HGA HDRM 3, PARM3 PYRO9B OFF-A	*none*
ZPWM2522SWON	V05-PR 1 HP IV, PARM4 PYRO1B ON-A	*none*
ZPWM2523SWON	V06-PR 1 LP IV, PARM4 PYRO2B ON-A	*none*
ZPWM2524SWON	V07-PR 2 HP PV, PARM4 PYRO3B ON-A	*none*
ZPWM2525SWON	V08-PR 2 HP PV, PARM4 PYRO4B ON-A	*none*
ZPWM2526SWON	V09-PR 2 LP OV, PARM4 PYRO5B ON-A	*none*
ZPWM2527SWON	V10-PR 2 LP OV, PARM4 PYRO6B ON-A	*none*
ZPWM2528SWOF	V05-PR 1 HP IV, PARM4 PYRO1B OFF-A	*none*
ZPWM2529SWOF	V06-PR 1 LP IV, PARM4 PYRO2B OFF-A	*none*
ZPWM2530SWOF	V07-PR 2 HP PV, PARM4 PYRO3B OFF-A	*none*
ZPWM2531SWOF	V08-PR 2 HP PV, PARM4 PYRO4B OFF-A	*none*
ZPWM2532SWOF	V09-PR 2 LP OV, PARM4 PYRO5B OFF-A	*none*
ZPWM2533SWOF	V10-PR 2 LP OV, PARM4 PYRO6B OFF-A	*none*
ZPWM2534SWON	V16-N2O4 LP IV, PARM5 PYRO1B ON-A	*none*
ZPWM2535SWON	V22-MMH LP IV, PARM5 PYRO2B ON-A	*none*
ZPWM2536SWON	V29-N2O4 LP IV, PARM5 PYRO3B ON-A	*none*
ZPWM2537SWON	V30-MMH LP IV, PARM5 PYRO4B ON-A	*none*
ZPWM2538SWOF	V16-N2O4 LP IV, PARM5 PYRO1B OFF-A	*none*
ZPWM2539SWOF	V22-MMH LP IV, PARM5 PYRO2B OFF-A	*none*
ZPWM2540SWOF	V29-N2O4 LP IV, PARM5 PYRO3B OFF-A	*none*

Name	Designation	Verif TM
ZPWM2541SWOF	V30-MMH LP IV, PARM5 PYRO4B OFF-A	*none*
ZPWM2542SWON	PYRO ARM 1B ON, PDU-S/S-A	*none*
ZPWM2543SWON	PYRO ARM 2B ON, PDU-S/S-A	*none*
ZPWM2544SWON	PYRO ARM 3B ON, PDU-S/S-A	*none*
ZPWM2545SWON	PYRO ARM 4B ON, PDU-S/S-A	*none*
ZPWM2546SWON	PYRO ARM 5B ON, PDU-S/S-A	*none*
ZPWM2547SWOF	PYRO ARM 1B OFF, PDU-S/S-A	*none*
ZPWM2548SWOF	PYRO ARM 2B OFF, PDU-S/S-A	*none*
ZPWM2549SWOF	PYRO ARM 3B OFF, PDU-S/S-A	*none*
ZPWM2550SWOF	PYRO ARM 4B OFF, PDU-S/S-A	*none*
ZPWM2551SWOF	PYRO ARM 5B OFF, PDU-S/S-A	*none*
ZPWM2552SWON	PYRO POWER BAT2 B ON, PDU-S/S-A	*none*
ZPWM2553SWON	PYRO POWER BAT3 B ON, PDU-S/S-A	*none*
ZPWM2554SWON	PYRO POWER BUS B ON, PDU-S/S-A	*none*
ZPWM2555SWOF	PYRO POWER BAT2 B OFF, PDU-S/S-A	*none*
ZPWM2556SWOF	PYRO POWER BAT3 B OFF, PDU-S/S-A	*none*
ZPWM2557SWOF	PYRO POWER BUS B OFF, PDU-S/S-A	*none*
ZPWM2558	PYRO FIRE B, PDU-S/S-A	NPWA2150
ZPWM2991	Generic MLC PDU-S/S-A RTU-A RouteOfCmd	*none*
ZPWM2993	Generic MLC PDU-S/S-A RTU-B RouteOfCmd	*none*
ZPWM2999	Generic MLC for PDU-S/S-A	*none*

8.4. SS-PDU (redundant) TC Packets

Link to PDF-file: SS-PDU-redundant.pdf

Name	Designation	Verif TM
ZPWM3010	UPDATE ALL TM, PDU-S/S-B	*none*
ZPWM3011	UPDATE SWITCH TM, PDU-S/S-B	*none*
ZPWM3012SWON	TM POWER ON, PDU-S/S-B	*none*
ZPWM3013SWOF	TM POWER OFF, PDU-S/S-B	*none*
ZPWM3014	TMpyro S/S-PDUF, PDU-S/S-B	*none*
ZPWM3015	RESET PYRO BUFFERS, PDU-S/S-B	*none*
ZPWM3016	START CONTINUOUS, PDU-S/S-B	*none*
ZPWM3017SWON	TWTA A, LCL 1A ON, PDU-S/S-B	NPWA2360
ZPWM3018SWOF	TWTA A, LCL 1A OFF, PDU-S/S-B	NPWA2360
ZPWM3019SWON	TX A, LCL 2A ON, PDU-S/S-B	NPWA2360
ZPWM3020SWOF	TX A, LCL 2A OFF, PDU-S/S-B	NPWA2360
ZPWM3021SWON	AIU-RCS 1, LCL 3A ON, PDU-S/S-B	NPWA2370
ZPWM3022SWOF	AIU-RCS 1, LCL 3A OFF, PDU-S/S-B	NPWA2370
ZPWM3023SWON	NAVCAM/STR1, LCL 4A ON, PDU-S/S-B	NPWA2370
ZPWM3024SWOF	NAVCAM/STR1, LCL 4A OFF, PDU-S/S-B	NPWA2370
ZPWM3025SWON	GYROS&ACC1, LCL 5A ON, PDU-S/S-B	NPWA2380
ZPWM3026SWOF	GYROS&ACC1, LCL 5A OFF, PDU-S/S-B	NPWA2380
ZPWM3027SWON	SADE A, LCL 6A ON, PDU-S/S-B	NPWA2380
ZPWM3028SWOF	SADE A, LCL 6A OFF, PDU-S/S-B	NPWA2380
ZPWM3029SWON	SSMM 1, LCL 7A ON, PDU-S/S-B	NPWA2390
ZPWM3030SWOF	SSMM 1, LCL 7A OFF, PDU-S/S-B	NPWA2390
ZPWM3031SWON	RTU S/S PS1, LCL 8A ON, PDU-S/S-B	NPWA2390
ZPWM3032SWOF	RTU S/S PS1, LCL 8A OFF, PDU-S/S-B	NPWA2390
ZPWM3033SWON	RTU P/L PS1, LCL 9A ON, PDU-S/S-B	NPWA2400
ZPWM3034SWOF	RTU P/L PS1, LCL 9A OFF, PDU-S/S-B	NPWA2400

Name	Designation	Verif TM
ZPWM3035SWON	USO A, LCL 10A ON, PDU-S/S-B	NPWA2400
ZPWM3036SWOF	USO A, LCL 10A OFF, PDU-S/S-B	NPWA2400
ZPWM3037SWON	AIU PS 1, LCL 11A ON, PDU-S/S-B	NPWA2410
ZPWM3038SWOF	AIU PS 1, LCL 11A OFF, PDU-S/S-B	NPWA2410
ZPWM3039SWON	PRESS TRANS A, LCL 12A ON, PDU-S/S-B	NPWA2410
ZPWM3040SWOF	PRESS TRANS A, LCL 12A OFF, PDU-S/S-B	NPWA2410
ZPWM3041SWON	WDE HTR 1, LCL 13A ON, PDU-S/S-B	NPWA2420
ZPWM3042SWOF	WDE HTR 1, LCL 13A OFF, PDU-S/S-B	NPWA2420
ZPWM3043SWON	WDE HTR 3, LCL 14A ON, PDU-S/S-B	NPWA2420
ZPWM3044SWOF	WDE HTR 3, LCL 14A OFF, PDU-S/S-B	NPWA2420
ZPWM3045SWON	LBM/VIRTDECH, LCL 15A ON, PDU-S/S-B	NPWA2440
ZPWM3046SWOF	LBM/VIRTDECH, LCL 15A OFF, PDU-S/S-B	NPWA2440
ZPWM3047SWON	UBMP/+Z/-ZTNKG, LCL 16A ON, PDU-S/S-B	NPWA2440
ZPWM3048SWOF	UBMP/+Z/-ZTNKG, LCL 16A OFF, PDU-S/S-B	NPWA2440
ZPWM3049SWON	VIRTIS, LCL 17A ON, PDU-S/S-B	NPWA2450
ZPWM3050SWOF	VIRTIS, LCL 17A OFF, PDU-S/S-B	NPWA2450
ZPWM3051SWON	RW1&2, LCL 18A ON, PDU-S/S-B	NPWA2450
ZPWM3052SWOF	RW1&2, LCL 18A OFF, PDU-S/S-B	NPWA2450
ZPWM3053SWON	STR1-2/NAVC1-2, LCL 19A ON, PDU-S/S-B	NPWA2340
ZPWM3054SWOF	STR1-2/NAVC1-2, LCL 19A OFF, PDU-S/S-B	NPWA2340
ZPWM3055SWON	BATT 1-3, LCL 20A ON, PDU-S/S-B	NPWA2340
ZPWM3056SWOF	BATT 1-3, LCL 20A OFF, PDU-S/S-B	NPWA2340
ZPWM3057SWON	SADM+Y/SADM -Y, LCL 21A ON, PDU-S/S-B	NPWA2350
ZPWM3058SWOF	SADM+Y/SADM -Y, LCL 21A OFF, PDU-S/S-B	NPWA2350
ZPWM3059SWON	OSIR CCD+STR, LCL 22A ON, PDU-S/S-B	NPWA2350
ZPWM3060SWOF	OSIR CCD+STR, LCL 22A OFF, PDU-S/S-B	NPWA2350
ZPWM3061SWON	WDE1, LCL 23A ON, PDU-S/S-B	NPWA2280

Name	Designation	Verif TM
ZPWM3062SWOF	WDE1, LCL 23A OFF, PDU-S/S-B	NPWA2280
ZPWM3063SWON	SPARE, LCL 24A ON, PDU-S/S-B	NPWA2280
ZPWM3064SWOF	SPARE, LCL 24A OFF, PDU-S/S-B	NPWA2280
ZPWM3065SWON	GYROS&ACC3, LCL 25A ON, PDU-S/S-B	NPWA2290
ZPWM3066SWOF	GYROS&ACC3, LCL 25A OFF, PDU-S/S-B	NPWA2290
ZPWM3067SWON	SPARE, LCL 26A ON, PDU-S/S-B	NPWA2290
ZPWM3068SWOF	SPARE, LCL 26A OFF, PDU-S/S-B	NPWA2290
ZPWM3069SWON	APME A, LCL 27A ON, PDU-S/S-B	NPWA2300
ZPWM3070SWOF	APME A, LCL 27A OFF, PDU-S/S-B	NPWA2300
ZPWM3071SWON	SPARE, LCL 28A ON, PDU-S/S-B	NPWA2300
ZPWM3072SWOF	SPARE, LCL 28A OFF, PDU-S/S-B	NPWA2300
ZPWM3073SWON	SPARE, LCL 29A ON, PDU-S/S-B	NPWA2310
ZPWM3074SWOF	SPARE, LCL 29A OFF, PDU-S/S-B	NPWA2310
ZPWM3075SWON	WDE 3, LCL 30A ON, PDU-S/S-B	NPWA2520
ZPWM3076SWOF	WDE 3, LCL 30A OFF, PDU-S/S-B	NPWA2520
ZPWM3077	TWTA A, SEL LCL 1A CURR. PROF-B	*none*
ZPWM3078	TX A, SEL LCL 2A CURR. PROF-B	*none*
ZPWM3079	AIU-RCS 1, SEL LCL 3A CURR. PROF-B	*none*
ZPWM3080	NAVCAM/STR 1, SEL LCL 4A CURR. PROF-B	*none*
ZPWM3081	GYROS&ACC 1, SEL LCL 5A CURR. PROF-B	*none*
ZPWM3082	SADE A, SEL LCL 6A CURR. PROF-B	*none*
ZPWM3083	SSMM 1, SEL LCL 7A CURR. PROF-B	*none*
ZPWM3084	RTU S/S PS 1, SEL LCL 8A CURR. PROF-B	*none*
ZPWM3085	RTU P/L PS 1, SEL LCL 9A CURR. PROF-B	*none*
ZPWM3086	USO A, SEL LCL 10A CURR. PROF-B	*none*
ZPWM3087	AIU PS 1, SEL LCL 11A CURR. PROF-B	*none*
ZPWM3088	PRESS TRANS A, SEL LCL 12A CURR. PROF-B	*none*

Name	Designation	Verif TM
ZPWM3089	WDE HTR 1, SEL LCL 13A CURR. PROF-B	*none*
ZPWM3090	WDE HTR 3, SEL LCL 14A CURR. PROF-B	*none*
ZPWM3091	LBM/VIRTDECH, SEL LCL 15A CURR. PROF-B	*none*
ZPWM3092	UBMP/+Z/-ZTNKG, SEL LCL 16A CURR. PROF-B	*none*
ZPWM3093	VIRTIS, SEL LCL 17A CURR. PROF-B	*none*
ZPWM3094	RW1&2, SEL LCL 18A CURR. PROF-B	*none*
ZPWM3095	STR1-2/NAVC1-2, SEL LCL 19A CURR. PROF-B	*none*
ZPWM3096	BATT 1-3, SEL LCL 20A CURR. PROF-B	*none*
ZPWM3097	SADM+Y/SADM -Y, SEL LCL 21A CURR. PROF-B	*none*
ZPWM3098	OSIR CCD+STR, SEL LCL 22A CURR. PROF-B	*none*
ZPWM3099	WDE1, SEL LCL 23A CURR. PROF-B	*none*
ZPWM3100	SPARE, SEL LCL 24A CURR. PROF-B	*none*
ZPWM3101	GYROS&ACC 3, SEL LCL 25A CURR. PROF-B	*none*
ZPWM3102	SPARE, SEL LCL 26A CURR. PROF-B	*none*
ZPWM3103	APME A, SEL LCL 27A CURR. PROF-B	*none*
ZPWM3104	SPARE, SEL LCL 28A CURR. PROF-B	*none*
ZPWM3105	SPARE, SEL LCL 29A CURR. PROF-B	*none*
ZPWM3106	WDE 3, SEL LCL 30A CURR. PROF-B	*none*
ZPWM3107SWON	LOWER BOOM MOTOR, PWR SW 1A ON-B	*none*
ZPWM3108SWOF	LOWER BOOM MOTOR, PWR SW 1A OFF-B	*none*
ZPWM3109SWON	VIRTIS DECONT, HTR SW 2A ON-B	*none*
ZPWM3110SWOF	VIRTIS DECONT, HTR SW 2A OFF-B	*none*
ZPWM3111SWON	SPARE, HTR SW 3A ON-B	*none*
ZPWM3112SWOF	SPARE, HTR SW 3A OFF-B	*none*
ZPWM3113SWON	SPARE, HTR SW 4A ON-B	*none*
ZPWM3114SWOF	SPARE, HTR SW 4A OFF-B	*none*
ZPWM3115SWON	SPARE, HTR SW 5A ON-B	*none*

Name	Designation	Verif TM
ZPWM3116SWOF	SPARE, HTR SW 5A OFF-B	*none*
ZPWM3117SWON	UPPER BOOM MOTOR, PWR SW 6A ON-B	*none*
ZPWM3118SWOF	UPPER BOOM MOTOR, PWR SW 6A OFF-B	*none*
ZPWM3119SWON	Z+ TANK GAUGE, HTR SW 7A ON-B	*none*
ZPWM3120SWOF	Z+ TANK GAUGE, HTR SW 7A OFF-B	*none*
ZPWM3121SWON	Z- TANK GAUGE, HTR SW 8A ON-B	*none*
ZPWM3122SWOF	Z- TANK GAUGE, HTR SW 8A OFF-B	*none*
ZPWM3123SWON	VIRTIS CCD, HTR SW 9A ON-B	*none*
ZPWM3124SWOF	VIRTIS CCD, HTR SW 9A OFF-B	*none*
ZPWM3125SWON	SPARE, HTR SW 10A ON-B	*none*
ZPWM3126SWOF	SPARE, HTR SW 10A OFF-B	*none*
ZPWM3127SWON	SPARE, HTR SW 11A ON-B	*none*
ZPWM3128SWOF	SPARE, HTR SW 11A OFF-B	*none*
ZPWM3129SWON	SPARE, HTR SW 12A ON-B	*none*
ZPWM3130SWOF	SPARE, HTR SW 12A OFF-B	*none*
ZPWM3131SWON	RW 1, HTR SW 13A ON-B	*none*
ZPWM3132SWOF	RW 1, HTR SW 13A OFF-B	*none*
ZPWM3133SWON	RW 2, HTR SW 14A ON-B	*none*
ZPWM3134SWOF	RW 2, HTR SW 14A OFF-B	*none*
ZPWM3135SWON	RW 3 (NC), HTR SW 15A ON-B	*none*
ZPWM3136SWOF	RW 3 (NC), HTR SW 15A OFF-B	*none*
ZPWM3137SWON	RW 4 (NC), HTR SW 16A ON-B	*none*
ZPWM3138SWOF	RW 4 (NC), HTR SW 16A OFF-B	*none*
ZPWM3139SWON	STR 1, HTR SW 17A ON-B	*none*
ZPWM3140SWOF	STR 1, HTR SW 17A OFF-B	*none*
ZPWM3141SWON	STR 2, HTR SW 18A ON-B	*none*
ZPWM3142SWOF	STR 2, HTR SW 18A OFF-B	*none*

Name	Designation	Verif TM
ZPWM3143SWON	NAVCAM 1, HTR SW 19A ON-B	*none*
ZPWM3144SWOF	NAVCAM 1, HTR SW 19A OFF-B	*none*
ZPWM3145SWON	NAVCAM 2, HTR SW 20A ON-B	*none*
ZPWM3146SWOF	NAVCAM 2, HTR SW 20A OFF-B	*none*
ZPWM3147SWON	BATT 1, HTR SW 21A ON-B	*none*
ZPWM3148SWOF	BATT 1, HTR SW 21A OFF-B	*none*
ZPWM3149SWON	BATT 3, HTR SW 22A ON-B	*none*
ZPWM3150SWOF	BATT 3, HTR SW 22A OFF-B	*none*
ZPWM3151SWON	SPARE, HTR SW 23A ON-B	*none*
ZPWM3152SWOF	SPARE, HTR SW 23A OFF-B	*none*
ZPWM3153SWON	BATT 2, HTR SW 24A ON-B	*none*
ZPWM3154SWOF	BATT 2, HTR SW 24A OFF-B	*none*
ZPWM3155SWON	SPARE, HTR SW 25A ON-B	*none*
ZPWM3156SWOF	SPARE, HTR SW 25A OFF-B	*none*
ZPWM3157SWON	SPARE, HTR SW 26A ON-B	*none*
ZPWM3158SWOF	SPARE, HTR SW 26A OFF-B	*none*
ZPWM3159SWON	SADM +Y CASE/SHAFT, HTR SW 27A ON-B	*none*
ZPWM3160SWOF	SADM +Y CASE/SHAFT, HTR SW 27A OFF-B	*none*
ZPWM3161SWON	SADM -Y CASE/SHAFT, HTR SW 28A ON-B	*none*
ZPWM3162SWOF	SADM -Y CASE/SHAFT, HTR SW 28A OFF-B	*none*
ZPWM3163SWON	OSIRIS NAC+WAC CCD, HTR SW 29A ON-B	*none*
ZPWM3164SWOF	OSIRIS NAC+WAC CCD, HTR SW 29A OFF-B	*none*
ZPWM3165SWON	OSIRIS NAC+WAC STRUCT, HTR SW 30A ON-B	*none*
ZPWM3166SWOF	OSIRIS NAC+WAC STRUCT, HTR SW 30A OFF-B	*none*
ZPWM3167SWON	SPARE, HTR SW 31A ON-B	*none*
ZPWM3168SWOF	SPARE, HTR SW 31A OFF-B	*none*
ZPWM3169SWON	SPARE, HTR SW 32A ON-B	*none*

Name	Designation	Verif TM
ZPWM3170SWOF	SPARE, HTR SW 32A OFF-B	*none*
ZPWM3173SWON	TK 1A ON, PDU-S/S-B	*none*
ZPWM3174SWOF	TK 1A OFF, PDU-S/S, PDU-S/S-B	*none*
ZPWM3175SWON	TK 2A ON, PDU-S/S-B	*none*
ZPWM3176SWOF	TK 2A OFF, PDU-S/S-B	*none*
ZPWM3177SWON	TK 3A ON, PDU-S/S-B	*none*
ZPWM3178SWOF	TK 3A OFF, PDU-S/S-B	*none*
ZPWM3179SWON	TK 4A ON, PDU-S/S-B	*none*
ZPWM3180SWOF	TK 4A OFF, PDU-S/S-B	*none*
ZPWM3181SWON	TK 5A ON, PDU-S/S-B	*none*
ZPWM3182SWOF	TK 5A OFF, PDU-S/S-B	*none*
ZPWM3183SWON	TK 6A ON, PDU-S/S-B	*none*
ZPWM3184SWOF	TK 6A OFF, PDU-S/S-B	*none*
ZPWM3185SWON	TK 7A ON, PDU-S/S-B	*none*
ZPWM3186SWOF	TK 7A OFF, PDU-S/S-B	*none*
ZPWM3187SWON	TK 8A ON, PDU-S/S-B	*none*
ZPWM3188SWOF	TK 8A OFF, PDU-S/S-B	*none*
ZPWM3189SWON	TK 9A ON, PDU-S/S-B	*none*
ZPWM3190SWOF	TK 9A OFF, PDU-S/S-B	*none*
ZPWM3191SWON	TK 10A ON, PDU-S/S-B	*none*
ZPWM3192SWOF	TK 10A OFF, PDU-S/S-B	*none*
ZPWM3193SWON	TK 11A ON, PDU-S/S-B	*none*
ZPWM3194SWOF	TK 11A OFF, PDU-S/S-B	*none*
ZPWM3195SWON	TK 12A ON, PDU-S/S-B	*none*
ZPWM3196SWOF	TK 12A OFF, PDU-S/S-B	*none*
ZPWM3197SWON	TK ARM A ON, PDU-S/S-B	*none*
ZPWM3198SWOF	TK ARM A OFF, PDU-S/S-B	*none*

Name	Designation	Verif TM
ZPWM3199SWON	TK FIRE A ON, PDU-S/S-B	NPWA2550
ZPWM3200SWOF	TK FIRE A OFF, PDU-S/S-B	NPWA2550
ZPWM3201SWON	V23-N2O4 TLFV, PARM1 PYRO1A ON-B	*none*
ZPWM3202SWON	V24-N2O4 TLFV, PARM1 PYRO2A ON-B	*none*
ZPWM3203SWON	V25-MMH TLFV, PARM1 PYRO3A ON-B	*none*
ZPWM3204SWON	V26-MMH TLFV, PARM1 PYRO4A ON-B	*none*
ZPWM3205SWON	V02-HE 1 PV, PARM1 PYRO5A ON-B	*none*
ZPWM3206SWON	V32-HE 1 PV, PARM1 PYRO6A ON-B	*none*
ZPWM3207SWON	V12-N2O4 1 PV, PARM1 PYRO7A ON-B	*none*
ZPWM3208SWON	V13-N2O4 1 PV, PARM1 PYRO8A ON-B	*none*
ZPWM3209SWON	V18-MMH 1 PV, PARM1 PYRO9A ON-B	*none*
ZPWM3210SWON	V19-MMH 1 PV, PARM1 PYRO10A ON-B	*none*
ZPWM3211SWOF	V23-N2O4 TLFV, PARM1 PYRO1A OFF-B	*none*
ZPWM3212SWOF	V24-N2O4 TLFV, PARM1 PYRO2A OFF-B	*none*
ZPWM3213SWOF	V25-MMH TLFV, PARM1 PYRO3A OFF-B	*none*
ZPWM3214SWOF	V26-MMH TLFV, PARM1 PYRO4A OFF-B	*none*
ZPWM3215SWOF	V02-HE 1 PV, PARM1 PYRO5A OFF-B	*none*
ZPWM3216SWOF	V32-HE 1 PV, PARM1 PYRO6A OFF-B	*none*
ZPWM3217SWOF	V12-N2O4 1 PV, PARM1 PYRO7A OFF-B	*none*
ZPWM3218SWOF	V13-N2O4 1 PV, PARM1 PYRO8A OFF-B	*none*
ZPWM3219SWOF	V18-MMH 1 PV, PARM1 PYRO9A OFF-B	*none*
ZPWM3220SWOF	V19-MMH 1 PV, PARM1 PYRO10A OFF-B	*none*
ZPWM3221SWON	V03-HE 2 PV, PARM2 PYRO1A ON-B	*none*
ZPWM3222SWON	V04-HE 2 PV, PARM2 PYRO2A ON-B	*none*
ZPWM3223SWON	V14-N2O4 2 PV, PARM2 PYRO3A ON-B	*none*
ZPWM3224SWON	V15-N2O4 2 PV, PARM2 PYRO4A ON-B	*none*
ZPWM3225SWON	V20-MMH 2 PV, PARM2 PYRO5A ON-B	*none*

Name	Designation	Verif TM
ZPWM3226SWON	V21-MMH 2 PV, PARM2 PYRO6A ON-B	*none*
ZPWM3227SWOF	V03-HE 2 PV, PARM2 PYRO1A OFF-B	*none*
ZPWM3228SWOF	V04-HE 2 PV, PARM2 PYRO2A OFF-B	*none*
ZPWM3229SWOF	V14-N2O4 2 PV, PARM2 PYRO3A OFF-B	*none*
ZPWM3230SWOF	V15-N2O4 2 PV, PARM2 PYRO4A OFF-B	*none*
ZPWM3231SWOF	V20-MMH 2 PV, PARM2 PYRO5A OFF-B	*none*
ZPWM3232SWOF	V21-MMH 2 PV, PARM2 PYRO6A OFF-B	*none*
ZPWM3233SWON	V01-HE 1 IV, PARM3 PYRO1A ON-B	*none*
ZPWM3234SWON	V31-HE 1 IV, PARM3 PYRO2A ON-B	*none*
ZPWM3235SWON	V11-N2O4 1 PIV, PARM3 PYRO3A ON-B	*none*
ZPWM3236SWON	V27-N2O4 1 PIV, PARM3 PYRO4A ON-B	*none*
ZPWM3237SWON	V17-MMH 1 PIV, PARM3 PYRO5A ON-B	*none*
ZPWM3238SWON	V28-MMH 1 PIV,PARM3 PYRO6A ON-B	*none*
ZPWM3239SWON	HGA HDRM 1, PARM3 PYRO7A ON-B	*none*
ZPWM3240SWON	HGA HDRM 2, PARM3 PYRO8A ON-B	*none*
ZPWM3241SWON	HGA HDRM 3, PARM3 PYRO9A ON-B	*none*
ZPWM3242SWOF	V01-HE 1 IV, PARM3 PYRO1A OFF-B	*none*
ZPWM3243SWOF	V31-HE 1 IV, PARM3 PYRO2A OFF-B	*none*
ZPWM3244SWOF	V11-N2O4 1 PIV, PARM3 PYRO3A OFF-B	*none*
ZPWM3245SWOF	V27-N2O4 1 PIV, PARM3 PYRO4A OFF-B	*none*
ZPWM3246SWOF	V17-MMH 1 PIV, PARM3 PYRO5A OFF-B	*none*
ZPWM3247SWOF	V28-MMH 1 PIV,PARM3 PYRO6A OFF-B	*none*
ZPWM3248SWOF	HGA HDRM 1, PARM3 PYRO7A OFF-B	*none*
ZPWM3249SWOF	HGA HDRM 2, PARM3 PYRO8A OFF-B	*none*
ZPWM3250SWOF	HGA HDRM 3, PARM3 PYRO9A OFF-B	*none*
ZPWM3251SWON	V05-PR 1 HP IV, PARM4 PYRO1A ON-B	*none*
ZPWM3252SWON	V06-PR 1 LP IV, PARM4 PYRO2A ON-B	*none*

Name	Designation	Verif TM
ZPWM3253SWON	V07-PR 2 HP PV, PARM4 PYRO3A ON-B	*none*
ZPWM3254SWON	V08-PR 2 HP PV, PARM4 PYRO4A ON-B	*none*
ZPWM3255SWON	V09-PR 2 LP OV, PARM4 PYRO5A ON-B	*none*
ZPWM3256SWON	V10-PR 2 LP OV, PARM4 PYRO6A ON-B	*none*
ZPWM3257SWOF	V05-PR 1 HP IV, PARM4 PYRO1A OFF-B	*none*
ZPWM3258SWOF	V06-PR 1 LP IV, PARM4 PYRO2A OFF-B	*none*
ZPWM3259SWOF	V07-PR 2 HP PV, PARM4 PYRO3A OFF-B	*none*
ZPWM3260SWOF	V08-PR 2 HP PV, PARM4 PYRO4A OFF-B	*none*
ZPWM3261SWOF	V09-PR 2 LP OV, PARM4 PYRO5A OFF-B	*none*
ZPWM3262SWOF	V10-PR 2 LP OV, PARM4 PYRO6A OFF-B	*none*
ZPWM3263SWON	V16-N2O4 LP IV, PARM5 PYRO1A ON-B	*none*
ZPWM3264SWON	V22-MMH LP IV, PARM5 PYRO2A ON-B	*none*
ZPWM3265SWON	V29-N2O4 LP IV, PARM5 PYRO3A ON-B	*none*
ZPWM3266SWON	V30-MMH LP IV, PARM5 PYRO4A ON-B	*none*
ZPWM3267SWOF	V16-N2O4 LP IV, PARM5 PYRO1A OFF-B	*none*
ZPWM3268SWOF	V22-MMH LP IV, PARM5 PYRO2A OFF-B	*none*
ZPWM3269SWOF	V29-N2O4 LP IV, PARM5 PYRO3A OFF-B	*none*
ZPWM3270SWOF	V30-MMH LP IV, PARM5 PYRO4A OFF-B	*none*
ZPWM3271SWON	PYRO ARM 1A ON, PDU-S/S-B	*none*
ZPWM3272SWON	PYRO ARM 2A ON, PDU-S/S-B	*none*
ZPWM3273SWON	PYRO ARM 3A ON, PDU-S/S-B	*none*
ZPWM3274SWON	PYRO ARM 4A ON, PDU-S/S-B	*none*
ZPWM3275SWON	PYRO ARM 5A ON, PDU-S/S-B	*none*
ZPWM3276SWOF	PYRO ARM 1A OFF, PDU-S/S-B	*none*
ZPWM3277SWOF	PYRO ARM 2A OFF, PDU-S/S-B	*none*
ZPWM3278SWOF	PYRO ARM 3A OFF, PDU-S/S-B	*none*
ZPWM3279SWOF	PYRO ARM 4A OFF, PDU-S/S-B	*none*

Name	Designation	Verif TM
ZPWM3280SWOF	PYRO ARM 5A OFF, PDU-S/S-B	*none*
ZPWM3281SWON	PYRO POWER BAT1 A ON, PDU-S/S-B	*none*
ZPWM3282SWON	PYRO POWER BAT2 A ON, PDU-S/S-B	*none*
ZPWM3283SWON	PYRO POWER BUS A ON, PDU-S/S-B	*none*
ZPWM3284SWOF	PYRO POWER BAT1 A OFF, PDU-S/S-B	*none*
ZPWM3285SWOF	PYRO POWER BAT2 A OFF, PDU-S/S-B	*none*
ZPWM3286SWOF	PYRO POWER BUS A OFF, PDU-S/S-B	*none*
ZPWM3287	PYRO FIRE A, PDU-S/S-B	NPWA2030
ZPWM3288SWON	TWTA B, LCL 1B ON, PDU-S/S-B	NPWA2680
ZPWM3289SWOF	TWTA B, LCL 1B OFF, PDU-S/S-B	NPWA2680
ZPWM3290SWON	TX B, LCL 2B ON, PDU-S/S-B	NPWA2680
ZPWM3291SWOF	TX B, LCL 2B OFF, PDU-S/S-B	NPWA2680
ZPWM3292SWON	AIU-RCS 2, LCL 3B ON, PDU-S/S-B	NPWA2690
ZPWM3293SWOF	AIU-RCS 2, LCL 3B OFF, PDU-S/S-B	NPWA2690
ZPWM3294SWON	NAVCAM/STR2, LCL 4B ON, PDU-S/S-B	NPWA2690
ZPWM3295SWOF	NAVCAM/STR2, LCL 4B OFF, PDU-S/S-B	NPWA2690
ZPWM3296SWON	GYROS&ACC2, LCL 5B ON, PDU-S/S-B	NPWA2700
ZPWM3297SWOF	GYROS&ACC2, LCL 5B OFF, PDU-S/S-B	NPWA2700
ZPWM3298SWON	SADE B LCL 6B, ON, PDU-S/S-B	NPWA2700
ZPWM3299SWOF	SADE B LCL 6B, OFF, PDU-S/S-B	NPWA2700
ZPWM3300SWON	SSMM 2 LCL 7B, ON, PDU-S/S-B	NPWA2710
ZPWM3301SWOF	SSMM 2 LCL 7B, OFF, PDU-S/S-B	NPWA2710
ZPWM3302SWON	RTU S/S PS2, LCL 8B ON, PDU-S/S-B	NPWA2710
ZPWM3303SWOF	RTU S/S PS2, LCL 8B OFF, PDU-S/S-B	NPWA2710
ZPWM3304SWON	RTU P/L PS2, LCL 9B ON, PDU-S/S-B	NPWA2720
ZPWM3305SWOF	RTU P/L PS2, LCL 9B OFF, PDU-S/S-B	NPWA2720
ZPWM3306SWON	USO B, LCL 10B ON, PDU-S/S-B	NPWA2720

Name	Designation	Verif TM
ZPWM3307SWOF	USO B, LCL 10B OFF, PDU-S/S-B	NPWA2720
ZPWM3308SWON	AIU PS 2, LCL 11B ON, PDU-S/S-B	NPWA2730
ZPWM3309SWOF	AIU PS 2, LCL 11B OFF, PDU-S/S-B	NPWA2730
ZPWM3310SWON	PRESS TRANS B, LCL 12B ON, PDU-S/S-B	NPWA2730
ZPWM3311SWOF	PRESS TRANS B, LCL 12B OFF, PDU-S/S-B	NPWA2730
ZPWM3312SWON	WDE HTR 2, LCL 13B ON, PDU-S/S-B	NPWA2740
ZPWM3313SWOF	WDE HTR 2, LCL 13B OFF, PDU-S/S-B	NPWA2740
ZPWM3314SWON	WDE HTR 4, LCL 14B ON, PDU-S/S-B	NPWA2740
ZPWM3315SWOF	WDE HTR 4, LCL 14B OFF, PDU-S/S-B	NPWA2740
ZPWM3316SWON	LBM/VIRTDECH, LCL 15B ON, PDU-S/S-B	NPWA2760
ZPWM3317SWOF	LBM/VIRTDECH, LCL 15B OFF, PDU-S/S-B	NPWA2760
ZPWM3318SWON	UBMP/+Z/-ZTNKG, LCL 16B ON, PDU-S/S-B	NPWA2760
ZPWM3319SWOF	UBMP/+Z/-ZTNKG, LCL 16B OFF, PDU-S/S-B	NPWA2760
ZPWM3320SWON	VIRTIS, LCL 17B ON, PDU-S/S-B	NPWA2770
ZPWM3321SWOF	VIRTIS, LCL 17B OFF, PDU-S/S-B	NPWA2770
ZPWM3322SWON	RW1&2, LCL 18B ON, PDU-S/S-B	NPWA2770
ZPWM3323SWOF	RW1&2, LCL 18B OFF, PDU-S/S-B	NPWA2770
ZPWM3324SWON	STR1-2/NAVC1-2, LCL 19B ON, PDU-S/S-B	NPWA2660
ZPWM3325SWOF	STR1-2/NAVC1-2, LCL 19B OFF, PDU-S/S-B	NPWA2660
ZPWM3326SWON	BATT 1-3, LCL 20B ON, PDU-S/S-B	NPWA2660
ZPWM3327SWOF	BATT 1-3, LCL 20B OFF, PDU-S/S-B	NPWA2660
ZPWM3328SWON	SADM+Y/SADM -Y, LCL 21B ON, PDU-S/S-B	NPWA2670
ZPWM3329SWOF	SADM+Y/SADM -Y, LCL 21B OFF, PDU-S/S-B	NPWA2670
ZPWM3330SWON	OSIR CCD+STR, LCL 22B ON, PDU-S/S-B	NPWA2670
ZPWM3331SWOF	OSIR CCD+STR, LCL 22B OFF, PDU-S/S-B	NPWA2670
ZPWM3332SWON	WDE 2, LCL 23B ON, PDU-S/S-B	NPWA2600
ZPWM3333SWOF	WDE 2, LCL 23B OFF, PDU-S/S-B	NPWA2600

Name	Designation	Verif TM
ZPWM3334SWON	SPARE, LCL 24B ON, PDU-S/S-B	NPWA2600
ZPWM3335SWOF	SPARE, LCL 24B OFF, PDU-S/S-B	NPWA2600
ZPWM3336SWON	SPARE, LCL 25B ON, PDU-S/S-B	NPWA2610
ZPWM3337SWOF	SPARE, LCL 25B OFF, PDU-S/S-B	NPWA2610
ZPWM3338SWON	SPARE, LCL 26B ON, PDU-S/S-B	NPWA2610
ZPWM3339SWOF	SPARE, LCL 26B OFF, PDU-S/S-B	NPWA2610
ZPWM3340SWON	APME B, LCL 27B ON, PDU-S/S-B	NPWA2620
ZPWM3341SWOF	APME B, LCL 27B OFF, PDU-S/S-B	NPWA2620
ZPWM3342SWON	SPARE, LCL 28B ON, PDU-S/S-B	NPWA2620
ZPWM3343SWOF	SPARE, LCL 28B OFF, PDU-S/S-B	NPWA2620
ZPWM3344SWON	SPARE, LCL 29B ON, PDU-S/S-B	NPWA2630
ZPWM3345SWOF	SPARE, LCL 29B OFF, PDU-S/S-B	NPWA2630
ZPWM3346SWON	WDE 4, LCL 30B ON, PDU-S/S-B	NPWA2840
ZPWM3347SWOF	WDE 4, LCL 30B OFF, PDU-S/S-B	NPWA2840
ZPWM3348	TWTA B, SEL LCL 1B CURR. PROF-B	*none*
ZPWM3349	TX B, SEL LCL 2B CURR. PROF-B	*none*
ZPWM3350	AIU-RCS 2, SEL LCL 3B CURR. PROF-B	*none*
ZPWM3351	NAVCAM/STR 2, SEL LCL 4B CURR. PROF-B	*none*
ZPWM3352	GYROS&ACC 2, SEL LCL 5B CURR. PROF-B	*none*
ZPWM3353	SADE B, SEL LCL 6B CURR. PROF-B	*none*
ZPWM3354	SSMM 2, SEL LCL 7B CURR. PROF-B	*none*
ZPWM3355	RTU S/S PS 2, SEL LCL 8B CURR. PROF-B	*none*
ZPWM3356	RTU P/L PS 2, SEL LCL 9B CURR. PROF-B	*none*
ZPWM3357	USO B, SEL LCL 10B CURR. PROF-B	*none*
ZPWM3358	AIU PS 2, SEL LCL 11B CURR. PROF-B	*none*
ZPWM3359	PRESS TRANS B, SEL LCL 12B CURR. PROF-B	*none*
ZPWM3360	WDE HTR 2, SEL LCL 13B CURR. PROF-B	*none*

Name	Designation	Verif TM
ZPWM3361	WDE HTR 4, SEL LCL 14B CURR. PROF-B	*none*
ZPWM3362	LBM/VIRTDECH, SEL LCL 15B CURR. PROF-B	*none*
ZPWM3363	UBMP/+Z/-ZTNKG, SEL LCL 16B CURR. PROF-B	*none*
ZPWM3364	VIRTIS, SEL LCL 17B CURR. PROF-B	*none*
ZPWM3365	RW1&2, SEL LCL 18B CURR. PROF-B	*none*
ZPWM3366	STR1-2/NAVC1-2, SEL LCL 19B CURR. PROF-B	*none*
ZPWM3367	BATT 1-3, SEL LCL 20B CURR. PROF-B	*none*
ZPWM3368	SADM+Y/SADM -Y, SEL LCL 21B CURR. PROF-B	*none*
ZPWM3369	OSIR CCD+STR, SEL LCL 22B CURR. PROF-B	*none*
ZPWM3370	WDE2, SEL LCL 23B CURR. PROF-B	*none*
ZPWM3371	SPARE, SEL LCL 24B CURR. PROF-B	*none*
ZPWM3372	SPARE, SEL LCL 25B CURR. PROF-B	*none*
ZPWM3373	SPARE, SEL LCL 26B CURR. PROF-B	*none*
ZPWM3374	APME B, SEL LCL 27B CURR. PROF-B	*none*
ZPWM3375	SPARE, SEL LCL 28B CURR. PROF-B	*none*
ZPWM3376	SPARE, SEL LCL 29B CURR. PROF-B	*none*
ZPWM3377	WDE 4, SEL LCL 30B CURR. PROF-B	*none*
ZPWM3378SWON	LOWER BOOM MOTOR, PWR SW 1B ON-B	*none*
ZPWM3379SWOF	LOWER BOOM MOTOR, PWR SW 1B OFF-B	*none*
ZPWM3380SWON	VIRTIS DECONT, HTR SW 2B ON-B	*none*
ZPWM3381SWOF	VIRTIS DECONT, HTR SW 2B OFF-B	*none*
ZPWM3382SWON	SPARE, HTR SW 3B ON-B	*none*
ZPWM3383SWOF	SPARE, HTR SW 3B OFF-B	*none*
ZPWM3384SWON	SPARE, HTR SW 4B ON-B	*none*
ZPWM3385SWOF	SPARE, HTR SW 4B OFF-B	*none*
ZPWM3386SWON	SPARE, HTR SW 5B ON-B	*none*
ZPWM3387SWOF	SPARE, HTR SW 5B OFF-B	*none*

Name	Designation	Verif TM
ZPWM3388SWON	UPPER BOOM MOTOR, PWR SW 6B ON-B	*none*
ZPWM3389SWOF	UPPER BOOM MOTOR, PWR SW 6B OFF-B	*none*
ZPWM3390SWON	Z+ TANK GAUGE, HTR SW 7B ON-B	*none*
ZPWM3391SWOF	Z+ TANK GAUGE, HTR SW 7B OFF-B	*none*
ZPWM3392SWON	Z- TANK GAUGE, HTR SW 8B ON-B	*none*
ZPWM3393SWOF	Z- TANK GAUGE, HTR SW 8B OFF-B	*none*
ZPWM3394SWON	VIRTIS CCD, HTR SW 9B ON-B	*none*
ZPWM3395SWOF	VIRTIS CCD, HTR SW 9B OFF-B	*none*
ZPWM3396SWON	SPARE, HTR SW 10B ON-B	*none*
ZPWM3397SWOF	SPARE, HTR SW 10B OFF-B	*none*
ZPWM3398SWON	SPARE, HTR SW 11B ON-B	*none*
ZPWM3399SWOF	SPARE, HTR SW 11B OFF-B	*none*
ZPWM3400SWON	SPARE, HTR SW 12B ON-B	*none*
ZPWM3401SWOF	SPARE, HTR SW 12B OFF-B	*none*
ZPWM3402SWON	RW 1, HTR SW 13B ON-B	*none*
ZPWM3403SWOF	RW 1, HTR SW 13B OFF-B	*none*
ZPWM3404SWON	RW 2, HTR SW 14B ON-B	*none*
ZPWM3405SWOF	RW 2, HTR SW 14B OFF-B	*none*
ZPWM3406SWON	RW 3 (NC), HTR SW 15B ON-B	*none*
ZPWM3407SWOF	RW 3 (NC), HTR SW 15B OFF-B	*none*
ZPWM3408SWON	RW 4 (NC), HTR SW 16B ON-B	*none*
ZPWM3409SWOF	RW 4 (NC), HTR SW 16B OFF-B	*none*
ZPWM3410SWON	STR 1, HTR SW 17B ON-B	*none*
ZPWM3411SWOF	STR 1, HTR SW 17B OFF-B	*none*
ZPWM3412SWON	STR 2, HTR SW 18B ON-B	*none*
ZPWM3413SWOF	STR 2, HTR SW 18B OFF-B	*none*
ZPWM3414SWON	NAVCAM 1, HTR SW 19B ON-B	*none*

Name	Designation	Verif TM
ZPWM3415SWOF	NAVCAM 1, HTR SW 19B OFF-B	*none*
ZPWM3416SWON	NAVCAM 2, HTR SW 20B ON-B	*none*
ZPWM3417SWOF	NAVCAM 2, HTR SW 20B OFF-B	*none*
ZPWM3418SWON	BATT 1, HTR SW 21B ON-B	*none*
ZPWM3419SWOF	BATT 1, HTR SW 21B OFF-B	*none*
ZPWM3420SWON	BATT 3, HTR SW 22B ON-B	*none*
ZPWM3421SWOF	BATT 3, HTR SW 22B OFF-B	*none*
ZPWM3422SWON	SPARE, HTR SW 23B ON-B	*none*
ZPWM3423SWOF	SPARE, HTR SW 23B OFF-B	*none*
ZPWM3424SWON	BATT 2, HTR SW 24B ON-B	*none*
ZPWM3425SWOF	BATT 2, HTR SW 24B OFF-B	*none*
ZPWM3426SWON	SPARE, HTR SW 25B ON-B	*none*
ZPWM3427SWOF	SPARE, HTR SW 25B OFF-B	*none*
ZPWM3428SWON	SPARE, HTR SW 26B ON-B	*none*
ZPWM3429SWOF	SPARE, HTR SW 26B OFF-B	*none*
ZPWM3430SWON	SADM +Y CASE/SHAFT, HTR SW 27B ON-B	*none*
ZPWM3431SWOF	SADM +Y CASE/SHAFT, HTR SW 27B OFF-B	*none*
ZPWM3432SWON	SADM -Y CASE/SHAFT, HTR SW 28B ON-B	*none*
ZPWM3433SWOF	SADM -Y CASE/SHAFT, HTR SW 28B OFF-B	*none*
ZPWM3434SWON	OSIRIS NAC+WAC CCD, HTR SW 29B ON-B	*none*
ZPWM3435SWOF	OSIRIS NAC+WAC CCD, HTR SW 29B OFF-B	*none*
ZPWM3436SWON	OSIRIS NAC+WAC STRUCT, HTR SW 30B ON-B	*none*
ZPWM3437SWOF	OSIRIS NAC+WAC STRUCT, HTR SW 30B OFF-B	*none*
ZPWM3438SWON	SPARE, HTR SW 31B ON-B	*none*
ZPWM3439SWOF	SPARE, HTR SW 31B OFF-B	*none*
ZPWM3440SWON	SPARE, HTR SW 32B ON-B	*none*
ZPWM3441SWOF	SPARE, HTR SW 32B OFF-B	*none*

Name	Designation	Verif TM
ZPWM3444SWON	TK1B ON, PDU-S/S-B	*none*
ZPWM3445SWOF	TK1B OFF, PDU-S/S-B	*none*
ZPWM3446SWON	TK2B ON, PDU-S/S-B	*none*
ZPWM3447SWOF	TK2B OFF, PDU-S/S-B	*none*
ZPWM3448SWON	TK3B ON, PDU-S/S-B	*none*
ZPWM3449SWOF	TK3B OFF, PDU-S/S-B	*none*
ZPWM3450SWON	TK4B ON, PDU-S/S-B	*none*
ZPWM3451SWOF	TK4B OFF, PDU-S/S-B	*none*
ZPWM3452SWON	TK5B ON, PDU-S/S-B	*none*
ZPWM3453SWOF	TK5B OFF, PDU-S/S-B	*none*
ZPWM3454SWON	TK6B ON, PDU-S/S-B	*none*
ZPWM3455SWOF	TK6B OFF, PDU-S/S-B	*none*
ZPWM3456SWON	TK7B ON, PDU-S/S-B	*none*
ZPWM3457SWOF	TK7B OFF, PDU-S/S-B	*none*
ZPWM3458SWON	TK8B ON, PDU-S/S-B	*none*
ZPWM3459SWOF	TK8B OFF, PDU-S/S-B	*none*
ZPWM3460SWON	TK9B ON, PDU-S/S-B	*none*
ZPWM3461SWOF	TK9B OFF, PDU-S/S-B	*none*
ZPWM3462SWON	TK10B ON, PDU-S/S-B	*none*
ZPWM3463SWOF	TK10B OFF, PDU-S/S-B	*none*
ZPWM3464SWON	TK11B ON, PDU-S/S-B	*none*
ZPWM3465SWOF	TK11B OFF, PDU-S/S-B	*none*
ZPWM3466SWON	TK12B ON, PDU-S/S-B	*none*
ZPWM3467SWOF	TK12B OFF, PDU-S/S-B	*none*
ZPWM3468SWON	TK ARM B ON, PDU-S/S-B	*none*
ZPWM3469SWOF	TK ARM B OFF, PDU-S/S-B	*none*
ZPWM3470SWON	TK FIRE B ON, PDU-S/S-B	NPWA2870

Name	Designation	Verif TM
ZPWM3471SWOF	TK FIRE B OFF, PDU-S/S-B	NPWA2870
ZPWM3472SWON	V23-N2O4 TLFV, PARM1 PYRO1B ON-B	*none*
ZPWM3473SWON	V24-N2O4 TLFV, PARM1 PYRO2B ON-B	*none*
ZPWM3474SWON	V25-MMH TLFV, PARM1 PYRO3B ON-B	*none*
ZPWM3475SWON	V26-MMH TLFV, PARM1 PYRO4B ON-B	*none*
ZPWM3476SWON	V02-HE 1 PV, PARM1 PYRO5B ON-B	*none*
ZPWM3477SWON	V32-HE 1 PV, PARM1 PYRO6B ON-B	*none*
ZPWM3478SWON	V12-N2O4 1 PV, PARM1 PYRO7B ON-B	*none*
ZPWM3479SWON	V13-N2O4 1 PV, PARM1 PYRO8B ON-B	*none*
ZPWM3480SWON	V18-MMH 1 PV, PARM1 PYRO9B ON-B	*none*
ZPWM3481SWON	V19-MMH 1 PV, PARM1 PYRO10B ON-B	*none*
ZPWM3482SWOF	V23-N2O4 TLFV, PARM1 PYRO1B OFF-B	*none*
ZPWM3483SWOF	V24-N2O4 TLFV, PARM1 PYRO2B OFF-B	*none*
ZPWM3484SWOF	V25-MMH TLFV, PARM1 PYRO3B OFF-B	*none*
ZPWM3485SWOF	V26-MMH TLFV, PARM1 PYRO4B OFF-B	*none*
ZPWM3486SWOF	V02-HE 1 PV, PARM1 PYRO5B OFF-B	*none*
ZPWM3487SWOF	V32-HE 1 PV, PARM1 PYRO6B OFF-B	*none*
ZPWM3488SWOF	V12-N2O4 1 PV, PARM1 PYRO7B OFF-B	*none*
ZPWM3489SWOF	V13-N2O4 1 PV, PARM1 PYRO8B OFF-B	*none*
ZPWM3490SWOF	V18-MMH 1 PV, PARM1 PYRO9B OFF-B	*none*
ZPWM3491SWOF	V19-MMH 1 PV, PARM1 PYRO10B OFF-B	*none*
ZPWM3492SWON	V03-HE 2 PV, PARM2 PYRO1B ON-B	*none*
ZPWM3493SWON	V04-HE 2 PV, PARM2 PYRO2B ON-B	*none*
ZPWM3494SWON	V14-N2O4 2 PV, PARM2 PYRO3B ON-B	*none*
ZPWM3495SWON	V15-N2O4 2 PV, PARM2 PYRO4B ON-B	*none*
ZPWM3496SWON	V20-MMH 2 PV, PARM2 PYRO5B ON-B	*none*
ZPWM3497SWON	V21-MMH 2 PV, PARM2 PYRO6B ON-B	*none*

Name	Designation	Verif TM
ZPWM3498SWOF	V03-HE 2 PV, PARM2 PYRO1B OFF-B	*none*
ZPWM3499SWOF	V04-HE 2 PV, PARM2 PYRO2B OFF-B	*none*
ZPWM3500SWOF	V14-N2O4 2 PV, PARM2 PYRO3B OFF-B	*none*
ZPWM3501SWOF	V15-N2O4 2 PV, PARM2 PYRO4B OFF-B	*none*
ZPWM3502SWOF	V20-MMH 2 PV, PARM2 PYRO5B OFF-B	*none*
ZPWM3503SWOF	V21-MMH 2 PV, PARM2 PYRO6B OFF-B	*none*
ZPWM3504SWON	V01-HE 1 IV, PARM3 PYRO1B ON-B	*none*
ZPWM3505SWON	V31-HE 1 IV, PARM3 PYRO2B ON-B	*none*
ZPWM3506SWON	V11-N2O4 1 PIV, PARM3 PYRO3B ON-B	*none*
ZPWM3507SWON	V27-N2O4 1 PIV, PARM3 PYRO4B ON-B	*none*
ZPWM3508SWON	V17-MMH 1 PIV, PARM3 PYRO5B ON-B	*none*
ZPWM3509SWON	V28-MMH 1 PIV,PARM3 PYRO6B ON-B	*none*
ZPWM3510SWON	HGA HDRM 1, PARM3 PYRO7B ON-B	*none*
ZPWM3511SWON	HGA HDRM 2, PARM3 PYRO8B ON-B	*none*
ZPWM3512SWON	HGA HDRM 3, PARM3 PYRO9B ON-B	*none*
ZPWM3513SWOF	V01-HE 1 IV, PARM3 PYRO1B OFF-B	*none*
ZPWM3514SWOF	V31-HE 1 IV, PARM3 PYRO2B OFF-B	*none*
ZPWM3515SWOF	V11-N2O4 1 PIV, PARM3 PYRO3B OFF-B	*none*
ZPWM3516SWOF	V27-N2O4 1 PIV, PARM3 PYRO4B OFF-B	*none*
ZPWM3517SWOF	V17-MMH 1 PIV, PARM3 PYRO5B OFF-B	*none*
ZPWM3518SWOF	V28-MMH 1 PIV,PARM3 PYRO6B OFF-B	*none*
ZPWM3519SWOF	HGA HDRM 1, PARM3 PYRO7B OFF-B	*none*
ZPWM3520SWOF	HGA HDRM 2, PARM3 PYRO8B OFF-B	*none*
ZPWM3521SWOF	HGA HDRM 3, PARM3 PYRO9B OFF-B	*none*
ZPWM3522SWON	V05-PR 1 HP IV, PARM4 PYRO1B ON-B	*none*
ZPWM3523SWON	V06-PR 1 LP IV, PARM4 PYRO2B ON-B	*none*
ZPWM3524SWON	V07-PR 2 HP PV, PARM4 PYRO3B ON-B	*none*

Name	Designation	Verif TM
ZPWM3525SWON	V08-PR 2 HP PV, PARM4 PYRO4B ON-B	*none*
ZPWM3526SWON	V09-PR 2 LP OV, PARM4 PYRO5B ON-B	*none*
ZPWM3527SWON	V10-PR 2 LP OV, PARM4 PYRO6B ON-B	*none*
ZPWM3528SWOF	V05-PR 1 HP IV, PARM4 PYRO1B OFF-B	*none*
ZPWM3529SWOF	V06-PR 1 LP IV, PARM4 PYRO2B OFF-B	*none*
ZPWM3530SWOF	V07-PR 2 HP PV, PARM4 PYRO3B OFF-B	*none*
ZPWM3531SWOF	V08-PR 2 HP PV, PARM4 PYRO4B OFF-B	*none*
ZPWM3532SWOF	V09-PR 2 LP OV, PARM4 PYRO5B OFF-B	*none*
ZPWM3533SWOF	V10-PR 2 LP OV, PARM4 PYRO6B OFF-B	*none*
ZPWM3534SWON	V16-N2O4 LP IV, PARM5 PYRO1B ON-B	*none*
ZPWM3535SWON	V22-MMH LP IV, PARM5 PYRO2B ON-B	*none*
ZPWM3536SWON	V29-N2O4 LP IV, PARM5 PYRO3B ON-B	*none*
ZPWM3537SWON	V30-MMH LP IV, PARM5 PYRO4B ON-B	*none*
ZPWM3538SWOF	V16-N2O4 LP IV, PARM5 PYRO1B OFF-B	*none*
ZPWM3539SWOF	V22-MMH LP IV, PARM5 PYRO2B OFF-B	*none*
ZPWM3540SWOF	V29-N2O4 LP IV, PARM5 PYRO3B OFF-B	*none*
ZPWM3541SWOF	V30-MMH LP IV, PARM5 PYRO4B OFF-B	*none*
ZPWM3542SWON	PYRO ARM 1B ON, PDU-S/S-B	*none*
ZPWM3543SWON	PYRO ARM 2B ON, PDU-S/S-B	*none*
ZPWM3544SWON	PYRO ARM 3B ON, PDU-S/S-B	*none*
ZPWM3545SWON	PYRO ARM 4B ON, PDU-S/S-B	*none*
ZPWM3546SWON	PYRO ARM 5B ON, PDU-S/S-B	*none*
ZPWM3547SWOF	PYRO ARM 1B OFF, PDU-S/S-B	*none*
ZPWM3548SWOF	PYRO ARM 2B OFF, PDU-S/S-B	*none*
ZPWM3549SWOF	PYRO ARM 3B OFF, PDU-S/S-B	*none*
ZPWM3550SWOF	PYRO ARM 4B OFF, PDU-S/S-B	*none*
ZPWM3551SWOF	PYRO ARM 5B OFF, PDU-S/S-B	*none*

Name	Designation	Verif TM
ZPWM3552SWON	PYRO POWER BAT2 B ON, PDU-S/S-B	*none*
ZPWM3553SWON	PYRO POWER BAT3 B ON, PDU-S/S-B	*none*
ZPWM3554SWON	PYRO POWER BUS B ON, PDU-S/S-B	*none*
ZPWM3555SWOF	PYRO POWER BAT2 B OFF, PDU-S/S-B	*none*
ZPWM3556SWOF	PYRO POWER BAT3 B OFF, PDU-S/S-B	*none*
ZPWM3557SWOF	PYRO POWER BUS B OFF, PDU-S/S-B	*none*
ZPWM3558	PYRO FIRE B, PDU-S/S-B	NPWA2150
ZPWM3991	Generic MLC PDU-S/S-B RTU-A RouteOfCmd	*none*
ZPWM3993	Generic MLC PDU-S/S-B RTU-B RouteOfCmd	*none*
ZPWM3999	Generic MLC for PDU-S/S-B	*none*

8.5. PL-PDU (nominal) TC Packets

Link to PDF-file: PL-PDU-nominal.pdf

Name	Designation	Verif TM
ZPWMA002	UPDATE ALL TM, PDU-P/L-A	*none*
ZPWMA003	UPDATE SWITCH TM, PDU-P/L-A	*none*
ZPWMA004SWON	TM POWER ON, PDU-P/L-A	*none*
ZPWMA005SWOF	TM POWER OFF, PDU-P/L-A	*none*
ZPWMA006	TMpyro P/L-PDU, PDU-P/L-A	*none*
ZPWMA007	RESET PYRO BUFFERS, PDU-P/L-A	*none*
ZPWMA008	START CONTINUOUS, PDU-P/L-A	*none*
ZPWMA009SWON	SSP REL A 1, LCL 1A ON, PDU-P/L-A	NPWAA520
ZPWMA010SWOF	SSP REL A 1, LCL 1A OFF, PDU-P/L-A	NPWAA520
ZPWMA011SWON	SSP REL B 1, LCL 2A ON, PDU-P/L-A	NPWAA520
ZPWMA012SWOF	SSP REL B 1, LCL 2A OFF, PDU-P/L-A	NPWAA520
ZPWMA013SWON	SPARE, LCL 3A ON, PDU-P/L-A	NPWAA530
ZPWMA014SWOF	SPARE, LCL 3A OFF, PDU-P/L-A	NPWAA530
ZPWMA015SWON	SPARE, LCL 4A ON, PDU-P/L-A	NPWAA530

Name	Designation	Verif TM
ZPWMA016SWOF	SPARE, LCL 4A OFF, PDU-P/L-A	NPWAA530
ZPWMA017SWON	SSP LANDER HTR, LCL 5A ON, PDU-P/L-A	NPWAA540
ZPWMA018SWOF	SSP LANDER HTR, LCL 5A OFF, PDU-P/L-A	NPWAA540
ZPWMA019SWON	MIDAS PS 1, LCL 6A ON, PDU-P/L-A	NPWAA540
ZPWMA020SWOF	MIDAS PS 1, LCL 6A OFF, PDU-P/L-A	NPWAA540
ZPWMA021SWON	MIRO ME+SE, LCL 7A ON, PDU-P/L-A	NPWAA550
ZPWMA022SWOF	MIRO ME+SE, LCL 7A OFF, PDU-P/L-A	NPWAA550
ZPWMA023SWON	VIR/OSIR/RXTX1&2, LCL 8A ON, PDU-P/L-A	NPWAA550
ZPWMA024SWOF	VIR/OSIR/RXTX1&2, LCL 8A OFF, PDU-P/L-A	NPWAA550
ZPWMA025SWON	CON/OS NAC-C/MID, LCL 9A ON, PDU-P/L-A	NPWAA560
ZPWMA026SWOF	CON/OS NAC-C/MID, LCL 9A OFF, PDU-P/L-A	NPWAA560
ZPWMA027SWON	ROS/COS/RPC/ , LCL 10A ON, PDU-P/L-A	NPWAA560
ZPWMA028SWOF	ROS/COS/RPC/ , LCL 10A OFF, PDU-P/L-A	NPWAA560
ZPWMA029SWON	ALICE PS 1, LCL 11A ON, PDU-P/L-A	NPWAA570
ZPWMA030SWOF	ALICE PS 1, LCL 11A OFF, PDU-P/L-A	NPWAA570
ZPWMA031SWON	SPARE, LCL 12A ON, PDU-P/L-A	NPWAA570
ZPWMA032SWOF	SPARE, LCL 12A OFF, PDU-P/L-A	NPWAA570
ZPWMA033SWON	ALICE HIB, LCL 13A ON, PDU-P/L-A	NPWAA580
ZPWMA034SWOF	ALICE HIB, LCL 13A OFF, PDU-P/L-A	NPWAA580
ZPWMA035SWON	SREM PS 1, LCL 14A ON, PDU-P/L-A	NPWAA580
ZPWMA036SWOF	SREM PS 1, LCL 14A OFF, PDU-P/L-A	NPWAA580
ZPWMA037SWON	SSP PS 1, LCL 15A ON, PDU-P/L-A	NPWAA440
ZPWMA038SWOF	SSP PS 1, LCL 15A OFF, PDU-P/L-A	NPWAA440
ZPWMA039SWON	SPARE, LCL 16A ON, PDU-P/L-A	NPWAA440
ZPWMA040SWOF	SPARE, LCL 16A OFF, PDU-P/L-A	NPWAA440
ZPWMA041SWON	SSP MSS HOUS, LCL 17A ON, PDU-P/L-A	NPWAA450
ZPWMA042SWOF	SSP MSS HOUS, LCL 17A OFF, PDU-P/L-A	NPWAA450

Name	Designation	Verif TM
ZPWMA043SWON	SSP ESS/ RPC IES, LCL 18A ON, PDU-P/L-A	NPWAA450
ZPWMA044SWOF	SSP ESS/ RPC IES, LCL 18A OFF, PDU-P/L-A	NPWAA450
ZPWMA045SWON	SPARE, LCL 19A ON, PDU-P/L-A	NPWAA460
ZPWMA046SWOF	SPARE, LCL 19A OFF, PDU-P/L-A	NPWAA460
ZPWMA047SWON	BOOM HINGE HTRS, LCL 20A ON, PDU-P/L-A	NPWAA460
ZPWMA048SWOF	BOOM HINGE HTRS, LCL 20A OFF, PDU-P/L-A	NPWAA460
ZPWMA049SWON	STR1-2/NAVCAM1-2, LCL 21A ON, PDU-P/L-A	NPWAA470
ZPWMA050SWOF	STR1-2/NAVCAM1-2, LCL 21A OFF, PDU-P/L-A	NPWAA470
ZPWMA051SWON	SPARE, LCL 22A ON, PDU-P/L-A	NPWAA470
ZPWMA052SWOF	SPARE, LCL 22A OFF, PDU-P/L-A	NPWAA470
ZPWMA053SWON	RCS1-4 (LINE1), LCL 23A ON, PDU-P/L-A	NPWAA480
ZPWMA054SWOF	RCS1-4 (LINE1), LCL 23A OFF, PDU-P/L-A	NPWAA480
ZPWMA055SWON	RCS5-8 (LINE2), LCL 24A ON, PDU-P/L-A	NPWAA480
ZPWMA056SWOF	RCS5-8 (LINE2), LCL 24A OFF, PDU-P/L-A	NPWAA480
ZPWMA057SWON	SPARE, LCL 25A ON, PDU-P/L-A	NPWAA490
ZPWMA058SWOF	SPARE, LCL 25A OFF, PDU-P/L-A	NPWAA490
ZPWMA059SWON	SPARE, LCL 26A ON, PDU-P/L-A	NPWAA490
ZPWMA060SWOF	SPARE, LCL 26A OFF, PDU-P/L-A	NPWAA490
ZPWMA061SWON	MIRO OPT BEN HTR, LCL 27A ON, PDU-P/L-A	NPWAA500
ZPWMA062SWOF	MIRO OPT BEN HTR, LCL 27A OFF, PDU-P/L-A	NPWAA500
ZPWMA063SWON	VIRTIS PEMM, LCL 28A ON, PDU-P/L-A	NPWAA500
ZPWMA064SWOF	VIRTIS PEMM, LCL 28A OFF, PDU-P/L-A	NPWAA500
ZPWMA065SWON	MIRO PS 1, LCL 29A ON, PDU-P/L-A	NPWAA360
ZPWMA066SWOF	MIRO PS 1, LCL 29A OFF, PDU-P/L-A	NPWAA360
ZPWMA067SWON	OSIRIS PS 1, LCL 30A ON, PDU-P/L-A	NPWAA360
ZPWMA068SWOF	OSIRIS PS 1, LCL 30A OFF, PDU-P/L-A	NPWAA360
ZPWMA069SWON	ROSINA PS 1, LCL 31A ON, PDU-P/L-A	NPWAA370

Name	Designation	Verif TM
ZPWMA070SWOF	ROSINA PS 1, LCL 31A OFF, PDU-P/L-A	NPWAA370
ZPWMA071SWON	COSIMA PS 1, LCL 32A ON, PDU-P/L-A	NPWAA370
ZPWMA072SWOF	COSIMA PS 1, LCL 32A OFF, PDU-P/L-A	NPWAA370
ZPWMA073SWON	GIADA PS 1, LCL 33A ON, PDU-P/L-A	NPWAA380
ZPWMA074SWOF	GIADA PS 1, LCL 33A OFF, PDU-P/L-A	NPWAA380
ZPWMA075SWON	ROSINA DFMS HTR, LCL 34A ON, PDU-P/L-A	NPWAA380
ZPWMA076SWOF	ROSINA DFMS HTR, LCL 34A OFF, PDU-P/L-A	NPWAA380
ZPWMA077SWON	PROP TANK +Z HTR, LCL 35A ON, PDU-P/L-A	NPWAA390
ZPWMA078SWOF	PROP TANK +Z HTR, LCL 35A OFF, PDU-P/L-A	NPWAA390
ZPWMA079SWON	PROP TANK -Z HTR, LCL 36A ON, PDU-P/L-A	NPWAA390
ZPWMA080SWOF	PROP TANK -Z HTR, LCL 36A OFF, PDU-P/L-A	NPWAA390
ZPWMA081SWON	RCS9-12 (LINE3), LCL 37A ON, PDU-P/L-A	NPWAA400
ZPWMA082SWOF	RCS9-12 (LINE3), LCL 37A OFF, PDU-P/L-A	NPWAA400
ZPWMA083SWON	SPARE, LCL 38A ON, PDU-P/L-A	NPWAA400
ZPWMA084SWOF	SPARE, LCL 38A OFF, PDU-P/L-A	NPWAA400
ZPWMA085SWON	OSRIS EL HIB HTR, LCL 39A ON, PDU-P/L-A	NPWAA410
ZPWMA086SWOF	OSRIS EL HIB HTR, LCL 39A OFF, PDU-P/L-A	NPWAA410
ZPWMA087SWON	RPC IES HTR, LCL 40A ON, PDU-P/L-A	NPWAA410
ZPWMA088SWOF	RPC IES HTR, LCL 40A OFF, PDU-P/L-A	NPWAA410
ZPWMA089SWON	RPC ICA A/SREM/L, LCL 41A ON, PDU-P/L-A	NPWAA420
ZPWMA090SWOF	RPC ICA A/SREM/L, LCL 41A OFF, PDU-P/L-A	NPWAA420
ZPWMA091SWON	ROSINA COPS HTR, LCL 42A ON, PDU-P/L-A	NPWAA420
ZPWMA092SWOF	ROSINA COPS HTR, LCL 42A OFF, PDU-P/L-A	NPWAA420
ZPWMA093SWON	HS1/APM/HS4, LCL 43A ON, PDU-P/L-A	NPWAA340
ZPWMA094SWOF	HS1/APM/HS4, LCL 43A OFF, PDU-P/L-A	NPWAA340
ZPWMA095SWON	HS5-8 THRS 1-4, LCL 44A ON, PDU-P/L-A	NPWAA340
ZPWMA096SWOF	HS5-8 THRS 1-4, LCL 44A OFF, PDU-P/L-A	NPWAA340

Name	Designation	Verif TM
ZPWMA097SWON	HS9-12 THRS 5-8, LCL 45A ON, PDU-P/L-A	NPWAA350
ZPWMA098SWOF	HS9-12 THRS 5-8, LCL 45A OFF, PDU-P/L-A	NPWAA350
ZPWMA099SWON	HS13-16 THRS9-12, LCL 46A ON, PDU-P/L-A	NPWAA350
ZPWMA100SWOF	HS13-16 THRS9-12, LCL 46A OFF, PDU-P/L-A	NPWAA350
ZPWMA101SWON	VIRTIS PS 1, LCL 47A ON, PDU-P/L-A	NPWAA280
ZPWMA102SWOF	VIRTIS PS 1, LCL 47A OFF, PDU-P/L-A	NPWAA280
ZPWMA103SWON	SPARE, LCL 48A ON, PDU-P/L-A	NPWAA280
ZPWMA104SWOF	SPARE, LCL 48A OFF, PDU-P/L-A	NPWAA280
ZPWMA105SWON	RPC PS 1, LCL 49A ON, PDU-P/L-A	NPWAA290
ZPWMA106SWOF	RPC PS 1, LCL 49A OFF, PDU-P/L-A	NPWAA290
ZPWMA107SWON	SPARE, LCL 50A ON, PDU-P/L-A	NPWAA290
ZPWMA108SWOF	SPARE, LCL 50A OFF, PDU-P/L-A	NPWAA290
ZPWMA109SWON	SPARE, LCL 51A ON, PDU-P/L-A	NPWAA300
ZPWMA110SWOF	SPARE, LCL 51A OFF, PDU-P/L-A	NPWAA300
ZPWMA111SWON	CONSERT PS 1, LCL 52A ON, PDU-P/L-A	NPWAA300
ZPWMA112SWOF	CONSERT PS 1, LCL 52A OFF, PDU-P/L-A	NPWAA300
ZPWMA113SWON	ROSINA RTOF HTR, LCL 53A ON, PDU-P/L-A	NPWAA310
ZPWMA114SWOF	ROSINA RTOF HTR, LCL 53A OFF, PDU-P/L-A	NPWAA310
ZPWMA115SWON	GIADA HIB HTR, LCL 54A ON, PDU-P/L-A	NPWAA310
ZPWMA116SWOF	GIADA HIB HTR, LCL 54A OFF, PDU-P/L-A	NPWAA310
ZPWMA117	SSP REL A 1, SEL LCL 1A CUR PROF-A	*none*
ZPWMA118	SSP REL B 1, SEL LCL 2A CUR PROF-A	*none*
ZPWMA119	SPARE, SEL LCL 3A CUR PROF-A	*none*
ZPWMA120	SPARE, SEL LCL 4A CUR PROF-A	*none*
ZPWMA121	SSP LANDER HTR, SEL LCL 5A CUR PROF-A	*none*
ZPWMA122	MIDAS PS 1, SEL LCL 6A CUR PROF-A	*none*
ZPWMA123	MIRO ME+SE, SEL LCL 7A CUR PROF-A	*none*

Name	Designation	Verif TM
ZPWMA124	VIR/OSIR/RXTX1&2, SEL LCL 8A CUR PROF-A	*none*
ZPWMA125	CON/OS NAC-C/MID, SEL LCL 9A CUR PROF-A	*none*
ZPWMA126	ROS/COS/RPC/ , SEL LCL 10A CUR PROF-A	*none*
ZPWMA127	ALICE PS 1, SEL LCL 11A CUR PROF-A	*none*
ZPWMA128	SPARE, SEL LCL 12A CUR PROF-A	*none*
ZPWMA129	ALICE HIB, SEL LCL 13A CUR PROF-A	*none*
ZPWMA130	SREM PS 1, SEL LCL 14A CUR PROF-A	*none*
ZPWMA131	SSP PS 1, SEL LCL 15A CUR PROF-A	*none*
ZPWMA132	SPARE, SEL LCL 16A CUR PROF-A	*none*
ZPWMA133	SSP MSS HOU, SEL LCL 17A CUR PROF-A	*none*
ZPWMA134	SSP ESS/ RPC IES, SEL LCL 18A CUR PROF-A	*none*
ZPWMA135	SPARE, SEL LCL 19A CUR PROF-A	*none*
ZPWMA136	BOOM HINGE HTRS, SEL LCL 20A CUR PROF-A	*none*
ZPWMA137	STR1-2/NAVCAM1-2, SEL LCL 21A CUR PROF-A	*none*
ZPWMA138	SPARE, SEL LCL 22A CUR PROF-A	*none*
ZPWMA139	RCS1-4 (LINE1), SEL LCL 23A CUR PROF-A	*none*
ZPWMA140	RCS5-8 (LINE2), SEL LCL 24A CUR PROF-A	*none*
ZPWMA141	SPARE, SEL LCL 25A CUR PROF-A	*none*
ZPWMA142	SPARE, SEL LCL 26A CUR PROF-A	*none*
ZPWMA143	MIRO OPT BEN HTR, SEL LCL 27A CUR PROF-A	*none*
ZPWMA144	VIRTIS PEMM, SEL LCL 28A CUR PROF-A	*none*
ZPWMA145	MIRO PS 1, SEL LCL 29A CUR PROF-A	*none*
ZPWMA146	OSIRIS PS 1, SEL LCL 30A CUR PROF-A	*none*
ZPWMA147	ROSINA PS 1, SEL LCL 31A CUR PROF-A	*none*
ZPWMA148	COSIMA PS 1, SEL LCL 32A CUR PROF-A	*none*
ZPWMA149	GIADA PS 1, SEL LCL 33A CUR PROF-A	*none*
ZPWMA150	ROSINA DFMS HTR, SEL LCL 34A CUR PROF-A	*none*

Name	Designation	Verif TM
ZPWMA151	PROP TANK +Z HTR, SEL LCL 35A CUR PROF-A	*none*
ZPWMA152	PROP TANK -Z HTR, SEL LCL 36A CUR PROF-A	*none*
ZPWMA153	RCS9-12 (LINE3), SEL LCL 37A CUR PROF-A	*none*
ZPWMA154	SPARE, SEL LCL 38A CUR PROF-A	*none*
ZPWMA155	OSRIS EL HIB HTR, SEL LCL 39A CUR PROF-A	*none*
ZPWMA156	RPC IES HTR, SEL LCL 40A CUR PROF-A	*none*
ZPWMA157	RPC ICA A/SREM/L, SEL LCL 41A CUR PROF-A	*none*
ZPWMA158	ROSINA COPS HTR, SEL LCL 42A CUR PROF-A	*none*
ZPWMA159	HS1/APM/HS4, SEL LCL 43A CUR PROF-A	*none*
ZPWMA160	HS5-8 THRS 1-4, SEL LCL 44A CUR PROF-A	*none*
ZPWMA161	HS9-12 THRS 5-8, SEL LCL 45A CUR PROF-A	*none*
ZPWMA162	HS13-16 THRS9-12, SEL LCL 46A CUR PROF-A	*none*
ZPWMA163	VIRTIS PS 1, SEL LCL 47A CUR PROF-A	*none*
ZPWMA164	SPARE, SEL LCL 48A CUR PROF-A	*none*
ZPWMA165	RPC PS 1, SEL LCL 49A CUR PROF-A	*none*
ZPWMA166	SPARE, SEL LCL 50A CUR PROF-A	*none*
ZPWMA167	SPARE, SEL LCL 51A CUR PROF-A	*none*
ZPWMA168	CONSERT PS 1, SEL LCL 52A CUR PROF-A	*none*
ZPWMA169	ROSINA RTOF HTR, SEL LCL 53A CUR PROF-A	*none*
ZPWMA170	GIADA HIB HTR, SEL LCL 54A CUR PROF-A	*none*
ZPWMA171SWON	SPARE, HTR SW 1A ON-A	*none*
ZPWMA172SWOF	SPARE, HTR SW 1A OFF-A	*none*
ZPWMA173SWON	APM, HTR SW 2A ON-A	*none*
ZPWMA174SWOF	APM, HTR SW 2A OFF-A	*none*
ZPWMA175SWON	SADM +Y Shaft/ CASE, HTR SW 3A ON-A	*none*
ZPWMA176SWOF	SADM +Y Shaft/ CASE, HTR SW 3A OFF-A	*none*
ZPWMA177SWON	SADM -Y Shaft/ CASE, HTR SW 4A ON-A	*none*

Name	Designation	Verif TM
ZPWMA178SWOF	SADM -Y Shaft/ CASE, HTR SW 4A OFF-A	*none*
ZPWMA179SWON	THR HSW MODULE 1, HTR SW 5A ON-A	*none*
ZPWMA180SWOF	THR HSW MODULE 1, HTR SW 5A OFF-A	*none*
ZPWMA181SWON	THR HSW MODULE 2, HTR SW 6A ON-A	*none*
ZPWMA182SWOF	THR HSW MODULE 2, HTR SW 6A OFF-A	*none*
ZPWMA183SWON	THR HSW MODULE 3, HTR SW 7A ON-A	*none*
ZPWMA184SWOF	THR HSW MODULE 3, HTR SW 7A OFF-A	*none*
ZPWMA185SWON	THR HSW MODULE 4, HTR SW 8A ON-A	*none*
ZPWMA186SWOF	THR HSW MODULE 4, HTR SW 8A OFF-A	*none*
ZPWMA187SWON	THR HSW MODULE 5, HTR SW 9A ON-A	*none*
ZPWMA188SWOF	THR HSW MODULE 5, HTR SW 9A OFF-A	*none*
ZPWMA189SWON	THR HSW MODULE 6, HTR SW 10A ON-A	*none*
ZPWMA190SWOF	THR HSW MODULE 6, HTR SW 10A OFF-A	*none*
ZPWMA191SWON	THR HSW MODULE 7, HTR SW 11A ON-A	*none*
ZPWMA192SWOF	THR HSW MODULE 7, HTR SW 11A OFF-A	*none*
ZPWMA193SWON	THR HSW MODULE 8, HTR SW 12A ON-A	*none*
ZPWMA194SWOF	THR HSW MODULE 8, HTR SW 12A OFF-A	*none*
ZPWMA195SWON	THR HSW MODULE 9, HTR SW 13A ON-A	*none*
ZPWMA196SWOF	THR HSW MODULE 9, HTR SW 13A OFF-A	*none*
ZPWMA197SWON	THR HSW MODULE 10, HTR SW 14A ON-A	*none*
ZPWMA198SWOF	THR HSW MODULE 10, HTR SW 14A OFF-A	*none*
ZPWMA199SWON	THR HSW MODULE 11, HTR SW 15A ON-A	*none*
ZPWMA200SWOF	THR HSW MODULE 11, HTR SW 15A OFF-A	*none*
ZPWMA201SWON	THR HSW MODULE 12, HTR SW 16A ON-A	*none*
ZPWMA202SWOF	THR HSW MODULE 12, HTR SW 16A OFF-A	*none*
ZPWMA203SWON	KAL CONVERTER A ON, PDU-P/L-A	NPWAA320
ZPWMA204SWOF	KAL CONVERTER A OFF, PDU-P/L-A	NPWAA320

Name	Designation	Verif TM
ZPWMA205SWON	SSP Emergncy Rel, PARM1 PYRO1A ON-A	*none*
ZPWMA206SWOF	SSP Emergncy Rel, PARM1 PYRO1A OFF-A	*none*
ZPWMA207SWON	Lower Boom Rel, PARM2 PYRO1A ON-A	*none*
ZPWMA208SWON	Upper Boom Rel, PARM2 PYRO2A ON-A	*none*
ZPWMA209SWON	SPARE 1A, PARM2 PYRO3A ON-A	*none*
ZPWMA210SWOF	Lower Boom Rel, PARM2 PYRO1A OFF-A	*none*
ZPWMA211SWOF	Upper Boom Rel, PARM2 PYRO2A OFF-A	*none*
ZPWMA212SWOF	SPARE 1A, PARM2 PYRO3A OFF-A	*none*
ZPWMA213SWON	Rosina DFMS Det, PARM3 PYRO1A ON-A	*none*
ZPWMA214SWON	Rosina RTOF Det, PARM3 PYRO2A ON-A	*none*
ZPWMA215SWON	Ros DFMS Fail/Safe, PARM3 PYRO3A ON-A	*none*
ZPWMA216SWON	SPARE 3A, PARM3 PYRO4A ON-A	*none*
ZPWMA217SWON	SPARE 4A, PARM3 PYRO5A ON-A	*none*
ZPWMA218SWON	SPARE 5A, PARM3 PYRO6A ON-A	*none*
ZPWMA219SWON	Consert Ant Rel, PARM3 PYRO7A ON-A	*none*
ZPWMA220SWOF	Rosina DFMS Det, PARM3 PYRO1A OFF-A	*none*
ZPWMA221SWOF	Rosina RTOF Det, PARM3 PYRO2A OFF-A	*none*
ZPWMA222SWOF	Ros DFMS Fail/Safe, PARM3 PYRO3A OFF-A	*none*
ZPWMA223SWOF	SPARE 3A, PARM3 PYRO4A OFF-A	*none*
ZPWMA224SWOF	SPARE 4A, PARM3 PYRO5A OFF-A	*none*
ZPWMA225SWOF	SPARE 5A, PARM3 PYRO6A OFF-A	*none*
ZPWMA226SWOF	Consert Ant Rel, PARM3 PYRO7A OFF-A	*none*
ZPWMA227SWON	Alice Det Door Rel, PARM4 PYRO1A ON-A	*none*
ZPWMA228SWON	Alice Apert Uncage, PARM4 PYRO2A ON-A	*none*
ZPWMA229SWON	Alice Fail Safe, PARM4 PYRO3A ON-A	*none*
ZPWMA230SWON	Midas Cover Rel, PARM4 PYRO4A ON-A	*none*
ZPWMA231SWON	SPARE, PARM4 PYRO5A ON-A	*none*

Name	Designation	Verif TM
ZPWMA232SWON	SPARE, PARM4 PYRO6A ON-A	*none*
ZPWMA233SWOF	Alice Det Door Rel, PARM4 PYRO1A OFF-A	*none*
ZPWMA234SWOF	Alice Apert Uncage, PARM4 PYRO2A OFF-A	*none*
ZPWMA235SWOF	Alice Fail Safe, PARM4 PYRO3A OFF-A	*none*
ZPWMA236SWOF	Midas Cover Rel, PARM4 PYRO4A OFF-A	*none*
ZPWMA237SWOF	SPARE, PARM4 PYRO5A OFF-A	*none*
ZPWMA238SWOF	SPARE, PARM4 PYRO6A OFF-A	*none*
ZPWMA239SWON	SSP Lander Rel 1, PARM5 PYRO1A ON-A	*none*
ZPWMA240SWON	SSP Lander Rel 2, PARM5 PYRO2A ON-A	*none*
ZPWMA241SWON	SSP Lander Rel 3, PARM5 PYRO3A ON-A	*none*
ZPWMA242SWON	SSP Lander Rel 4, PARM5 PYRO4A ON-A	*none*
ZPWMA243SWON	SPARE 2A, PARM5 PYRO5A ON-A	*none*
ZPWMA244SWOF	SSP Lander Rel 1, PARM5 PYRO1A OFF-A	*none*
ZPWMA245SWOF	SSP Lander Rel 2, PARM5 PYRO2A OFF-A	*none*
ZPWMA246SWOF	SSP Lander Rel 3, PARM5 PYRO3A OFF-A	*none*
ZPWMA247SWOF	SSP Lander Rel 4, PARM5 PYRO4A OFF-A	*none*
ZPWMA248SWOF	SPARE 2A, PARM5 PYRO5A OFF-A	*none*
ZPWMA249SWON	PYRO ARM 1A ON, PDU-P/L-A	*none*
ZPWMA250SWON	PYRO ARM 2A ON, PDU-P/L-A	*none*
ZPWMA251SWON	PYRO ARM 3A ON, PDU-P/L-A	*none*
ZPWMA252SWON	PYRO ARM 4A ON, PDU-P/L-A	*none*
ZPWMA253SWON	PYRO ARM 5A ON, PDU-P/L-A	*none*
ZPWMA254SWOF	PYRO ARM 1A OFF, PDU-P/L-A	*none*
ZPWMA255SWOF	PYRO ARM 2A OFF, PDU-P/L-A	*none*
ZPWMA256SWOF	PYRO ARM 3A OFF, PDU-P/L-A	*none*
ZPWMA257SWOF	PYRO ARM 4A OFF, PDU-P/L-A	*none*
ZPWMA258SWOF	PYRO ARM 5A OFF, PDU-P/L-A	*none*

Name	Designation	Verif TM
ZPWMA259SWON	PYRO POWER BAT1 A ON, PDU-P/L-A	*none*
ZPWMA260SWON	PYRO POWER BAT2 A ON, PDU-P/L-A	*none*
ZPWMA261SWON	PYRO POWER BUS A ON, PDU-P/L-A	*none*
ZPWMA262SWOF	PYRO POWER BAT1 A OFF, PDU-P/L-A	*none*
ZPWMA263SWOF	PYRO POWER BAT2 A OFF, PDU-P/L-A	*none*
ZPWMA264SWOF	PYRO POWER BUS A OFF, PDU-P/L-A	*none*
ZPWMA265	PYRO FIRE A, PDU-P/L-A	NPWAA030
ZPWMA266SWON	SSP REL A 2, LCL 1B ON, PDU-P/L-A	NPWAA840
ZPWMA267SWOF	SSP REL A 2, LCL 1B OFF, PDU-P/L-A	NPWAA840
ZPWMA268SWON	SSP REL B 2, LCL 2B ON, PDU-P/L-A	NPWAA840
ZPWMA269SWOF	SSP REL B 2, LCL 2B OFF, PDU-P/L-A	NPWAA840
ZPWMA270SWON	SPARE, LCL 3B ON, PDU-P/L-A	NPWAA850
ZPWMA271SWOF	SPARE, LCL 3B OFF, PDU-P/L-A	NPWAA850
ZPWMA272SWON	SPARE, LCL 4B ON, PDU-P/L-A	NPWAA850
ZPWMA273SWOF	SPARE, LCL 4B OFF, PDU-P/L-A	NPWAA850
ZPWMA274SWON	SSP LANDER HTR, LCL 5B ON, PDU-P/L-A	NPWAA860
ZPWMA275SWOF	SSP LANDER HTR, LCL 5B OFF, PDU-P/L-A	NPWAA860
ZPWMA276SWON	MIDAS PS 2, LCL 6B ON, PDU-P/L-A	NPWAA860
ZPWMA277SWOF	MIDAS PS 2, LCL 6B OFF, PDU-P/L-A	NPWAA860
ZPWMA278SWON	MIRO ME+SE, LCL 7B ON, PDU-P/L-A	NPWAA870
ZPWMA279SWOF	MIRO ME+SE, LCL 7B OFF, PDU-P/L-A	NPWAA870
ZPWMA280SWON	VIR/OSIR/RXTX1&2, LCL 8B ON, PDU-P/L-A	NPWAA870
ZPWMA281SWOF	VIR/OSIR/RXTX1&2, LCL 8B OFF, PDU-P/L-A	NPWAA870
ZPWMA282SWON	CON/OS NAC-C/MID, LCL 9B ON, PDU-P/L-A	NPWAA880
ZPWMA283SWOF	CON/OS NAC-C/MID, LCL 9B OFF, PDU-P/L-A	NPWAA880
ZPWMA284SWON	ROS/COS/RPC/ , LCL 10B ON, PDU-P/L-A	NPWAA880
ZPWMA285SWOF	ROS/COS/RPC/ , LCL 10B OFF, PDU-P/L-A	NPWAA880

Name	Designation	Verif TM
ZPWMA286SWON	ALICE PS 2, LCL 11B ON, PDU-P/L-A	NPWAA890
ZPWMA287SWOF	ALICE PS 2, LCL 11B OFF, PDU-P/L-A	NPWAA890
ZPWMA288SWON	SPARE, LCL 12B ON, PDU-P/L-A	NPWAA890
ZPWMA289SWOF	SPARE, LCL 12B OFF, PDU-P/L-A	NPWAA890
ZPWMA290SWON	ALICE HIB, LCL 13B ON, PDU-P/L-A	NPWAA900
ZPWMA291SWOF	ALICE HIB, LCL 13B OFF, PDU-P/L-A	NPWAA900
ZPWMA292SWON	SREM PS 2, LCL 14B ON, PDU-P/L-A	NPWAA900
ZPWMA293SWOF	SREM PS 2, LCL 14B OFF, PDU-P/L-A	NPWAA900
ZPWMA294SWON	SSP PS 2, LCL 15B ON, PDU-P/L-A	NPWAA760
ZPWMA295SWOF	SSP PS 2, LCL 15B OFF, PDU-P/L-A	NPWAA760
ZPWMA296SWON	SPARE, LCL 16B ON, PDU-P/L-A	NPWAA760
ZPWMA297SWOF	SPARE, LCL 16B OFF, PDU-P/L-A	NPWAA760
ZPWMA298SWON	SSP MSS HOUS, LCL 17B ON, PDU-P/L-A	NPWAA770
ZPWMA299SWOF	SSP MSS HOUS, LCL 17B OFF, PDU-P/L-A	NPWAA770
ZPWMA300SWON	SSP ESS/ RPC IES, LCL 18B ON, PDU-P/L-A	NPWAA770
ZPWMA301SWOF	SSP ESS/ RPC IES, LCL 18B OFF, PDU-P/L-A	NPWAA770
ZPWMA302SWON	SPARE, LCL 19B ON, PDU-P/L-A	NPWAA780
ZPWMA303SWOF	SPARE, LCL 19B OFF, PDU-P/L-A	NPWAA780
ZPWMA304SWON	BOOM HINGE HTRS, LCL 20B ON, PDU-P/L-A	NPWAA780
ZPWMA305SWOF	BOOM HINGE HTRS, LCL 20B OFF, PDU-P/L-A	NPWAA780
ZPWMA306SWON	STR1-2/NAVCAM1-2, LCL 21B ON, PDU-P/L-A	NPWAA790
ZPWMA307SWOF	STR1-2/NAVCAM1-2, LCL 21B OFF, PDU-P/L-A	NPWAA790
ZPWMA308SWON	SPARE, LCL 22B ON, PDU-P/L-A	NPWAA790
ZPWMA309SWOF	SPARE, LCL 22B OFF, PDU-P/L-A	NPWAA790
ZPWMA310SWON	RCS1-4 (LINE1), LCL 23B ON, PDU-P/L-A	NPWAA800
ZPWMA311SWOF	RCS1-4 (LINE1), LCL 23B OFF, PDU-P/L-A	NPWAA800
ZPWMA312SWON	RCS5-8 (LINE2), LCL 24B ON, PDU-P/L-A	NPWAA800

Name	Designation	Verif TM
ZPWMA313SWOF	RCS5-8 (LINE2), LCL 24B OFF, PDU-P/L-A	NPWAA800
ZPWMA314SWON	SPARE, LCL 25B ON, PDU-P/L-A	NPWAA810
ZPWMA315SWOF	SPARE, LCL 25B OFF, PDU-P/L-A	NPWAA810
ZPWMA316SWON	SPARE, LCL 26B ON, PDU-P/L-A	NPWAA810
ZPWMA317SWOF	SPARE, LCL 26B OFF, PDU-P/L-A	NPWAA810
ZPWMA318SWON	MR OPT BENCH HTR, LCL 27B ON, PDU-P/L-A	NPWAA820
ZPWMA319SWOF	MR OPT BENCH HTR, LCL 27B OFF, PDU-P/L-A	NPWAA820
ZPWMA320SWON	VIRTIS PEMM, LCL 28B ON, PDU-P/L-A	NPWAA820
ZPWMA321SWOF	VIRTIS PEMM, LCL 28B OFF, PDU-P/L-A	NPWAA820
ZPWMA322SWON	MIRO PS 2, LCL 29B ON, PDU-P/L-A	NPWAA680
ZPWMA323SWOF	MIRO PS 2, LCL 29B OFF, PDU-P/L-A	NPWAA680
ZPWMA324SWON	OSIRIS PS 2, LCL 30B ON, PDU-P/L-A	NPWAA680
ZPWMA325SWOF	OSIRIS PS 2, LCL 30B OFF, PDU-P/L-A	NPWAA680
ZPWMA326SWON	ROSINA PS 2, LCL 31B ON, PDU-P/L-A	NPWAA690
ZPWMA327SWOF	ROSINA PS 2, LCL 31B OFF, PDU-P/L-A	NPWAA690
ZPWMA328SWON	COSIMA PS 2, LCL 32B ON, PDU-P/L-A	NPWAA690
ZPWMA329SWOF	COSIMA PS 2, LCL 32B OFF, PDU-P/L-A	NPWAA690
ZPWMA330SWON	GIADA PS 2, LCL 33B ON, PDU-P/L-A	NPWAA700
ZPWMA331SWOF	GIADA PS 2, LCL 33B OFF, PDU-P/L-A	NPWAA700
ZPWMA332SWON	ROSINA DFMS HTR, LCL 34B ON, PDU-P/L-A	NPWAA700
ZPWMA333SWOF	ROSINA DFMS HTR, LCL 34B OFF, PDU-P/L-A	NPWAA700
ZPWMA334SWON	PROP TANK +Z HTR, LCL 35B ON, PDU-P/L-A	NPWAA710
ZPWMA335SWOF	PROP TANK +Z HTR, LCL 35B OFF, PDU-P/L-A	NPWAA710
ZPWMA336SWON	PROP TANK -Z HTR, LCL 36B ON, PDU-P/L-A	NPWAA710
ZPWMA337SWOF	PROP TANK -Z HTR, LCL 36B OFF, PDU-P/L-A	NPWAA710
ZPWMA338SWON	RCS9-12 (LINE3), LCL 37B ON, PDU-P/L-A	NPWAA720
ZPWMA339SWOF	RCS9-12 (LINE3), LCL 37B OFF, PDU-P/L-A	NPWAA720

Name	Designation	Verif TM
ZPWMA340SWON	SPARE, LCL 38B ON, PDU-P/L-A	NPWAA720
ZPWMA341SWOF	SPARE, LCL 38B OFF, PDU-P/L-A	NPWAA720
ZPWMA342SWON	OSRIS EL HIB HTR, LCL 39B ON, PDU-P/L-A	NPWAA730
ZPWMA343SWOF	OSRIS EL HIB HTR, LCL 39B OFF, PDU-P/L-A	NPWAA730
ZPWMA344SWON	RPC IES HTR, LCL 40B ON, PDU-P/L-A	NPWAA730
ZPWMA345SWOF	RPC IES HTR, LCL 40B OFF, PDU-P/L-A	NPWAA730
ZPWMA346SWON	RPC ICA A/SREM/L, LCL 41B ON, PDU-P/L-A	NPWAA740
ZPWMA347SWOF	RPC ICA A/SREM/L, LCL 41B OFF, PDU-P/L-A	NPWAA740
ZPWMA348SWON	ROSINA COPS HTR, LCL 42B ON, PDU-P/L-A	NPWAA740
ZPWMA349SWOF	ROSINA COPS HTR, LCL 42B OFF, PDU-P/L-A	NPWAA740
ZPWMA350SWON	HS1/APM/HS4, LCL 43B ON, PDU-P/L-A	NPWAA660
ZPWMA351SWOF	HS1/APM/HS4, LCL 43B OFF, PDU-P/L-A	NPWAA660
ZPWMA352SWON	HS5-8 THRS 1-4, LCL 44B ON, PDU-P/L-A	NPWAA660
ZPWMA353SWOF	HS5-8 THRS 1-4, LCL 44B OFF, PDU-P/L-A	NPWAA660
ZPWMA354SWON	HS9-12 THRS 5-8, LCL 45B ON, PDU-P/L-A	NPWAA670
ZPWMA355SWOF	HS9-12 THRS 5-8, LCL 45B OFF, PDU-P/L-A	NPWAA670
ZPWMA356SWON	HS13-16 THRS9-12, LCL 46B ON, PDU-P/L-A	NPWAA670
ZPWMA357SWOF	HS13-16 THRS9-12, LCL 46B OFF, PDU-P/L-A	NPWAA670
ZPWMA358SWON	VIRTIS PS 2, LCL 47B ON, PDU-P/L-A	NPWAA600
ZPWMA359SWOF	VIRTIS PS 2, LCL 47B OFF, PDU-P/L-A	NPWAA600
ZPWMA360SWON	SPARE, LCL 48B ON, PDU-P/L-A	NPWAA600
ZPWMA361SWOF	SPARE, LCL 48B OFF, PDU-P/L-A	NPWAA600
ZPWMA362SWON	RPC PS 2, LCL 49B ON, PDU-P/L-A	NPWAA610
ZPWMA363SWOF	RPC PS 2, LCL 49B OFF, PDU-P/L-A	NPWAA610
ZPWMA364SWON	SPARE, LCL 50B ON, PDU-P/L-A	NPWAA610
ZPWMA365SWOF	SPARE, LCL 50B OFF, PDU-P/L-A	NPWAA610
ZPWMA366SWON	SPARE, LCL 51B ON, PDU-P/L-A	NPWAA620

Name	Designation	Verif TM
ZPWMA367SWOF	SPARE, LCL 51B OFF, PDU-P/L-A	NPWAA620
ZPWMA368SWON	CONSERT PS 2, LCL 52B ON, PDU-P/L-A	NPWAA620
ZPWMA369SWOF	CONSERT PS 2, LCL 52B OFF, PDU-P/L-A	NPWAA620
ZPWMA370SWON	ROSINA RTOF HTR, LCL 53B ON, PDU-P/L-A	NPWAA630
ZPWMA371SWOF	ROSINA RTOF HTR, LCL 53B OFF, PDU-P/L-A	NPWAA630
ZPWMA372SWON	GIADA HIB HTR, LCL 54B ON, PDU-P/L-A	NPWAA630
ZPWMA373SWOF	GIADA HIB HTR, LCL 54B OFF, PDU-P/L-A	NPWAA630
ZPWMA374	SSP REL A 2, SEL LCL 1B CUR PROF-A	*none*
ZPWMA375	SSP REL B 2, SEL LCL 2B CUR PROF-A	*none*
ZPWMA376	SPARE, SEL LCL 3B CUR PROF-A	*none*
ZPWMA377	SPARE, SEL LCL 4B CUR PROF-A	*none*
ZPWMA378	SSP LANDER HTR, SEL LCL 5B CUR PROF-A	*none*
ZPWMA379	MIDAS PS 2, SEL LCL 6B CUR PROF-A	*none*
ZPWMA380	MIRO ME+SE, SEL LCL 7B CUR PROF-A	*none*
ZPWMA381	VIR/OSIR/RXTX1&2, SEL LCL 8B CUR PROF-A	*none*
ZPWMA382	CON/OS NAC-C/MID, SEL LCL 9B CUR PROF-A	*none*
ZPWMA383	ROS/COS/RPC/ , SEL LCL 10B CUR PROF-A	*none*
ZPWMA384	ALICE PS 2, SEL LCL 11B CUR PROF-A	*none*
ZPWMA385	SPARE, SEL LCL 12B CUR PROF-A	*none*
ZPWMA386	ALICE HIB, SEL LCL 13B CUR PROF-A	*none*
ZPWMA387	SREM PS 2, SEL LCL 14B CUR PROF-A	*none*
ZPWMA388	SSP PS 2, SEL LCL 15B CUR PROF-A	*none*
ZPWMA389	SPARE, SEL LCL 16B CUR PROF-A	*none*
ZPWMA390	SSP MSS HOU, SEL LCL 17B CUR PROF-A	*none*
ZPWMA391	SSP ESS/ RPC IES, SEL LCL 18B CUR PROF-A	*none*
ZPWMA392	SPARE, SEL LCL 19B CUR PROF-A	*none*
ZPWMA393	BOOM HINGE HTRS, SEL LCL 20B CUR PROF-A	*none*

Name	Designation	Verif TM
ZPWMA394	STR1-2/NAVCAM1-2, SEL LCL 21B CUR PROF-A	*none*
ZPWMA395	SPARE, SEL LCL 22B CUR PROF-A	*none*
ZPWMA396	RCS1-4 (LINE1), SEL LCL 23B CUR PROF-A	*none*
ZPWMA397	RCS5-8 (LINE2), SEL LCL 24B CUR PROF-A	*none*
ZPWMA398	SPARE, SEL LCL 25B CUR PROF-A	*none*
ZPWMA399	SPARE, SEL LCL 26B CUR PROF-A	*none*
ZPWMA400	MR OPT BENCH HTR, SEL LCL 27B CUR PROF-A	*none*
ZPWMA401	VIRTIS PEMM, SEL LCL 28B CUR PROF-A	*none*
ZPWMA402	MIRO PS 2, SEL LCL 29B CUR PROF-A	*none*
ZPWMA403	OSIRIS PS 2, SEL LCL 30B CUR PROF-A	*none*
ZPWMA404	ROSINA PS 2, SEL LCL 31B CUR PROF-A	*none*
ZPWMA405	COSIMA PS 2, SEL LCL 32B CUR PROF-A	*none*
ZPWMA406	GIADA PS 2, SEL LCL 33B CUR PROF-A	*none*
ZPWMA407	ROSINA DFMS HTR, SEL LCL 34B CUR PROF-A	*none*
ZPWMA408	PROP TANK +Z HTR, SEL LCL 35B CUR PROF-A	*none*
ZPWMA409	PROP TANK -Z HTR, SEL LCL 36B CUR PROF-A	*none*
ZPWMA410	RCS9-12 (LINE3), SEL LCL 37B CUR PROF-A	*none*
ZPWMA411	SPARE, SEL LCL 38B CUR PROF-A	*none*
ZPWMA412	OSRIS EL HIB HTR, SEL LCL 39B CUR PROF-A	*none*
ZPWMA413	RPC IES HTR, SEL LCL 40B CUR PROF-A	*none*
ZPWMA414	RPC ICA A/SREM/L, SEL LCL 41B CUR PROF-A	*none*
ZPWMA415	ROSINA COPS HTR, SEL LCL 42B CUR PROF-A	*none*
ZPWMA416	HS1/APM/HS4, SEL LCL 43B CUR PROF-A	*none*
ZPWMA417	HS5-8 THRS 1-4, SEL LCL 44B CUR PROF-A	*none*
ZPWMA418	HS9-12 THRS 5-8, SEL LCL 45B CUR PROF-A	*none*
ZPWMA419	HS13-16 THRS9-12, SEL LCL 46B CUR PROF-A	*none*
ZPWMA420	VIRTIS PS 2, SEL LCL 47B CUR PROF-A	*none*

Name	Designation	Verif TM
ZPWMA421	SPARE, SEL LCL 48B CUR PROF-A	*none*
ZPWMA422	RPC PS 2, SEL LCL 49B CUR PROF-A	*none*
ZPWMA423	SPARE, SEL LCL 50B CUR PROF-A	*none*
ZPWMA424	SPARE, SEL LCL 51B CUR PROF-A	*none*
ZPWMA425	CONSERT PS 2, SEL LCL 52B CUR PROF-A	*none*
ZPWMA426	ROSINA RTOF HTR, SEL LCL 53B CUR PROF-A	*none*
ZPWMA427	GIADA HIB HTR, SEL LCL 54B CUR PROF-A	*none*
ZPWMA428SWON	SPARE, HTR SW 1B ON-A	*none*
ZPWMA429SWOF	SPARE, HTR SW 1B OFF-A	*none*
ZPWMA430SWON	APM, HTR SW 2B ON-A	*none*
ZPWMA431SWOF	APM, HTR SW 2B OFF-A	*none*
ZPWMA432SWON	SADM +Y Shaft/ CASE, HTR SW 3B ON-A	*none*
ZPWMA433SWOF	SADM +Y Shaft/ CASE, HTR SW 3B OFF-A	*none*
ZPWMA434SWON	SADM -Y Shaft/ CASE, HTR SW 4B ON-A	*none*
ZPWMA435SWOF	SADM -Y Shaft/ CASE, HTR SW 4B OFF-A	*none*
ZPWMA436SWON	THR HSW MODULE 1, HTR SW 5B ON-A	*none*
ZPWMA437SWOF	THR HSW MODULE 1, HTR SW 5B OFF-A	*none*
ZPWMA438SWON	THR HSW MODULE 2, HTR SW 6B ON-A	*none*
ZPWMA439SWOF	THR HSW MODULE 2, HTR SW 6B OFF-A	*none*
ZPWMA440SWON	THR HSW MODULE 3, HTR SW 7B ON-A	*none*
ZPWMA441SWOF	THR HSW MODULE 3, HTR SW 7B OFF-A	*none*
ZPWMA442SWON	THR HSW MODULE 4, HTR SW 8B ON-A	*none*
ZPWMA443SWOF	THR HSW MODULE 4, HTR SW 8B OFF-A	*none*
ZPWMA444SWON	THR HSW MODULE 5, HTR SW 9B ON-A	*none*
ZPWMA445SWOF	THR HSW MODULE 5, HTR SW 9B OFF-A	*none*
ZPWMA446SWON	THR HSW MODULE 6, HTR SW 10B ON-A	*none*
ZPWMA447SWOF	THR HSW MODULE 6, HTR SW 10B OFF-A	*none*

Name	Designation	Verif TM
ZPWMA448SWON	THR HSW MODULE 7, HTR SW 11B ON-A	*none*
ZPWMA449SWOF	THR HSW MODULE 7, HTR SW 11B OFF-A	*none*
ZPWMA450SWON	THR HSW MODULE 8, HTR SW 12B ON-A	*none*
ZPWMA451SWOF	THR HSW MODULE 8, HTR SW 12B OFF-A	*none*
ZPWMA452SWON	THR HSW MODULE 9, HTR SW 13B ON-A	*none*
ZPWMA453SWOF	THR HSW MODULE 9, HTR SW 13B OFF-A	*none*
ZPWMA454SWON	THR HSW MODULE 10, HTR SW 14B ON-A	*none*
ZPWMA455SWOF	THR HSW MODULE 10, HTR SW 14B OFF-A	*none*
ZPWMA456SWON	THR HSW MODULE 11, HTR SW 15B ON-A	*none*
ZPWMA457SWOF	THR HSW MODULE 11, HTR SW 15B OFF-A	*none*
ZPWMA458SWON	THR HSW MODULE 12, HTR SW 16B ON-A	*none*
ZPWMA459SWOF	THR HSW MODULE 12, HTR SW 16B OFF-A	*none*
ZPWMA460SWON	KAL CONVERTER B ON, PDU-P/L-A	NPWAA640
ZPWMA461SWOF	KAL CONVERTER B OFF, PDU-P/L-A	NPWAA640
ZPWMA462SWON	SSP Emergncy Rel, PARM1 PYRO1B ON-A	*none*
ZPWMA463SWOF	SSP Emergncy Rel, PARM1 PYRO1B OFF-A	*none*
ZPWMA464SWON	Lower Boom Rel, PARM2 PYRO1B ON-A	*none*
ZPWMA465SWON	Upper Boom Rel, PARM2 PYRO2B ON-A	*none*
ZPWMA466SWON	SPARE 1B, PARM2 PYRO3B ON-A	*none*
ZPWMA467SWOF	Lower Boom Rel, PARM2 PYRO1B OFF-A	*none*
ZPWMA468SWOF	Upper Boom Rel, PARM2 PYRO2B OFF-A	*none*
ZPWMA469SWOF	SPARE 1B, PARM2 PYRO3B OFF-A	*none*
ZPWMA470SWON	Rosina DFMS Det, PARM3 PYRO1B ON-A	*none*
ZPWMA471SWON	Rosina RTOF Det, PARM3 PYRO2B ON-A	*none*
ZPWMA472SWON	Ros DFMS Fail/Safe, PARM3 PYRO3B ON-A	*none*
ZPWMA473SWON	SPARE 3B, PARM3 PYRO4B ON-A	*none*
ZPWMA474SWON	SPARE 4B, PARM3 PYRO5B ON-A	*none*

Name	Designation	Verif TM
ZPWMA475SWON	SPARE 5B, PARM3 PYRO6B ON-A	*none*
ZPWMA476SWON	Consert Ant Rel, PARM3 PYRO7B ON-A	*none*
ZPWMA477SWOF	Rosina DFMS Det, PARM3 PYRO1B OFF-A	*none*
ZPWMA478SWOF	Rosina RTOF Det, PARM3 PYRO2B OFF-A	*none*
ZPWMA479SWOF	Ros DFMS Fail/Safe, PARM3 PYRO3B OFF-A	*none*
ZPWMA480SWOF	SPARE 3B, PARM3 PYRO4B OFF-A	*none*
ZPWMA481SWOF	SPARE 4B, PARM3 PYRO5B OFF-A	*none*
ZPWMA482SWOF	SPARE 5B, PARM3 PYRO6B OFF-A	*none*
ZPWMA483SWOF	Consert Ant Rel, PARM3 PYRO7B OFF-A	*none*
ZPWMA484SWON	Alice Det Door Rel, PARM4 PYRO1B ON-A	*none*
ZPWMA485SWON	Alice Apert Uncage, PARM4 PYRO2B ON-A	*none*
ZPWMA486SWON	Alice Fail Safe, PARM4 PYRO3B ON-A	*none*
ZPWMA487SWON	Midas Cover Rel, PARM4 PYRO4B ON-A	*none*
ZPWMA488SWON	SPARE, PARM4 PYRO5B ON-A	*none*
ZPWMA489SWON	SPARE, PARM4 PYRO6B ON-A	*none*
ZPWMA490SWOF	Alice Det Door Rel, PARM4 PYRO1B OFF-A	*none*
ZPWMA491SWOF	Alice Apert Uncage, PARM4 PYRO2B OFF-A	*none*
ZPWMA492SWOF	Alice Fail Safe, PARM4 PYRO3B OFF-A	*none*
ZPWMA493SWOF	Midas Cover Rel, PARM4 PYRO4B OFF-A	*none*
ZPWMA494SWOF	SPARE, PARM4 PYRO5B OFF-A	*none*
ZPWMA495SWOF	SPARE, PARM4 PYRO6B OFF-A	*none*
ZPWMA496SWON	SSP Lander Rel 1, PARM5 PYRO1B ON-A	*none*
ZPWMA497SWON	SSP Lander Rel 2, PARM5 PYRO2B ON-A	*none*
ZPWMA498SWON	SSP Lander Rel 3, PARM5 PYRO3B ON-A	*none*
ZPWMA499SWON	SSP Lander Rel 4, PARM5 PYRO4B ON-A	*none*
ZPWMA500SWON	SPARE 2B, PARM5 PYRO5B ON-A	*none*
ZPWMA501SWOF	SSP Lander Rel 1, PARM5 PYRO1B OFF-A	*none*

Name	Designation	Verif TM
ZPWMA502SWOF	SSP Lander Rel 2, PARM5 PYRO2B OFF-A	*none*
ZPWMA503SWOF	SSP Lander Rel 3, PARM5 PYRO3B OFF-A	*none*
ZPWMA504SWOF	SSP Lander Rel 4, PARM5 PYRO4B OFF-A	*none*
ZPWMA505SWOF	SPARE 2B, PARM5 PYRO5B OFF-A	*none*
ZPWMA506SWON	PYRO ARM 1B ON, PDU-P/L-A	*none*
ZPWMA507SWON	PYRO ARM 2B ON, PDU-P/L-A	*none*
ZPWMA508SWON	PYRO ARM 3B ON, PDU-P/L-A	*none*
ZPWMA509SWON	PYRO ARM 4B ON, PDU-P/L-A	*none*
ZPWMA510SWON	PYRO ARM 5B ON, PDU-P/L-A	*none*
ZPWMA511SWOF	PYRO ARM 1B OFF, PDU-P/L-A	*none*
ZPWMA512SWOF	PYRO ARM 2B OFF, PDU-P/L-A	*none*
ZPWMA513SWOF	PYRO ARM 3B OFF, PDU-P/L-A	*none*
ZPWMA514SWOF	PYRO ARM 4B OFF, PDU-P/L-A	*none*
ZPWMA515SWOF	PYRO ARM 5B OFF, PDU-P/L-A	*none*
ZPWMA516SWON	PYRO POWER BAT2 B ON, PDU-P/L-A	*none*
ZPWMA517SWON	PYRO POWER BAT3 B ON, PDU-P/L-A	*none*
ZPWMA518SWON	PYRO POWER BUS B ON, PDU-P/L-A	*none*
ZPWMA519SWOF	PYRO POWER BAT2 B OFF, PDU-P/L-A	*none*
ZPWMA520SWOF	PYRO POWER BAT3 B OFF, PDU-P/L-A	*none*
ZPWMA521SWOF	PYRO POWER BUS B OFF, PDU-P/L-A	*none*
ZPWMA522	PYRO FIRE B, PDU-P/L-A	NPWAA150
ZPWMA991	Generic MLC PDU-P/L-A RTU-A RouteOfCmd	*none*
ZPWMA993	Generic MLC PDU-P/L-A RTU-B RouteOfCmd	*none*
ZPWMA999	Generic MLC for PDU-P/L-A	*none*

8.6. PL-PDU (redundant) TC Packets

Link to PDF-file: PL-PDU-redundant.pdf

Name	Designation	Verif TM
ZPWMB002	UPDATE ALL TM, PDU-P/L-B	*none*
ZPWMB003	UPDATE SWITCH TM, PDU-P/L-B	*none*
ZPWMB004SWON	TM POWER ON, PDU-P/L-B	*none*
ZPWMB005SWOF	TM POWER OFF, PDU-P/L-B	*none*
ZPWMB006	TMpyro P/L-PDU, PDU-P/L-B	*none*
ZPWMB007	RESET PYRO BUFFERS, PDU-P/L-B	*none*
ZPWMB008	START CONTINUOUS, PDU-P/L-B	*none*
ZPWMB009SWON	SSP REL A 1, LCL 1A ON, PDU-P/L-B	NPWAA520
ZPWMB010SWOF	SSP REL A 1, LCL 1A OFF, PDU-P/L-B	NPWAA520
ZPWMB011SWON	SSP REL B 1, LCL 2A ON, PDU-P/L-B	NPWAA520
ZPWMB012SWOF	SSP REL B 1, LCL 2A OFF, PDU-P/L-B	NPWAA520
ZPWMB013SWON	SPARE, LCL 3A ON, PDU-P/L-B	NPWAA530
ZPWMB014SWOF	SPARE, LCL 3A OFF, PDU-P/L-B	NPWAA530
ZPWMB015SWON	SPARE, LCL 4A ON, PDU-P/L-B	NPWAA530
ZPWMB016SWOF	SPARE, LCL 4A OFF, PDU-P/L-B	NPWAA530
ZPWMB017SWON	SSP LANDER HTR, LCL 5A ON, PDU-P/L-B	NPWAA540
ZPWMB018SWOF	SSP LANDER HTR, LCL 5A OFF, PDU-P/L-B	NPWAA540
ZPWMB019SWON	MIDAS PS 1, LCL 6A ON, PDU-P/L-B	NPWAA540
ZPWMB020SWOF	MIDAS PS 1, LCL 6A OFF, PDU-P/L-B	NPWAA540
ZPWMB021SWON	MIRO ME+SE, LCL 7A ON, PDU-P/L-B	NPWAA550
ZPWMB022SWOF	MIRO ME+SE, LCL 7A OFF, PDU-P/L-B	NPWAA550
ZPWMB023SWON	VIR/OSIR/RXTX1&2, LCL 8A ON, PDU-P/L-B	NPWAA550
ZPWMB024SWOF	VIR/OSIR/RXTX1&2, LCL 8A OFF, PDU-P/L-B	NPWAA550
ZPWMB025SWON	CON/OS NAC-C/MID, LCL 9A ON, PDU-P/L-B	NPWAA560
ZPWMB026SWOF	CON/OS NAC-C/MID, LCL 9A OFF, PDU-P/L-B	NPWAA560

Name	Designation	Verif TM
ZPWMB027SWON	ROS/COS/RPC/ , LCL 10A ON, PDU-P/L-B	NPWAA560
ZPWMB028SWOF	ROS/COS/RPC/ , LCL 10A OFF, PDU-P/L-B	NPWAA560
ZPWMB029SWON	ALICE PS 1, LCL 11A ON, PDU-P/L-B	NPWAA570
ZPWMB030SWOF	ALICE PS 1, LCL 11A OFF, PDU-P/L-B	NPWAA570
ZPWMB031SWON	SPARE, LCL 12A ON, PDU-P/L-B	NPWAA570
ZPWMB032SWOF	SPARE, LCL 12A OFF, PDU-P/L-B	NPWAA570
ZPWMB033SWON	ALICE HIB, LCL 13A ON, PDU-P/L-B	NPWAA580
ZPWMB034SWOF	ALICE HIB, LCL 13A OFF, PDU-P/L-B	NPWAA580
ZPWMB035SWON	SREM PS 1, LCL 14A ON, PDU-P/L-B	NPWAA580
ZPWMB036SWOF	SREM PS 1, LCL 14A OFF, PDU-P/L-B	NPWAA580
ZPWMB037SWON	SSP PS 1, LCL 15A ON, PDU-P/L-B	NPWAA440
ZPWMB038SWOF	SSP PS 1, LCL 15A OFF, PDU-P/L-B	NPWAA440
ZPWMB039SWON	SPARE, LCL 16A ON, PDU-P/L-B	NPWAA440
ZPWMB040SWOF	SPARE, LCL 16A OFF, PDU-P/L-B	NPWAA440
ZPWMB041SWON	SSP MSS HOUS, LCL 17A ON, PDU-P/L-B	NPWAA450
ZPWMB042SWOF	SSP MSS HOUS, LCL 17A OFF, PDU-P/L-B	NPWAA450
ZPWMB043SWON	SSP ESS/ RPC IES, LCL 18A ON, PDU-P/L-B	NPWAA450
ZPWMB044SWOF	SSP ESS/ RPC IES, LCL 18A OFF, PDU-P/L-B	NPWAA450
ZPWMB045SWON	SPARE, LCL 19A ON, PDU-P/L-B	NPWAA460
ZPWMB046SWOF	SPARE, LCL 19A OFF, PDU-P/L-B	NPWAA460
ZPWMB047SWON	BOOM HINGE HTRS, LCL 20A ON, PDU-P/L-B	NPWAA460
ZPWMB048SWOF	BOOM HINGE HTRS, LCL 20A OFF, PDU-P/L-B	NPWAA460
ZPWMB049SWON	STR1-2/NAVCAM1-2, LCL 21A ON, PDU-P/L-B	NPWAA470
ZPWMB050SWOF	STR1-2/NAVCAM1-2, LCL 21A OFF, PDU-P/L-B	NPWAA470
ZPWMB051SWON	SPARE, LCL 22A ON, PDU-P/L-B	NPWAA470
ZPWMB052SWOF	SPARE, LCL 22A OFF, PDU-P/L-B	NPWAA470
ZPWMB053SWON	RCS1-4 (LINE1), LCL 23A ON, PDU-P/L-B	NPWAA480

Name	Designation	Verif TM
ZPWMB054SWOF	RCS1-4 (LINE1), LCL 23A OFF, PDU-P/L-B	NPWAA480
ZPWMB055SWON	RCS5-8 (LINE2), LCL 24A ON, PDU-P/L-B	NPWAA480
ZPWMB056SWOF	RCS5-8 (LINE2), LCL 24A OFF, PDU-P/L-B	NPWAA480
ZPWMB057SWON	SPARE, LCL 25A ON, PDU-P/L-B	NPWAA490
ZPWMB058SWOF	SPARE, LCL 25A OFF, PDU-P/L-B	NPWAA490
ZPWMB059SWON	SPARE, LCL 26A ON, PDU-P/L-B	NPWAA490
ZPWMB060SWOF	SPARE, LCL 26A OFF, PDU-P/L-B	NPWAA490
ZPWMB061SWON	MIRO OPT BEN HTR, LCL 27A ON, PDU-P/L-B	NPWAA500
ZPWMB062SWOF	MIRO OPT BEN HTR, LCL 27A OFF, PDU-P/L-B	NPWAA500
ZPWMB063SWON	VIRTIS PEMM, LCL 28A ON, PDU-P/L-B	NPWAA500
ZPWMB064SWOF	VIRTIS PEMM, LCL 28A OFF, PDU-P/L-B	NPWAA500
ZPWMB065SWON	MIRO PS 1, LCL 29A ON, PDU-P/L-B	NPWAA360
ZPWMB066SWOF	MIRO PS 1, LCL 29A OFF, PDU-P/L-B	NPWAA360
ZPWMB067SWON	OSIRIS PS 1, LCL 30A ON, PDU-P/L-B	NPWAA360
ZPWMB068SWOF	OSIRIS PS 1, LCL 30A OFF, PDU-P/L-B	NPWAA360
ZPWMB069SWON	ROSINA PS 1, LCL 31A ON, PDU-P/L-B	NPWAA370
ZPWMB070SWOF	ROSINA PS 1, LCL 31A OFF, PDU-P/L-B	NPWAA370
ZPWMB071SWON	COSIMA PS 1, LCL 32A ON, PDU-P/L-B	NPWAA370
ZPWMB072SWOF	COSIMA PS 1, LCL 32A OFF, PDU-P/L-B	NPWAA370
ZPWMB073SWON	GIADA PS 1, LCL 33A ON, PDU-P/L-B	NPWAA380
ZPWMB074SWOF	GIADA PS 1, LCL 33A OFF, PDU-P/L-B	NPWAA380
ZPWMB075SWON	ROSINA DFMS HTR, LCL 34A ON, PDU-P/L-B	NPWAA380
ZPWMB076SWOF	ROSINA DFMS HTR, LCL 34A OFF, PDU-P/L-B	NPWAA380
ZPWMB077SWON	PROP TANK +Z HTR, LCL 35A ON, PDU-P/L-B	NPWAA390
ZPWMB078SWOF	PROP TANK +Z HTR, LCL 35A OFF, PDU-P/L-B	NPWAA390
ZPWMB079SWON	PROP TANK -Z HTR, LCL 36A ON, PDU-P/L-B	NPWAA390
ZPWMB080SWOF	PROP TANK -Z HTR, LCL 36A OFF, PDU-P/L-B	NPWAA390

Name	Designation	Verif TM
ZPWMB081SWON	RCS9-12 (LINE3), LCL 37A ON, PDU-P/L-B	NPWAA400
ZPWMB082SWOF	RCS9-12 (LINE3), LCL 37A OFF, PDU-P/L-B	NPWAA400
ZPWMB083SWON	SPARE, LCL 38A ON, PDU-P/L-B	NPWAA400
ZPWMB084SWOF	SPARE, LCL 38A OFF, PDU-P/L-B	NPWAA400
ZPWMB085SWON	OSRIS EL HIB HTR, LCL 39A ON, PDU-P/L-B	NPWAA410
ZPWMB086SWOF	OSRIS EL HIB HTR, LCL 39A OFF, PDU-P/L-B	NPWAA410
ZPWMB087SWON	RPC IES HTR, LCL 40A ON, PDU-P/L-B	NPWAA410
ZPWMB088SWOF	RPC IES HTR, LCL 40A OFF, PDU-P/L-B	NPWAA410
ZPWMB089SWON	RPC ICA A/SREM/L, LCL 41A ON, PDU-P/L-B	NPWAA420
ZPWMB090SWOF	RPC ICA A/SREM/L, LCL 41A OFF, PDU-P/L-B	NPWAA420
ZPWMB091SWON	ROSINA COPS HTR, LCL 42A ON, PDU-P/L-B	NPWAA420
ZPWMB092SWOF	ROSINA COPS HTR, LCL 42A OFF, PDU-P/L-B	NPWAA420
ZPWMB093SWON	HS1/APM/HS4, LCL 43A ON, PDU-P/L-B	NPWAA340
ZPWMB094SWOF	HS1/APM/HS4, LCL 43A OFF, PDU-P/L-B	NPWAA340
ZPWMB095SWON	HS5-8 THRS 1-4, LCL 44A ON, PDU-P/L-B	NPWAA340
ZPWMB096SWOF	HS5-8 THRS 1-4, LCL 44A OFF, PDU-P/L-B	NPWAA340
ZPWMB097SWON	HS9-12 THRS 5-8, LCL 45A ON, PDU-P/L-B	NPWAA350
ZPWMB098SWOF	HS9-12 THRS 5-8, LCL 45A OFF, PDU-P/L-B	NPWAA350
ZPWMB099SWON	HS13-16 THRS9-12, LCL 46A ON, PDU-P/L-B	NPWAA350
ZPWMB100SWOF	HS13-16 THRS9-12, LCL 46A OFF, PDU-P/L-B	NPWAA350
ZPWMB101SWON	VIRTIS PS 1, LCL 47A ON, PDU-P/L-B	NPWAA280
ZPWMB102SWOF	VIRTIS PS 1, LCL 47A OFF, PDU-P/L-B	NPWAA280
ZPWMB103SWON	SPARE, LCL 48A ON, PDU-P/L-B	NPWAA280
ZPWMB104SWOF	SPARE, LCL 48A OFF, PDU-P/L-B	NPWAA280
ZPWMB105SWON	RPC PS 1, LCL 49A ON, PDU-P/L-B	NPWAA290
ZPWMB106SWOF	RPC PS 1, LCL 49A OFF, PDU-P/L-B	NPWAA290
ZPWMB107SWON	SPARE, LCL 50A ON, PDU-P/L-B	NPWAA290

Name	Designation	Verif TM
ZPWMB108SWOF	SPARE, LCL 50A OFF, PDU-P/L-B	NPWAA290
ZPWMB109SWON	SPARE, LCL 51A ON, PDU-P/L-B	NPWAA300
ZPWMB110SWOF	SPARE, LCL 51A OFF, PDU-P/L-B	NPWAA300
ZPWMB111SWON	CONSERT PS 1, LCL 52A ON, PDU-P/L-B	NPWAA300
ZPWMB112SWOF	CONSERT PS 1, LCL 52A OFF, PDU-P/L-B	NPWAA300
ZPWMB113SWON	ROSINA RTOF HTR, LCL 53A ON, PDU-P/L-B	NPWAA310
ZPWMB114SWOF	ROSINA RTOF HTR, LCL 53A OFF, PDU-P/L-B	NPWAA310
ZPWMB115SWON	GIADA HIB HTR, LCL 54A ON, PDU-P/L-B	NPWAA310
ZPWMB116SWOF	GIADA HIB HTR, LCL 54A OFF, PDU-P/L-B	NPWAA310
ZPWMB117	SSP REL A 1, SEL LCL 1A CUR PROF-B	*none*
ZPWMB118	SSP REL B 1, SEL LCL 2A CUR PROF-B	*none*
ZPWMB119	SPARE, SEL LCL 3A CUR PROF-B	*none*
ZPWMB120	SPARE, SEL LCL 4A CUR PROF-B	*none*
ZPWMB121	SSP LANDER HTR, SEL LCL 5A CUR PROF-B	*none*
ZPWMB122	MIDAS PS 1, SEL LCL 6A CUR PROF-B	*none*
ZPWMB123	MIRO ME+SE, SEL LCL 7A CUR PROF-B	*none*
ZPWMB124	VIR/OSIR/RXTX1&2, SEL LCL 8A CUR PROF-B	*none*
ZPWMB125	CON/OS NAC-C/MID, SEL LCL 9A CUR PROF-B	*none*
ZPWMB126	ROS/COS/RPC/ , SEL LCL 10A CUR PROF-B	*none*
ZPWMB127	ALICE PS 1, SEL LCL 11A CUR PROF-B	*none*
ZPWMB128	SPARE, SEL LCL 12A CUR PROF-B	*none*
ZPWMB129	ALICE HIB, SEL LCL 13A CUR PROF-B	*none*
ZPWMB130	SREM PS 1, SEL LCL 14A CUR PROF-B	*none*
ZPWMB131	SSP PS 1, SEL LCL 15A CUR PROF-B	*none*
ZPWMB132	SPARE, SEL LCL 16A CUR PROF-B	*none*
ZPWMB133	SSP MSS HOU, SEL LCL 17A CUR PROF-B	*none*
ZPWMB134	SSP ESS/ RPC IES, SEL LCL 18A CUR PROF-B	*none*

Name	Designation	Verif TM
ZPWMB135	SPARE, SEL LCL 19A CUR PROF-B	*none*
ZPWMB136	BOOM HINGE HTRS, SEL LCL 20A CUR PROF-B	*none*
ZPWMB137	STR1-2/NAVCAM1-2, SEL LCL 21A CUR PROF-B	*none*
ZPWMB138	SPARE, SEL LCL 22A CUR PROF-B	*none*
ZPWMB139	RCS1-4 (LINE1), SEL LCL 23A CUR PROF-B	*none*
ZPWMB140	RCS5-8 (LINE2), SEL LCL 24A CUR PROF-B	*none*
ZPWMB141	SPARE, SEL LCL 25A CUR PROF-B	*none*
ZPWMB142	SPARE, SEL LCL 26A CUR PROF-B	*none*
ZPWMB143	MIRO OPT BEN HTR, SEL LCL 27A CUR PROF-B	*none*
ZPWMB144	VIRTIS PEMM, SEL LCL 28A CUR PROF-B	*none*
ZPWMB145	MIRO PS 1, SEL LCL 29A CUR PROF-B	*none*
ZPWMB146	OSIRIS PS 1, SEL LCL 30A CUR PROF-B	*none*
ZPWMB147	ROSINA PS 1, SEL LCL 31A CUR PROF-B	*none*
ZPWMB148	COSIMA PS 1, SEL LCL 32A CUR PROF-B	*none*
ZPWMB149	GIADA PS 1, SEL LCL 33A CUR PROF-B	*none*
ZPWMB150	ROSINA DFMS HTR, SEL LCL 34A CUR PROF-B	*none*
ZPWMB151	PROP TANK +Z HTR, SEL LCL 35A CUR PROF-B	*none*
ZPWMB152	PROP TANK -Z HTR, SEL LCL 36A CUR PROF-B	*none*
ZPWMB153	RCS9-12 (LINE3), SEL LCL 37A CUR PROF-B	*none*
ZPWMB154	SPARE, SEL LCL 38A CUR PROF-B	*none*
ZPWMB155	OSRIS EL HIB HTR, SEL LCL 39A CUR PROF-B	*none*
ZPWMB156	RPC IES HTR, SEL LCL 40A CUR PROF-B	*none*
ZPWMB157	RPC ICA A/SREM/L, SEL LCL 41A CUR PROF-B	*none*
ZPWMB158	ROSINA COPS HTR, SEL LCL 42A CUR PROF-B	*none*
ZPWMB159	HS1/APM/HS4, SEL LCL 43A CUR PROF-B	*none*
ZPWMB160	HS5-8 THRS 1-4, SEL LCL 44A CUR PROF-B	*none*
ZPWMB161	HS9-12 THRS 5-8, SEL LCL 45A CUR PROF-B	*none*

Name	Designation	Verif TM
ZPWMB162	HS13-16 THRS9-12, SEL LCL 46A CUR PROF-B	*none*
ZPWMB163	VIRTIS PS 1, SEL LCL 47A CUR PROF-B	*none*
ZPWMB164	SPARE, SEL LCL 48A CUR PROF-B	*none*
ZPWMB165	RPC PS 1, SEL LCL 49A CUR PROF-B	*none*
ZPWMB166	SPARE, SEL LCL 50A CUR PROF-B	*none*
ZPWMB167	SPARE, SEL LCL 51A CUR PROF-B	*none*
ZPWMB168	CONSERT PS 1, SEL LCL 52A CUR PROF-B	*none*
ZPWMB169	ROSINA RTOF HTR, SEL LCL 53A CUR PROF-B	*none*
ZPWMB170	GIADA HIB HTR, SEL LCL 54A CUR PROF-B	*none*
ZPWMB171SWON	SPARE, HTR SW 1A ON-B	*none*
ZPWMB172SWOF	SPARE, HTR SW 1A OFF-B	*none*
ZPWMB173SWON	APM, HTR SW 2A ON-B	*none*
ZPWMB174SWOF	APM, HTR SW 2A OFF-B	*none*
ZPWMB175SWON	SADM +Y Shaft/ CASE, HTR SW 3A ON-B	*none*
ZPWMB176SWOF	SADM +Y Shaft/ CASE, HTR SW 3A OFF-B	*none*
ZPWMB177SWON	SADM -Y Shaft/ CASE, HTR SW 4A ON-B	*none*
ZPWMB178SWOF	SADM -Y Shaft/ CASE, HTR SW 4A OFF-B	*none*
ZPWMB179SWON	THR HSW MODULE 1, HTR SW 5A ON-B	*none*
ZPWMB180SWOF	THR HSW MODULE 1, HTR SW 5A OFF-B	*none*
ZPWMB181SWON	THR HSW MODULE 2, HTR SW 6A ON-B	*none*
ZPWMB182SWOF	THR HSW MODULE 2, HTR SW 6A OFF-B	*none*
ZPWMB183SWON	THR HSW MODULE 3, HTR SW 7A ON-B	*none*
ZPWMB184SWOF	THR HSW MODULE 3, HTR SW 7A OFF-B	*none*
ZPWMB185SWON	THR HSW MODULE 4, HTR SW 8A ON-B	*none*
ZPWMB186SWOF	THR HSW MODULE 4, HTR SW 8A OFF-B	*none*
ZPWMB187SWON	THR HSW MODULE 5, HTR SW 9A ON-B	*none*
ZPWMB188SWOF	THR HSW MODULE 5, HTR SW 9A OFF-B	*none*

Name	Designation	Verif TM
ZPWMB189SWON	THR HSW MODULE 6, HTR SW 10A ON-B	*none*
ZPWMB190SWOF	THR HSW MODULE 6, HTR SW 10A OFF-B	*none*
ZPWMB191SWON	THR HSW MODULE 7, HTR SW 11A ON-B	*none*
ZPWMB192SWOF	THR HSW MODULE 7, HTR SW 11A OFF-B	*none*
ZPWMB193SWON	THR HSW MODULE 8, HTR SW 12A ON-B	*none*
ZPWMB194SWOF	THR HSW MODULE 8, HTR SW 12A OFF-B	*none*
ZPWMB195SWON	THR HSW MODULE 9, HTR SW 13A ON-B	*none*
ZPWMB196SWOF	THR HSW MODULE 9, HTR SW 13A OFF-B	*none*
ZPWMB197SWON	THR HSW MODULE 10, HTR SW 14A ON-B	*none*
ZPWMB198SWOF	THR HSW MODULE 10, HTR SW 14A OFF-B	*none*
ZPWMB199SWON	THR HSW MODULE 11, HTR SW 15A ON-B	*none*
ZPWMB200SWOF	THR HSW MODULE 11, HTR SW 15A OFF-B	*none*
ZPWMB201SWON	THR HSW MODULE 12, HTR SW 16A ON-B	*none*
ZPWMB202SWOF	THR HSW MODULE 12, HTR SW 16A OFF-B	*none*
ZPWMB203SWON	KAL CONVERTER A ON, PDU-P/L-B	NPWAA320
ZPWMB204SWOF	KAL CONVERTER A OFF, PDU-P/L-B	NPWAA320
ZPWMB205SWON	SSP Emergncy Rel, PARM1 PYRO1A ON-B	*none*
ZPWMB206SWOF	SSP Emergncy Rel, PARM1 PYRO1A OFF-B	*none*
ZPWMB207SWON	Lower Boom Rel, PARM2 PYRO1A ON-B	*none*
ZPWMB208SWON	Upper Boom Rel, PARM2 PYRO2A ON-B	*none*
ZPWMB209SWON	SPARE 1A, PARM2 PYRO3A ON-B	*none*
ZPWMB210SWOF	Lower Boom Rel, PARM2 PYRO1A OFF-B	*none*
ZPWMB211SWOF	Upper Boom Rel, PARM2 PYRO2A OFF-B	*none*
ZPWMB212SWOF	SPARE 1A, PARM2 PYRO3A OFF-B	*none*
ZPWMB213SWON	Rosina DFMS Det, PARM3 PYRO1A ON-B	*none*
ZPWMB214SWON	Rosina RTOF Det, PARM3 PYRO2A ON-B	*none*
ZPWMB215SWON	Ros DFMS Fail/Safe, PARM3 PYRO3A ON-B	*none*

Name	Designation	Verif TM
ZPWMB216SWON	SPARE 3A, PARM3 PYRO4A ON-B	*none*
ZPWMB217SWON	SPARE 4A, PARM3 PYRO5A ON-B	*none*
ZPWMB218SWON	SPARE 5A, PARM3 PYRO6A ON-B	*none*
ZPWMB219SWON	Consert Ant Rel, PARM3 PYRO7A ON-B	*none*
ZPWMB220SWOF	Rosina DFMS Det, PARM3 PYRO1A OFF-B	*none*
ZPWMB221SWOF	Rosina RTOF Det, PARM3 PYRO2A OFF-B	*none*
ZPWMB222SWOF	Ros DFMS Fail/Safe, PARM3 PYRO3A OFF-B	*none*
ZPWMB223SWOF	SPARE 3A, PARM3 PYRO4A OFF-B	*none*
ZPWMB224SWOF	SPARE 4A, PARM3 PYRO5A OFF-B	*none*
ZPWMB225SWOF	SPARE 5A, PARM3 PYRO6A OFF-B	*none*
ZPWMB226SWOF	Consert Ant Rel, PARM3 PYRO7A OFF-B	*none*
ZPWMB227SWON	Alice Det Door Rel, PARM4 PYRO1A ON-B	*none*
ZPWMB228SWON	Alice Apert Uncage, PARM4 PYRO2A ON-B	*none*
ZPWMB229SWON	Alice Fail Safe, PARM4 PYRO3A ON-B	*none*
ZPWMB230SWON	Midas Cover Rel, PARM4 PYRO4A ON-B	*none*
ZPWMB231SWON	SPARE, PARM4 PYRO5A ON-B	*none*
ZPWMB232SWON	SPARE, PARM4 PYRO6A ON-B	*none*
ZPWMB233SWOF	Alice Det Door Rel, PARM4 PYRO1A OFF-B	*none*
ZPWMB234SWOF	Alice Apert Uncage, PARM4 PYRO2A OFF-B	*none*
ZPWMB235SWOF	Alice Fail Safe, PARM4 PYRO3A OFF-B	*none*
ZPWMB236SWOF	Midas Cover Rel, PARM4 PYRO4A OFF-B	*none*
ZPWMB237SWOF	SPARE, PARM4 PYRO5A OFF-B	*none*
ZPWMB238SWOF	SPARE, PARM4 PYRO6A OFF-B	*none*
ZPWMB239SWON	SSP Lander Rel 1, PARM5 PYRO1A ON-B	*none*
ZPWMB240SWON	SSP Lander Rel 2, PARM5 PYRO2A ON-B	*none*
ZPWMB241SWON	SSP Lander Rel 3, PARM5 PYRO3A ON-B	*none*
ZPWMB242SWON	SSP Lander Rel 4, PARM5 PYRO4A ON-B	*none*

Name	Designation	Verif TM
ZPWMB243SWON	SPARE 2A, PARM5 PYRO5A ON-B	*none*
ZPWMB244SWOF	SSP Lander Rel 1, PARM5 PYRO1A OFF-B	*none*
ZPWMB245SWOF	SSP Lander Rel 2, PARM5 PYRO2A OFF-B	*none*
ZPWMB246SWOF	SSP Lander Rel 3, PARM5 PYRO3A OFF-B	*none*
ZPWMB247SWOF	SSP Lander Rel 4, PARM5 PYRO4A OFF-B	*none*
ZPWMB248SWOF	SPARE 2A, PARM5 PYRO5A OFF-B	*none*
ZPWMB249SWON	PYRO ARM 1A ON, PDU-P/L-B	*none*
ZPWMB250SWON	PYRO ARM 2A ON, PDU-P/L-B	*none*
ZPWMB251SWON	PYRO ARM 3A ON, PDU-P/L-B	*none*
ZPWMB252SWON	PYRO ARM 4A ON, PDU-P/L-B	*none*
ZPWMB253SWON	PYRO ARM 5A ON, PDU-P/L-B	*none*
ZPWMB254SWOF	PYRO ARM 1A OFF, PDU-P/L-B	*none*
ZPWMB255SWOF	PYRO ARM 2A OFF, PDU-P/L-B	*none*
ZPWMB256SWOF	PYRO ARM 3A OFF, PDU-P/L-B	*none*
ZPWMB257SWOF	PYRO ARM 4A OFF, PDU-P/L-B	*none*
ZPWMB258SWOF	PYRO ARM 5A OFF, PDU-P/L-B	*none*
ZPWMB259SWON	PYRO POWER BAT1 A ON, PDU-P/L-B	*none*
ZPWMB260SWON	PYRO POWER BAT2 A ON, PDU-P/L-B	*none*
ZPWMB261SWON	PYRO POWER BUS A ON, PDU-P/L-B	*none*
ZPWMB262SWOF	PYRO POWER BAT1 A OFF, PDU-P/L-B	*none*
ZPWMB263SWOF	PYRO POWER BAT2 A OFF, PDU-P/L-B	*none*
ZPWMB264SWOF	PYRO POWER BUS A OFF, PDU-P/L-B	*none*
ZPWMB265	PYRO FIRE A, PDU-P/L-B	NPWAA030
ZPWMB266SWON	SSP REL A 2, LCL 1B ON, PDU-P/L-B	NPWAA840
ZPWMB267SWOF	SSP REL A 2, LCL 1B OFF, PDU-P/L-B	NPWAA840
ZPWMB268SWON	SSP REL B 2, LCL 2B ON, PDU-P/L-B	NPWAA840
ZPWMB269SWOF	SSP REL B 2, LCL 2B OFF, PDU-P/L-B	NPWAA840

Name	Designation	Verif TM
ZPWMB270SWON	SPARE, LCL 3B ON, PDU-P/L-B	NPWAA850
ZPWMB271SWOF	SPARE, LCL 3B OFF, PDU-P/L-B	NPWAA850
ZPWMB272SWON	SPARE, LCL 4B ON, PDU-P/L-B	NPWAA850
ZPWMB273SWOF	SPARE, LCL 4B OFF, PDU-P/L-B	NPWAA850
ZPWMB274SWON	SSP LANDER HTR, LCL 5B ON, PDU-P/L-B	NPWAA860
ZPWMB275SWOF	SSP LANDER HTR, LCL 5B OFF, PDU-P/L-B	NPWAA860
ZPWMB276SWON	MIDAS PS 2, LCL 6B ON, PDU-P/L-B	NPWAA860
ZPWMB277SWOF	MIDAS PS 2, LCL 6B OFF, PDU-P/L-B	NPWAA860
ZPWMB278SWON	MIRO ME+SE, LCL 7B ON, PDU-P/L-B	NPWAA870
ZPWMB279SWOF	MIRO ME+SE, LCL 7B OFF, PDU-P/L-B	NPWAA870
ZPWMB280SWON	VIR/OSIR/RXTX1&2, LCL 8B ON, PDU-P/L-B	NPWAA870
ZPWMB281SWOF	VIR/OSIR/RXTX1&2, LCL 8B OFF, PDU-P/L-B	NPWAA870
ZPWMB282SWON	CON/OS NAC-C/MID, LCL 9B ON, PDU-P/L-B	NPWAA880
ZPWMB283SWOF	CON/OS NAC-C/MID, LCL 9B OFF, PDU-P/L-B	NPWAA880
ZPWMB284SWON	ROS/COS/RPC/ , LCL 10B ON, PDU-P/L-B	NPWAA880
ZPWMB285SWOF	ROS/COS/RPC/ , LCL 10B OFF, PDU-P/L-B	NPWAA880
ZPWMB286SWON	ALICE PS 2, LCL 11B ON, PDU-P/L-B	NPWAA890
ZPWMB287SWOF	ALICE PS 2, LCL 11B OFF, PDU-P/L-B	NPWAA890
ZPWMB288SWON	SPARE, LCL 12B ON, PDU-P/L-B	NPWAA890
ZPWMB289SWOF	SPARE, LCL 12B OFF, PDU-P/L-B	NPWAA890
ZPWMB290SWON	ALICE HIB, LCL 13B ON, PDU-P/L-B	NPWAA900
ZPWMB291SWOF	ALICE HIB, LCL 13B OFF, PDU-P/L-B	NPWAA900
ZPWMB292SWON	SREM PS 2, LCL 14B ON, PDU-P/L-B	NPWAA900
ZPWMB293SWOF	SREM PS 2, LCL 14B OFF, PDU-P/L-B	NPWAA900
ZPWMB294SWON	SSP PS 2, LCL 15B ON, PDU-P/L-B	NPWAA760
ZPWMB295SWOF	SSP PS 2, LCL 15B OFF, PDU-P/L-B	NPWAA760
ZPWMB296SWON	SPARE, LCL 16B ON, PDU-P/L-B	NPWAA760

Name	Designation	Verif TM
ZPWMB297SWOF	SPARE, LCL 16B OFF, PDU-P/L-B	NPWAA760
ZPWMB298SWON	SSP MSS HOUS, LCL 17B ON, PDU-P/L-B	NPWAA770
ZPWMB299SWOF	SSP MSS HOUS, LCL 17B OFF, PDU-P/L-B	NPWAA770
ZPWMB300SWON	SSP ESS/ RPC IES, LCL 18B ON, PDU-P/L-B	NPWAA770
ZPWMB301SWOF	SSP ESS/ RPC IES, LCL 18B OFF, PDU-P/L-B	NPWAA770
ZPWMB302SWON	SPARE, LCL 19B ON, PDU-P/L-B	NPWAA780
ZPWMB303SWOF	SPARE, LCL 19B OFF, PDU-P/L-B	NPWAA780
ZPWMB304SWON	BOOM HINGE HTRS, LCL 20B ON, PDU-P/L-B	NPWAA780
ZPWMB305SWOF	BOOM HINGE HTRS, LCL 20B OFF, PDU-P/L-B	NPWAA780
ZPWMB306SWON	STR1-2/NAVCAM1-2, LCL 21B ON, PDU-P/L-B	NPWAA790
ZPWMB307SWOF	STR1-2/NAVCAM1-2, LCL 21B OFF, PDU-P/L-B	NPWAA790
ZPWMB308SWON	SPARE, LCL 22B ON, PDU-P/L-B	NPWAA790
ZPWMB309SWOF	SPARE, LCL 22B OFF, PDU-P/L-B	NPWAA790
ZPWMB310SWON	RCS1-4 (LINE1), LCL 23B ON, PDU-P/L-B	NPWAA800
ZPWMB311SWOF	RCS1-4 (LINE1), LCL 23B OFF, PDU-P/L-B	NPWAA800
ZPWMB312SWON	RCS5-8 (LINE2), LCL 24B ON, PDU-P/L-B	NPWAA800
ZPWMB313SWOF	RCS5-8 (LINE2), LCL 24B OFF, PDU-P/L-B	NPWAA800
ZPWMB314SWON	SPARE, LCL 25B ON, PDU-P/L-B	NPWAA810
ZPWMB315SWOF	SPARE, LCL 25B OFF, PDU-P/L-B	NPWAA810
ZPWMB316SWON	SPARE, LCL 26B ON, PDU-P/L-B	NPWAA810
ZPWMB317SWOF	SPARE, LCL 26B OFF, PDU-P/L-B	NPWAA810
ZPWMB318SWON	MR OPT BENCH HTR, LCL 27B ON, PDU-P/L-B	NPWAA820
ZPWMB319SWOF	MR OPT BENCH HTR, LCL 27B OFF, PDU-P/L-B	NPWAA820
ZPWMB320SWON	VIRTIS PEMM, LCL 28B ON, PDU-P/L-B	NPWAA820
ZPWMB321SWOF	VIRTIS PEMM, LCL 28B OFF, PDU-P/L-B	NPWAA820
ZPWMB322SWON	MIRO PS 2, LCL 29B ON, PDU-P/L-B	NPWAA680
ZPWMB323SWOF	MIRO PS 2, LCL 29B OFF, PDU-P/L-B	NPWAA680

Name	Designation	Verif TM
ZPWMB324SWON	OSIRIS PS 2, LCL 30B ON, PDU-P/L-B	NPWAA680
ZPWMB325SWOF	OSIRIS PS 2, LCL 30B OFF, PDU-P/L-B	NPWAA680
ZPWMB326SWON	ROSINA PS 2, LCL 31B ON, PDU-P/L-B	NPWAA690
ZPWMB327SWOF	ROSINA PS 2, LCL 31B OFF, PDU-P/L-B	NPWAA690
ZPWMB328SWON	COSIMA PS 2, LCL 32B ON, PDU-P/L-B	NPWAA690
ZPWMB329SWOF	COSIMA PS 2, LCL 32B OFF, PDU-P/L-B	NPWAA690
ZPWMB330SWON	GIADA PS 2, LCL 33B ON, PDU-P/L-B	NPWAA700
ZPWMB331SWOF	GIADA PS 2, LCL 33B OFF, PDU-P/L-B	NPWAA700
ZPWMB332SWON	ROSINA DFMS HTR, LCL 34B ON, PDU-P/L-B	NPWAA700
ZPWMB333SWOF	ROSINA DFMS HTR, LCL 34B OFF, PDU-P/L-B	NPWAA700
ZPWMB334SWON	PROP TANK +Z HTR, LCL 35B ON, PDU-P/L-B	NPWAA710
ZPWMB335SWOF	PROP TANK +Z HTR, LCL 35B OFF, PDU-P/L-B	NPWAA710
ZPWMB336SWON	PROP TANK -Z HTR, LCL 36B ON, PDU-P/L-B	NPWAA710
ZPWMB337SWOF	PROP TANK -Z HTR, LCL 36B OFF, PDU-P/L-B	NPWAA710
ZPWMB338SWON	RCS9-12 (LINE3), LCL 37B ON, PDU-P/L-B	NPWAA720
ZPWMB339SWOF	RCS9-12 (LINE3), LCL 37B OFF, PDU-P/L-B	NPWAA720
ZPWMB340SWON	SPARE, LCL 38B ON, PDU-P/L-B	NPWAA720
ZPWMB341SWOF	SPARE, LCL 38B OFF, PDU-P/L-B	NPWAA720
ZPWMB342SWON	OSRIS EL HIB HTR, LCL 39B ON, PDU-P/L-B	NPWAA730
ZPWMB343SWOF	OSRIS EL HIB HTR, LCL 39B OFF, PDU-P/L-B	NPWAA730
ZPWMB344SWON	RPC IES HTR, LCL 40B ON, PDU-P/L-B	NPWAA730
ZPWMB345SWOF	RPC IES HTR, LCL 40B OFF, PDU-P/L-B	NPWAA730
ZPWMB346SWON	RPC ICA A/SREM/L, LCL 41B ON, PDU-P/L-B	NPWAA740
ZPWMB347SWOF	RPC ICA A/SREM/L, LCL 41B OFF, PDU-P/L-B	NPWAA740
ZPWMB348SWON	ROSINA COPS HTR, LCL 42B ON, PDU-P/L-B	NPWAA740
ZPWMB349SWOF	ROSINA COPS HTR, LCL 42B OFF, PDU-P/L-B	NPWAA740
ZPWMB350SWON	HS1/APM/HS4, LCL 43B ON, PDU-P/L-B	NPWAA660

Name	Designation	Verif TM
ZPWMB351SWOF	HS1/APM/HS4, LCL 43B OFF, PDU-P/L-B	NPWAA660
ZPWMB352SWON	HS5-8 THRS 1-4, LCL 44B ON, PDU-P/L-B	NPWAA660
ZPWMB353SWOF	HS5-8 THRS 1-4, LCL 44B OFF, PDU-P/L-B	NPWAA660
ZPWMB354SWON	HS9-12 THRS 5-8, LCL 45B ON, PDU-P/L-B	NPWAA670
ZPWMB355SWOF	HS9-12 THRS 5-8, LCL 45B OFF, PDU-P/L-B	NPWAA670
ZPWMB356SWON	HS13-16 THRS9-12, LCL 46B ON, PDU-P/L-B	NPWAA670
ZPWMB357SWOF	HS13-16 THRS9-12, LCL 46B OFF, PDU-P/L-B	NPWAA670
ZPWMB358SWON	VIRTIS PS 2, LCL 47B ON, PDU-P/L-B	NPWAA600
ZPWMB359SWOF	VIRTIS PS 2, LCL 47B OFF, PDU-P/L-B	NPWAA600
ZPWMB360SWON	SPARE, LCL 48B ON, PDU-P/L-B	NPWAA600
ZPWMB361SWOF	SPARE, LCL 48B OFF, PDU-P/L-B	NPWAA600
ZPWMB362SWON	RPC PS 2, LCL 49B ON, PDU-P/L-B	NPWAA610
ZPWMB363SWOF	RPC PS 2, LCL 49B OFF, PDU-P/L-B	NPWAA610
ZPWMB364SWON	SPARE, LCL 50B ON, PDU-P/L-B	NPWAA610
ZPWMB365SWOF	SPARE, LCL 50B OFF, PDU-P/L-B	NPWAA610
ZPWMB366SWON	SPARE, LCL 51B ON, PDU-P/L-B	NPWAA620
ZPWMB367SWOF	SPARE, LCL 51B OFF, PDU-P/L-B	NPWAA620
ZPWMB368SWON	CONSERT PS 2, LCL 52B ON, PDU-P/L-B	NPWAA620
ZPWMB369SWOF	CONSERT PS 2, LCL 52B OFF, PDU-P/L-B	NPWAA620
ZPWMB370SWON	ROSINA RTOF HTR, LCL 53B ON, PDU-P/L-B	NPWAA630
ZPWMB371SWOF	ROSINA RTOF HTR, LCL 53B OFF, PDU-P/L-B	NPWAA630
ZPWMB372SWON	GIADA HIB HTR, LCL 54B ON, PDU-P/L-B	NPWAA630
ZPWMB373SWOF	GIADA HIB HTR, LCL 54B OFF, PDU-P/L-B	NPWAA630
ZPWMB374	SSP REL A 2, SEL LCL 1B CUR PROF-B	*none*
ZPWMB375	SSP REL B 2, SEL LCL 2B CUR PROF-B	*none*
ZPWMB376	SPARE, SEL LCL 3B CUR PROF-B	*none*
ZPWMB377	SPARE, SEL LCL 4B CUR PROF-B	*none*

Name	Designation	Verif TM
ZPWMB378	SSP LANDER HTR, SEL LCL 5B CUR PROF-B	*none*
ZPWMB379	MIDAS PS 2, SEL LCL 6B CUR PROF-B	*none*
ZPWMB380	MIRO ME+SE, SEL LCL 7B CUR PROF-B	*none*
ZPWMB381	VIR/OSIR/RXTX1&2, SEL LCL 8B CUR PROF-B	*none*
ZPWMB382	CON/OS NAC-C/MID, SEL LCL 9B CUR PROF-B	*none*
ZPWMB383	ROS/COS/RPC/ , SEL LCL 10B CUR PROF-B	*none*
ZPWMB384	ALICE PS 2, SEL LCL 11B CUR PROF-B	*none*
ZPWMB385	SPARE, SEL LCL 12B CUR PROF-B	*none*
ZPWMB386	ALICE HIB, SEL LCL 13B CUR PROF-B	*none*
ZPWMB387	SREM PS 2, SEL LCL 14B CUR PROF-B	*none*
ZPWMB388	SSP PS 2, SEL LCL 15B CUR PROF-B	*none*
ZPWMB389	SPARE, SEL LCL 16B CUR PROF-B	*none*
ZPWMB390	SSP MSS HOU, SEL LCL 17B CUR PROF-B	*none*
ZPWMB391	SSP ESS/ RPC IES, SEL LCL 18B CUR PROF-B	*none*
ZPWMB392	SPARE, SEL LCL 19B CUR PROF-B	*none*
ZPWMB393	BOOM HINGE HTRS, SEL LCL 20B CUR PROF-B	*none*
ZPWMB394	STR1-2/NAVCAM1-2, SEL LCL 21B CUR PROF-B	*none*
ZPWMB395	SPARE, SEL LCL 22B CUR PROF-B	*none*
ZPWMB396	RCS1-4 (LINE1), SEL LCL 23B CUR PROF-B	*none*
ZPWMB397	RCS5-8 (LINE2), SEL LCL 24B CUR PROF-B	*none*
ZPWMB398	SPARE, SEL LCL 25B CUR PROF-B	*none*
ZPWMB399	SPARE, SEL LCL 26B CUR PROF-B	*none*
ZPWMB400	MR OPT BENCH HTR, SEL LCL 27B CUR PROF-B	*none*
ZPWMB401	VIRTIS PEMM, SEL LCL 28B CUR PROF-B	*none*
ZPWMB402	MIRO PS 2, SEL LCL 29B CUR PROF-B	*none*
ZPWMB403	OSIRIS PS 2, SEL LCL 30B CUR PROF-B	*none*
ZPWMB404	ROSINA PS 2, SEL LCL 31B CUR PROF-B	*none*

Name	Designation	Verif TM
ZPWMB405	COSIMA PS 2, SEL LCL 32B CUR PROF-B	*none*
ZPWMB406	GIADA PS 2, SEL LCL 33B CUR PROF-B	*none*
ZPWMB407	ROSINA DFMS HTR, SEL LCL 34B CUR PROF-B	*none*
ZPWMB408	PROP TANK +Z HTR, SEL LCL 35B CUR PROF-B	*none*
ZPWMB409	PROP TANK -Z HTR, SEL LCL 36B CUR PROF-B	*none*
ZPWMB410	RCS9-12 (LINE3), SEL LCL 37B CUR PROF-B	*none*
ZPWMB411	SPARE, SEL LCL 38B CUR PROF-B	*none*
ZPWMB412	OSRIS EL HIB HTR, SEL LCL 39B CUR PROF-B	*none*
ZPWMB413	RPC IES HTR, SEL LCL 40B CUR PROF-B	*none*
ZPWMB414	RPC ICA A/SREM/L, SEL LCL 41B CUR PROF-B	*none*
ZPWMB415	ROSINA COPS HTR, SEL LCL 42B CUR PROF-B	*none*
ZPWMB416	HS1/APM/HS4, SEL LCL 43B CUR PROF-B	*none*
ZPWMB417	HS5-8 THRS 1-4, SEL LCL 44B CUR PROF-B	*none*
ZPWMB418	HS9-12 THRS 5-8, SEL LCL 45B CUR PROF-B	*none*
ZPWMB419	HS13-16 THRS9-12, SEL LCL 46B CUR PROF-B	*none*
ZPWMB420	VIRTIS PS 2, SEL LCL 47B CUR PROF-B	*none*
ZPWMB421	SPARE, SEL LCL 48B CUR PROF-B	*none*
ZPWMB422	RPC PS 2, SEL LCL 49B CUR PROF-B	*none*
ZPWMB423	SPARE, SEL LCL 50B CUR PROF-B	*none*
ZPWMB424	SPARE, SEL LCL 51B CUR PROF-B	*none*
ZPWMB425	CONSERT PS 2, SEL LCL 52B CUR PROF-B	*none*
ZPWMB426	ROSINA RTOF HTR, SEL LCL 53B CUR PROF-B	*none*
ZPWMB427	GIADA HIB HTR, SEL LCL 54B CUR PROF-B	*none*
ZPWMB428SWON	SPARE, HTR SW 1B ON-B	*none*
ZPWMB429SWOF	SPARE, HTR SW 1B OFF-B	*none*
ZPWMB430SWON	APM, HTR SW 2B ON-B	*none*
ZPWMB431SWOF	APM, HTR SW 2B OFF-B	*none*

Name	Designation	Verif TM
ZPWMB432SWON	SADM +Y Shaft/ CASE, HTR SW 3B ON-B	*none*
ZPWMB433SWOF	SADM +Y Shaft/ CASE, HTR SW 3B OFF-B	*none*
ZPWMB434SWON	SADM -Y Shaft/ CASE, HTR SW 4B ON-B	*none*
ZPWMB435SWOF	SADM -Y Shaft/ CASE, HTR SW 4B OFF-B	*none*
ZPWMB436SWON	THR HSW MODULE 1, HTR SW 5B ON-B	*none*
ZPWMB437SWOF	THR HSW MODULE 1, HTR SW 5B OFF-B	*none*
ZPWMB438SWON	THR HSW MODULE 2, HTR SW 6B ON-B	*none*
ZPWMB439SWOF	THR HSW MODULE 2, HTR SW 6B OFF-B	*none*
ZPWMB440SWON	THR HSW MODULE 3, HTR SW 7B ON-B	*none*
ZPWMB441SWOF	THR HSW MODULE 3, HTR SW 7B OFF-B	*none*
ZPWMB442SWON	THR HSW MODULE 4, HTR SW 8B ON-B	*none*
ZPWMB443SWOF	THR HSW MODULE 4, HTR SW 8B OFF-B	*none*
ZPWMB444SWON	THR HSW MODULE 5, HTR SW 9B ON-B	*none*
ZPWMB445SWOF	THR HSW MODULE 5, HTR SW 9B OFF-B	*none*
ZPWMB446SWON	THR HSW MODULE 6, HTR SW 10B ON-B	*none*
ZPWMB447SWOF	THR HSW MODULE 6, HTR SW 10B OFF-B	*none*
ZPWMB448SWON	THR HSW MODULE 7, HTR SW 11B ON-B	*none*
ZPWMB449SWOF	THR HSW MODULE 7, HTR SW 11B OFF-B	*none*
ZPWMB450SWON	THR HSW MODULE 8, HTR SW 12B ON-B	*none*
ZPWMB451SWOF	THR HSW MODULE 8, HTR SW 12B OFF-B	*none*
ZPWMB452SWON	THR HSW MODULE 9, HTR SW 13B ON-B	*none*
ZPWMB453SWOF	THR HSW MODULE 9, HTR SW 13B OFF-B	*none*
ZPWMB454SWON	THR HSW MODULE 10, HTR SW 14B ON-B	*none*
ZPWMB455SWOF	THR HSW MODULE 10, HTR SW 14B OFF-B	*none*
ZPWMB456SWON	THR HSW MODULE 11, HTR SW 15B ON-B	*none*
ZPWMB457SWOF	THR HSW MODULE 11, HTR SW 15B OFF-B	*none*
ZPWMB458SWON	THR HSW MODULE 12, HTR SW 16B ON-B	*none*

Name	Designation	Verif TM
ZPWMB459SWOF	THR HSW MODULE 12, HTR SW 16B OFF-B	*none*
ZPWMB460SWON	KAL CONVERTER B ON, PDU-P/L-B	NPWAA640
ZPWMB461SWOF	KAL CONVERTER B OFF, PDU-P/L-B	NPWAA640
ZPWMB462SWON	SSP Emergncy Rel, PARM1 PYRO1B ON-B	*none*
ZPWMB463SWOF	SSP Emergncy Rel, PARM1 PYRO1B OFF-B	*none*
ZPWMB464SWON	Lower Boom Rel, PARM2 PYRO1B ON-B	*none*
ZPWMB465SWON	Upper Boom Rel, PARM2 PYRO2B ON-B	*none*
ZPWMB466SWON	SPARE 1B, PARM2 PYRO3B ON-B	*none*
ZPWMB467SWOF	Lower Boom Rel, PARM2 PYRO1B OFF-B	*none*
ZPWMB468SWOF	Upper Boom Rel, PARM2 PYRO2B OFF-B	*none*
ZPWMB469SWOF	SPARE 1B, PARM2 PYRO3B OFF-B	*none*
ZPWMB470SWON	Rosina DFMS Det, PARM3 PYRO1B ON-B	*none*
ZPWMB471SWON	Rosina RTOF Det, PARM3 PYRO2B ON-B	*none*
ZPWMB472SWON	Ros DFMS Fail/Safe, PARM3 PYRO3B ON-B	*none*
ZPWMB473SWON	SPARE 3B, PARM3 PYRO4B ON-B	*none*
ZPWMB474SWON	SPARE 4B, PARM3 PYRO5B ON-B	*none*
ZPWMB475SWON	SPARE 5B, PARM3 PYRO6B ON-B	*none*
ZPWMB476SWON	Consert Ant Rel, PARM3 PYRO7B ON-B	*none*
ZPWMB477SWOF	Rosina DFMS Det, PARM3 PYRO1B OFF-B	*none*
ZPWMB478SWOF	Rosina RTOF Det, PARM3 PYRO2B OFF-B	*none*
ZPWMB479SWOF	Ros DFMS Fail/Safe, PARM3 PYRO3B OFF-B	*none*
ZPWMB480SWOF	SPARE 3B, PARM3 PYRO4B OFF-B	*none*
ZPWMB481SWOF	SPARE 4B, PARM3 PYRO5B OFF-B	*none*
ZPWMB482SWOF	SPARE 5B, PARM3 PYRO6B OFF-B	*none*
ZPWMB483SWOF	Consert Ant Rel, PARM3 PYRO7B OFF-B	*none*
ZPWMB484SWON	Alice Det Door Rel, PARM4 PYRO1B ON-B	*none*
ZPWMB485SWON	Alice Apert Uncage, PARM4 PYRO2B ON-B	*none*

Name	Designation	Verif TM
ZPWMB486SWON	Alice Fail Safe, PARM4 PYRO3B ON-B	*none*
ZPWMB487SWON	Midas Cover Rel, PARM4 PYRO4B ON-B	*none*
ZPWMB488SWON	SPARE, PARM4 PYRO5B ON-B	*none*
ZPWMB489SWON	SPARE, PARM4 PYRO6B ON-B	*none*
ZPWMB490SWOF	Alice Det Door Rel, PARM4 PYRO1B OFF-B	*none*
ZPWMB491SWOF	Alice Apert Uncage, PARM4 PYRO2B OFF-B	*none*
ZPWMB492SWOF	Alice Fail Safe, PARM4 PYRO3B OFF-B	*none*
ZPWMB493SWOF	Midas Cover Rel, PARM4 PYRO4B OFF-B	*none*
ZPWMB494SWOF	SPARE, PARM4 PYRO5B OFF-B	*none*
ZPWMB495SWOF	SPARE, PARM4 PYRO6B OFF-B	*none*
ZPWMB496SWON	SSP Lander Rel 1, PARM5 PYRO1B ON-B	*none*
ZPWMB497SWON	SSP Lander Rel 2, PARM5 PYRO2B ON-B	*none*
ZPWMB498SWON	SSP Lander Rel 3, PARM5 PYRO3B ON-B	*none*
ZPWMB499SWON	SSP Lander Rel 4, PARM5 PYRO4B ON-B	*none*
ZPWMB500SWON	SPARE 2B, PARM5 PYRO5B ON-B	*none*
ZPWMB501SWOF	SSP Lander Rel 1, PARM5 PYRO1B OFF-B	*none*
ZPWMB502SWOF	SSP Lander Rel 2, PARM5 PYRO2B OFF-B	*none*
ZPWMB503SWOF	SSP Lander Rel 3, PARM5 PYRO3B OFF-B	*none*
ZPWMB504SWOF	SSP Lander Rel 4, PARM5 PYRO4B OFF-B	*none*
ZPWMB505SWOF	SPARE 2B, PARM5 PYRO5B OFF-B	*none*
ZPWMB506SWON	PYRO ARM 1B ON, PDU-P/L-B	*none*
ZPWMB507SWON	PYRO ARM 2B ON, PDU-P/L-B	*none*
ZPWMB508SWON	PYRO ARM 3B ON, PDU-P/L-B	*none*
ZPWMB509SWON	PYRO ARM 4B ON, PDU-P/L-B	*none*
ZPWMB510SWON	PYRO ARM 5B ON, PDU-P/L-B	*none*
ZPWMB511SWOF	PYRO ARM 1B OFF, PDU-P/L-B	*none*
ZPWMB512SWOF	PYRO ARM 2B OFF, PDU-P/L-B	*none*

Name	Designation	Verif TM
ZPWMB513SWOF	PYRO ARM 3B OFF, PDU-P/L-B	*none*
ZPWMB514SWOF	PYRO ARM 4B OFF, PDU-P/L-B	*none*
ZPWMB515SWOF	PYRO ARM 5B OFF, PDU-P/L-B	*none*
ZPWMB516SWON	PYRO POWER BAT2 B ON, PDU-P/L-B	*none*
ZPWMB517SWON	PYRO POWER BAT3 B ON, PDU-P/L-B	*none*
ZPWMB518SWON	PYRO POWER BUS B ON, PDU-P/L-B	*none*
ZPWMB519SWOF	PYRO POWER BAT2 B OFF, PDU-P/L-B	*none*
ZPWMB520SWOF	PYRO POWER BAT3 B OFF, PDU-P/L-B	*none*
ZPWMB521SWOF	PYRO POWER BUS B OFF, PDU-P/L-B	*none*
ZPWMB522	PYRO FIRE B, PDU-P/L-B	NPWAA150
ZPWMB991	Generic MLC PDU-P/L-B RTU-A RouteOfCmd	*none*
ZPWMB993	Generic MLC PDU-P/L-B RTU-B RouteOfCmd	*none*
ZPWMB999	Generic MLC for PDU-P/L-B	*none*

8.7. RFDU TC Packets

RFDU TC Packets are contained in HPC-CMDs.pdf .

8.8. TWTA TC Packets

TWTA TC Packets are contained in HPC-CMDs.pdf and in the transponder section.

8.9. USO TC Packets

USO TC Packets are contained in HPC-CMDs.pdf .

8.10. WIU TC Packets

WIU TC Packets are contained in HPC-CMDs.pdf

8.11. Transponder 1 (nominal) TC Packets

Link to PDF-file: Transponder-1-nominal.pdf

Name	Designation	Verif TM
ZTTM1010ST05	TRSP-1 S-TM MOD INDEX 0.5-A	*none*
ZTTM1020ST07	TRSP-1 S-TM MOD INDEX 0.7-A	*none*
ZTTM1030ST08	TRSP-1 S-TM MOD INDEX 0.8-A	*none*
ZTTM1040ST09	TRSP-1 S-TM MOD INDEX 0.9-A	*none*
ZTTM1050ST10	TRSP-1 S-TM MOD INDEX 1.0-A	*none*
ZTTM1060ST11	TRSP-1 S-TM MOD INDEX 1.1-A	*none*
ZTTM1070ST12	TRSP-1 S-TM MOD INDEX 1.18-A	*none*
ZTTM1080ST13	TRSP-1 S-TM MOD INDEX 1.25-A	*none*
ZTTM1110XT05	TRSP-1 X-TM MOD INDEX 0.5-A	*none*
ZTTM1120XT07	TRSP-1 X-TM MOD INDEX 0.7-A	*none*
ZTTM1130XT08	TRSP-1 X-TM MOD INDEX 0.8-A	*none*
ZTTM1140XT09	TRSP-1 X-TM MOD INDEX 0.9-A	*none*
ZTTM1150XT10	TRSP-1 X-TM MOD INDEX 1.0-A	*none*
ZTTM1160XT11	TRSP-1 X-TM MOD INDEX 1.1-A	*none*
ZTTM1170XT12	TRSP-1 X-TM MOD INDEX 1.18-A	*none*
ZTTM1180XT13	TRSP-1 X-TM MOD INDEX 1.25-A	*none*
ZTTM1210SR01	TRSP-1 S-RNG MOD INDEX 0.1-A	*none*
ZTTM1220SR02	TRSP-1 S-RNG MOD INDEX 0.2-A	*none*
ZTTM1230SR03	TRSP-1 S-RNG MOD INDEX 0.3-A	*none*
ZTTM1240SR04	TRSP-1 S-RNG MOD INDEX 0.4-A	*none*
ZTTM1250SR05	TRSP-1 S-RNG MOD INDEX 0.5-A	*none*
ZTTM1260SR06	TRSP-1 S-RNG MOD INDEX 0.6-A	*none*
ZTTM1270SR07	TRSP-1 S-RNG MOD INDEX 0.7-A	*none*

Name	Designation	Verif TM
ZTTM1310XR01	TRSP-1 X-RNG MOD INDEX 0.1-A	*none*
ZTTM1320XR02	TRSP-1 X-RNG MOD INDEX 0.2-A	*none*
ZTTM1330XR03	TRSP-1 X-RNG MOD INDEX 0.3-A	*none*
ZTTM1340XR04	TRSP-1 X-RNG MOD INDEX 0.4-A	*none*
ZTTM1350XR05	TRSP-1 X-RNG MOD INDEX 0.5-A	*none*
ZTTM1360XR06	TRSP-1 X-RNG MOD INDEX 0.6-A	*none*
ZTTM1370XR07	TRSP-1 X-RNG MOD INDEX 0.7-A	*none*
ZTTM1410STON	TRSP-1 S-BD TM ON-A	*none*
ZTTM1420STOF	TRSP-1 S-BD TM OFF-A	*none*
ZTTM1430XTON	TRSP-1 X-BD TM ON-A	*none*
ZTTM1440XTOF	TRSP-1 X-BD TM OFF-A	*none*
ZTTM1450SRON	TRSP-1 S-BD RNG ON-A	*none*
ZTTM1460SROF	TRSP-1 S-BD RNG OFF-A	*none*
ZTTM1470XRON	TRSP-1 X-BD RNG ON-A	*none*
ZTTM1480XROF	TRSP-1 X-BD RNG OFF-A	*none*
ZTTM1490CMON	TRSP-1 COHERENT MODE ON-A	*none*
ZTTM1500CMOF	TRSP-1 COHERENT MODE OFF-A	*none*
ZTTM1510TCON	TRSP-1 TCXO On USO Off-A	*none*
ZTTM1520TCOF	TRSP-1 TCXO Off USO On-A	*none*
ZTTM1610BR07	TRSP-1 BR SELECTION 7.125-A	*none*
ZTTM1620BR15	TRSP-1 BR SELECTION 15.625-A	*none*
ZTTM1630BR25	TRSP-1 BR SELECTION 250-A	*none*
ZTTM1640BR13	TRSP-1 BR SELECTION 1000-A	*none*
ZTTM1650BR23	TRSP-1 BR SELECTION 2000-A	*none*
ZTTM1700TMRQ	TRSP-1 TM REQUEST-A	*none*
ZTTM1991	Generic MLC TRSP1 RTU-A RouteOfCmd	*none*
ZTTM1993	Generic MLC TRSP1 RTU-B RouteOfCmd	*none*

Name	Designation	Verif TM
ZTTM1999	Generic MLC for TRSP1-A	*none*

8.12. Transponder 2 (redundant) TC Packets

Link to PDF-file: Transponder-2-redundant.pdf

Name	Designation	Verif TM
ZTTM4010ST05	TRSP-2 S-TM MOD INDEX 0.5-B	*none*
ZTTM4020ST07	TRSP-2 S-TM MOD INDEX 0.7-B	*none*
ZTTM4030ST08	TRSP-2 S-TM MOD INDEX 0.8-B	*none*
ZTTM4040ST09	TRSP-2 S-TM MOD INDEX 0.9-B	*none*
ZTTM4050ST10	TRSP-2 S-TM MOD INDEX 1.0-B	*none*
ZTTM4060ST11	TRSP-2 S-TM MOD INDEX 1.1-B	*none*
ZTTM4070ST12	TRSP-2 S-TM MOD INDEX 1.18-B	*none*
ZTTM4080ST13	TRSP-2 S-TM MOD INDEX 1.25-B	*none*
ZTTM4110XT05	TRSP-2 X-TM MOD INDEX 0.5-B	*none*
ZTTM4120XT07	TRSP-2 X-TM MOD INDEX 0.7-B	*none*
ZTTM4130XT08	TRSP-2 X-TM MOD INDEX 0.8-B	*none*
ZTTM4140XT09	TRSP-2 X-TM MOD INDEX 0.9-B	*none*
ZTTM4150XT10	TRSP-2 X-TM MOD INDEX 1.0-B	*none*
ZTTM4160XT11	TRSP-2 X-TM MOD INDEX 1.1-B	*none*
ZTTM4170XT12	TRSP-2 X-TM MOD INDEX 1.18-B	*none*
ZTTM4180XT13	TRSP-2 X-TM MOD INDEX 1.25-B	*none*
ZTTM4210SR01	TRSP-2 S-RNG MOD INDEX 0.1-B	*none*
ZTTM4220SR02	TRSP-2 S-RNG MOD INDEX 0.2-B	*none*
ZTTM4230SR03	TRSP-2 S-RNG MOD INDEX 0.3-B	*none*
ZTTM4240SR04	TRSP-2 S-RNG MOD INDEX 0.4-B	*none*
ZTTM4250SR05	TRSP-2 S-RNG MOD INDEX 0.5-B	*none*

Name	Designation	Verif TM
ZTTM4260SR06	TRSP-2 S-RNG MOD INDEX 0.6-B	*none*
ZTTM4270SR07	TRSP-2 S-RNG MOD INDEX 0.7-B	*none*
ZTTM4310XR01	TRSP-2 X-RNG MOD INDEX 0.1-B	*none*
ZTTM4320XR02	TRSP-2 X-RNG MOD INDEX 0.2-B	*none*
ZTTM4330XR03	TRSP-2 X-RNG MOD INDEX 0.3-B	*none*
ZTTM4340XR04	TRSP-2 X-RNG MOD INDEX 0.4-B	*none*
ZTTM4350XR05	TRSP-2 X-RNG MOD INDEX 0.5-B	*none*
ZTTM4360XR06	TRSP-2 X-RNG MOD INDEX 0.6-B	*none*
ZTTM4370XR07	TRSP-2 X-RNG MOD INDEX 0.7-B	*none*
ZTTM4410STON	TRSP-2 S-BD TM ON-B	*none*
ZTTM4420STOF	TRSP-2 S-BD TM OFF-B	*none*
ZTTM4430XTON	TRSP-2 X-BD TM ON-B	*none*
ZTTM4440XTOF	TRSP-2 X-BD TM OFF-B	*none*
ZTTM4450SRON	TRSP-2 S-BD RNG ON-B	*none*
ZTTM4460SROF	TRSP-2 S-BD RNG OFF-B	*none*
ZTTM4470XRON	TRSP-2 X-BD RNG ON-B	*none*
ZTTM4480XROF	TRSP-2 X-BD RNG OFF-B	*none*
ZTTM4490CMON	TRSP-2 COHERENT MODE ON-B	*none*
ZTTM4500CMOF	TRSP-2 COHERENT MODE OFF-B	*none*
ZTTM4510TCON	TRSP-2 TCXO On USO Off-B	*none*
ZTTM4520TCOF	TRSP-2 TCXO Off USO On-B	*none*
ZTTM4610BR07	TRSP-2 BR SELECTION 7.125-B	*none*
ZTTM4620BR15	TRSP-2 BR SELECTION 15.625-B	*none*
ZTTM4630BR25	TRSP-2 BR SELECTION 250-B	*none*
ZTTM4640BR13	TRSP-2 BR SELECTION 1000-B	*none*
ZTTM4650BR23	TRSP-2 BR SELECTION 2000-B	*none*
ZTTM4700TMRQ	TRSP-2 TM REQUEST-B	*none*

Name	Designation	Verif TM
ZTTM4991	Generic MLC TRSP2 RTU-A RouteOfCmd	*none*
ZTTM4993	Generic MLC TRSP2 RTU-B RouteOfCmd	*none*
ZTTM4999	Generic MLC for TRSP2-B	*none*

8.13. HPC Commands

Link to PDF-file: HPC.pdf

Name	Designation	Verif TM
ZDM01901SWON	PS1 SSMM ON	NDMA1100
ZDM01902SWOF	PS1 SSMM OFF	NDMA1100
ZDM01903SWON	MC1 on PS1	*none*
ZDM01904SWON	MC2 on PS1	*none*
ZDM01905SWON	MC1 ON	*none*
ZDM01906SWOF	MC1 OFF	*none*
ZDM01907SWON	MM1 on PS1	*none*
ZDM01908SWON	MM2 on PS1	*none*
ZDM01909SWON	MM3 on PS1	*none*
ZDM01910SWON	PS2 SSMM ON	NDMA1200
ZDM01911SWOF	PS2 SSMM OFF	NDMA1200
ZDM01912SWON	MC1 on PS2	*none*
ZDM01913SWON	MC2 on PS2	*none*
ZDM01914SWON	MC2 ON	*none*
ZDM01915SWOF	MC2 OFF	*none*
ZDM01916SWON	MM1 on PS2	*none*
ZDM01917SWON	MM2 on PS2	*none*
ZDM01918SWON	MM3 on PS2	*none*
ZDM01919	PS1 AIU ON / PS2 AIU OFF	*none*
ZDM01920SWOF	PS1 AIU OFF	*none*

Name	Designation	Verif TM
ZDM01921SWON	Cmd & Acq Module A on PS1	*none*
ZDM01922SWON	Cmd & Acq Module B on PS1	*none*
ZDM01923	PS2 AIU ON / PS1 AIU OFF	*none*
ZDM01924SWOF	PS2 AIU OFF	*none*
ZDM01925SWON	Cmd & Acq Module A on PS2	*none*
ZDM01926SWON	Cmd & Acq Module B on PS2	*none*
ZDM01927SWON	Gyro set 1 ON	*none*
ZDM01928SWOF	Gyro set 1 OFF	*none*
ZDM01929SWON	Gyro set 2 ON	*none*
ZDM01930SWOF	Gyro set 2 OFF	*none*
ZDM01931SWON	Gyro set 3 ON	*none*
ZDM01932SWOF	Gyro set 3 OFF	*none*
ZDM01933SWON	RW1 ON	*none*
ZDM01934SWOF	RW1 OFF	*none*
ZDM01935SWON	RW2 ON	*none*
ZDM01936SWOF	RW2 OFF	*none*
ZDM01937SWON	RW3 ON	*none*
ZDM01938SWOF	RW3 OFF	*none*
ZDM01939SWON	RW4 ON	*none*
ZDM01940SWOF	RW4 OFF	*none*
ZDM01941SWON	Pressure Transducer set A ON	*none*
ZDM01942SWOF	Pressure Transducer set A OFF	*none*
ZDM01943SWON	Pressure Transducer set B ON	*none*
ZDM01944SWOF	Pressure Transducer set B OFF	*none*
ZDM01945SWON	STR 1 ON	*none*
ZDM01946SWOF	STR 1 OFF	*none*
ZDM01947SWON	STR 2 ON	*none*

Name	Designation	Verif TM
ZDM01948SWOF	STR 2 OFF	*none*
ZDM01949SWON	CAM 1 ON	*none*
ZDM01950SWOF	CAM 1 OFF	*none*
ZDM01951SWON	CAM 2 ON	*none*
ZDM01952SWOF	CAM 2 OFF	*none*
ZDM01953	THRN_LCLN	*none*
ZDM01954	THRN_LCLR	*none*
ZDM01955	THRR_LCLN	*none*
ZDM01956	THRR_LCLR	*none*
ZDM01957	RTUS_DIS_AV_A	*none*
ZDM01958	RTUS_EN_AV_A	*none*
ZDM01959	RTUS_DIS_AV_B	*none*
ZDM01960	RTUS_EN_AV_B	*none*
ZDM01961	28V IO1 PS1	*none*
ZDM01962	28V IO2 PS2	*none*
ZDM01963	28V IO1 PS2	*none*
ZDM01964	28V IO2 PS1	*none*
ZDMDUMMY	Start AOCMS SCOE Simulation	*none*
ZDMH1000	SSMMA_SEL_N	*none*
ZDMH1001	SSMMB_SEL_N	*none*
ZDMH2000	SSMMA_SEL_R	*none*
ZDMH2001	SSMMB_SEL_R	*none*
ZDMR1901SWON	PS1 SSMM ON	NDMA1100
ZDMR1902SWOF	PS1 SSMM OFF	NDMA1100
ZDMR1903SWON	MC1 on PS1	*none*
ZDMR1904SWON	MC2 on PS1	*none*
ZDMR1905SWON	MC1 ON	*none*

Name	Designation	Verif TM
ZDMR1906SWOF	MC1 OFF	*none*
ZDMR1907SWON	MM1 on PS1	*none*
ZDMR1908SWON	MM2 on PS1	*none*
ZDMR1909SWON	MM3 on PS1	*none*
ZDMR1910SWON	PS2 SSMM ON	NDMA1200
ZDMR1911SWOF	PS2 SSMM OFF	NDMA1200
ZDMR1912SWON	MC1 on PS2	*none*
ZDMR1913SWON	MC2 on PS2	*none*
ZDMR1914SWON	MC2 ON	*none*
ZDMR1915SWOF	MC2 OFF	*none*
ZDMR1916SWON	MM1 on PS2	*none*
ZDMR1917SWON	MM2 on PS2	*none*
ZDMR1918SWON	MM3 on PS2	*none*
ZDMR1919	PS1 AIU ON / PS2 AIU OFF	*none*
ZDMR1920SWOF	PS1 AIU OFF	*none*
ZDMR1921SWON	Cmd & Acq Module A on PS1	*none*
ZDMR1922SWON	Cmd & Acq Module B on PS1	*none*
ZDMR1923	PS2 AIU ON / PS1 AIU OFF	*none*
ZDMR1924SWOF	PS2 AIU OFF	*none*
ZDMR1925SWON	Cmd & Acq Module A on PS2	*none*
ZDMR1926SWON	Cmd & Acq Module B on PS2	*none*
ZDMR1927SWON	Gyro set 1 ON	*none*
ZDMR1928SWOF	Gyro set 1 OFF	*none*
ZDMR1929SWON	Gyro set 2 ON	*none*
ZDMR1930SWOF	Gyro set 2 OFF	*none*
ZDMR1931SWON	Gyro set 3 ON	*none*
ZDMR1932SWOF	Gyro set 3 OFF	*none*

Name	Designation	Verif TM
ZDMR1933SWON	RW1 ON	*none*
ZDMR1934SWOF	RW1 OFF	*none*
ZDMR1935SWON	RW2 ON	*none*
ZDMR1936SWOF	RW2 OFF	*none*
ZDMR1937SWON	RW3 ON	*none*
ZDMR1938SWOF	RW3 OFF	*none*
ZDMR1939SWON	RW4 ON	*none*
ZDMR1940SWOF	RW4 OFF	*none*
ZDMR1945SWON	STR 1 ON	*none*
ZDMR1946SWOF	STR 1 OFF	*none*
ZDMR1947SWON	STR 2 ON	*none*
ZDMR1948SWOF	STR 2 OFF	*none*
ZDMR1949SWON	CAM 1 ON	*none*
ZDMR1950SWOF	CAM 1 OFF	*none*
ZDMR1951SWON	CAM 2 ON	*none*
ZDMR1952SWOF	CAM 2 OFF	*none*
ZDMR1953	THRN_LCLN	*none*
ZDMR1954	THRN_LCLR	*none*
ZDMR1955	THRR_LCLN	*none*
ZDMR1956	THRR_LCLR	*none*
ZDMR1957	RTUS_DIS_AV_A	*none*
ZDMR1958	RTUS_EN_AV_A	*none*
ZDMR1959	RTUS_DIS_AV_B	*none*
ZDMR1960	RTUS_EN_AV_B	*none*
ZDMR1961	28V IO1 PS1	*none*
ZDMR1962	28V IO2 PS2	*none*
ZDMR1963	28V IO1 PS2	*none*

Name	Designation	Verif TM
ZDMR1964	28V IO2 PS1	*none*
ZHGHA100	APME A, PWR ON, RTU-S/S-A	*none*
ZHGHA101	APME A, PWR OFF, RTU-S/S-A	*none*
ZHGHA110	APME B, PWR ON, RTU-S/S-A	*none*
ZHGHA111	APME B, PWR OFF, RTU-S/S-A	*none*
ZHGHA200	APME A, PWR ON, RTU-S/S-B	*none*
ZHGHA201	APME A, PWR OFF, RTU-S/S-B	*none*
ZHGHA210	APME B, PWR ON, RTU-S/S-B	*none*
ZHGHA211	APME B, PWR OFF, RTU-S/S-B	*none*
ZPWH1000	BAT1, DIS REL ON, RTU-S/S-A	*none*
ZPWH1001	BAT1, DIS REL OFF, RTU-S/S-A	*none*
ZPWH1002	BAT3, DIS REL ON, RTU-S/S-A	*none*
ZPWH1003	BAT3, DIS REL OFF, RTU-S/S-A	*none*
ZPWH2000	BAT1, DIS REL ON, RTU-S/S-B	*none*
ZPWH2001	BAT1, DIS REL OFF, RTU-S/S-B	*none*
ZPWH2002	BAT2, DIS REL ON, RTU-S/S-B	*none*
ZPWH2003	BAT2, DIS REL OFF, RTU-S/S-B	*none*
ZPWH2008	CV RESET A, PDU-S/S-A	*none*
ZPWH3009	CV RESET B, PDU-S/S-B	*none*
ZPWHA000	CV RESET A, PDU-P/L-A	*none*
ZPWHB001	CV RESET B, PDU-P/L-B	*none*
ZRNH1000	ROSINA, HPC SET, RTU-P/L-A	*none*
ZRNH1001	ROSINA, HPC RESET, RTU-P/L-A	*none*
ZRNH2000	ROSINA, HPC SET, RTU-P/L-B	*none*
ZRNH2001	ROSINA, HPC RESET, RTU-P/L-B	*none*
ZRPH1000	RPC, HPC, RTU-P/L-A	*none*
ZRPH2000	RPC, HPC, RTU-P/L-B	*none*

Name	Designation	Verif TM
ZSAHS100	SADE A, PWR ON, RTU-S/S-A	*none*
ZSAHS101	SADE A, PWR OFF, RTU-S/S-A	*none*
ZSAHS110	SADE B, PWR ON, RTU-S/S-A	*none*
ZSAHS111	SADE B, PWR OFF, RTU-S/S-A	*none*
ZSAHS200	SADE A, PWR ON, RTU-S/S-B	*none*
ZSAHS201	SADE A, PWR OFF, RTU-S/S-B	*none*
ZSAHS210	SADE B, PWR ON, RTU-S/S-B	*none*
ZSAHS211	SADE B, PWR OFF, RTU-S/S-B	*none*
ZSBE0999	Generic EHPC for RTU-S/S Units	*none*
ZSBH0999	Generic HPC for RTU-S/S Units	*none*
ZSBH1999	Generic HPC for RTU-P/L Units	*none*
ZSDHDUMA	DUMMY HIGH POWER CMD via I/O A, HPC114-A	*none*
ZSDHDUMB	DUMMY HIGH POWER CMD via I/O B, HPC114-B	*none*
ZSEH1000	SREM, HPC ON, RTU-P/L-A	*none*
ZSEH1001	SREM, HPC OFF, RTU-P/L-A	*none*
ZSRH1000	RTUP1_OSIRIS_N	*none*
ZSRH1001	RTUP2_OSIRIS_N	*none*
ZSRH2000	RTUP1_OSIRIS_R	*none*
ZSRH2001	RTUP2_OSIRIS_R	*none*
ZTTERF10	RFDU, SWITCH-1 TO POSITION-1, RTU-S/S-A	*none*
ZTTERF11	RFDU, SWITCH-1 TO POSITION-2, RTU-S/S-A	*none*
ZTTERF12	RFDU, SWITCH-2 TO POSITION-1, RTU-S/S-A	*none*
ZTTERF13	RFDU, SWITCH-2 TO POSITION-2, RTU-S/S-A	*none*
ZTTERF14	RFDU, SWITCH-3 TO POSITION-1, RTU-S/S-A	*none*
ZTTERF15	RFDU, SWITCH-3 TO POSITION-2, RTU-S/S-A	*none*
ZTTERF16	RFDU, SWITCH-4 TO POSITION-1, RTU-S/S-A	*none*
ZTTERF17	RFDU, SWITCH-4 TO POSITION-2, RTU-S/S-A	*none*

Name	Designation	Verif TM
ZTTERF18	RFDU, SWITCH-5 TO POSITION-1, RTU-S/S-A	*none*
ZTTERF19	RFDU, SWITCH-5 TO POSITION-2, RTU-S/S-A	*none*
ZTTERF20	RFDU, SWITCH-1 TO POSITION-1, RTU-S/S-B	*none*
ZTTERF21	RFDU, SWITCH-1 TO POSITION-2, RTU-S/S-B	*none*
ZTTERF22	RFDU, SWITCH-2 TO POSITION-1, RTU-S/S-B	*none*
ZTTERF23	RFDU, SWITCH-2 TO POSITION-2, RTU-S/S-B	*none*
ZTTERF24	RFDU, SWITCH-3 TO POSITION-1, RTU-S/S-B	*none*
ZTTERF25	RFDU, SWITCH-3 TO POSITION-2, RTU-S/S-B	*none*
ZTTERF26	RFDU, SWITCH-4 TO POSITION-1, RTU-S/S-B	*none*
ZTTERF27	RFDU, SWITCH-4 TO POSITION-2, RTU-S/S-B	*none*
ZTTERF28	RFDU, SWITCH-5 TO POSITION-1, RTU-S/S-B	*none*
ZTTERF29	RFDU, SWITCH-5 TO POSITION-2, RTU-S/S-B	*none*
ZTTEW100	WIU, SWITCH-6 TO POSITION-1, RTU-S/S-A	*none*
ZTTEW101	WIU, SWITCH-6 TO POSITION-2, RTU-S/S-A	*none*
ZTTEW102	WIU, SWITCH-7 TO POSITION-1, RTU-S/S-A	*none*
ZTTEW103	WIU, SWITCH-7 TO POSITION-2, RTU-S/S-A	*none*
ZTTEW200	WIU, SWITCH-6 TO POSITION-1, RTU-S/S-B	*none*
ZTTEW201	WIU, SWITCH-6 TO POSITION-2, RTU-S/S-B	*none*
ZTTEW202	WIU, SWITCH-7 TO POSITION-1, RTU-S/S-B	*none*
ZTTEW203	WIU, SWITCH-7 TO POSITION-2, RTU-S/S-B	*none*
ZTTHT100	TWTA-1, TWTA ON, RTU-S/S-A	*none*
ZTTHT101	TWTA-1, TWTA OFF, RTU-S/S-A	*none*
ZTTHT102	TWTA-1, HIGH VOLT ON, RTU-S/S-A	*none*
ZTTHT103	TWTA-1, HIGH VOLT OFF, RTU-S/S-A	*none*
ZTTHT200	TWTA-2, TWTA ON, RTU-S/S-B	*none*
ZTTHT201	TWTA-2, TWTA OFF, RTU-S/S-B	*none*
ZTTHT202	TWTA-2, HIGH VOLT ON, RTU-S/S-B	*none*

Name	Designation	Verif TM
ZTTHT203	TWTA-2, HIGH VOLT OFF, RTU-S/S-B	*none*
ZTTHU100	USO, PWR ON, RTU-S/S-A	*none*
ZTTHU101	USO, PWR OFF A, RTU-S/S-A	*none*
ZTTHU102	USO, OVEN SHIFT ON, RTU-S/S-A	*none*
ZTTHU103	USO, OVEN SHIFT OFF, RTU-S/S-A	*none*
ZTTHU104	USO, RF MUTE, RTU-S/S-A	*none*
ZTTHU105	USO, RF ENABLE, RTU-S/S-A	*none*
ZTTHU200	USO, PWR ON, RTU-S/S-B	*none*
ZTTHU201	USO, OVEN SHIFT ON, RTU-S/S-B	*none*
ZTTHU202	USO, OVEN SHIFT OFF, RTU-S/S-B	*none*
ZTTHU203	USO, RF MUTE, RTU-S/S-B	*none*
ZTTHU204	USO, RF ENABLE, RTU-S/S-B	*none*
ZTTHX100	TRSP-1, S-TX ON, RTU-S/S-A	*none*
ZTTHX101	TRSP-1, S-TX OFF, RTU-S/S-A	*none*
ZTTHX102	TRSP-1, X-TX ON, RTU-S/S-A	*none*
ZTTHX103	TRSP-1, X-TX OFF, RTU-S/S-A	*none*
ZTTHX104	TRSP-1, S-BD RX SEL SIG, RTU-S/S-A	*none*
ZTTHX105	TRSP-1, X-BD RX SEL SIG, RTU-S/S-A	*none*
ZTTHX106	TRSP-1, SW RESET ARM, RTU-S/S-A	*none*
ZTTHX107	TRSP-1, SW RESET FIRE, RTU-S/S-A	*none*
ZTTHX200	TRSP-2, S-TX ON, RTU-S/S-A	*none*
ZTTHX201	TRSP-2, S-TX OFF, RTU-S/S-A	*none*
ZTTHX202	TRSP-2, X-TX ON, RTU-S/S-A	*none*
ZTTHX203	TRSP-2, X-TX OFF, RTU-S/S-A	*none*
ZTTHX206	TRSP 2, SW RESET ARM, RTU-S/S-A	*none*
ZTTHX207	TRSP 2, SW RESET FIRE, RTU-S/S-A	*none*
ZTTHX300	TRSP-1, S-TX ON, RTU-S/S-B	*none*

Name	Designation	Verif TM
ZTTHX301	TRSP-1, S-TX OFF, RTU-S/S-B	*none*
ZTTHX302	TRSP-1, X-TX ON, RTU-S/S-B	*none*
ZTTHX303	TRSP-1, X-TX OFF, RTU-S/S-B	*none*
ZTTHX306	TRSP-1, SW RESET ARM, RTU-S/S-B	*none*
ZTTHX307	TRSP-1, SW RESET FIRE, RTU-S/S-B	*none*
ZTTHX400	TRSP-2, S-TX ON, RTU-S/S-B	*none*
ZTTHX401	TRSP-2, S-TX OFF, RTU-S/S-B	*none*
ZTTHX402	TRSP-2, X-TX ON, RTU-S/S-B	*none*
ZTTHX403	TRSP-2, X-TX OFF, RTU-S/S-B	*none*
ZTTHX404	TRSP-2, S-BD RX SEL SIG, RTU-S/S-B	*none*
ZTTHX405	TRSP-2, X-BD RX SEL SIG, RTU-S/S-B	*none*
ZTTHX406	TRSP-2, SW RESET ARM, RTU-S/S-B	*none*
ZTTHX407	TRSP-2, SW RESET FIRE, RTU-S/S-B	*none*
ZVRH1000	RTUP1_VIRTIS_N	*none*
ZVRH1001	RTUP2_VIRTIS_N	*none*
ZVRH2000	RTUP1_VIRTIS_R	*none*
ZVRH2001	RTUP2_VIRTIS_R	*none*

8.14. PCU TM Datasheets

Link to PDF-file: TM Datasheets PCU.pdf

Name	Designation
NDMWBT50	Fine OBT:PCU Acqs
NPWA1000	Word 00 TMGA PCU
NPWA1010	Word 01 TMGA PCU
NPWA1020	Word 02 TMGA PCU

Name	Designation
NPWA1030	Word 03 TMGA PCU
NPWA1040	Word 04 TMGA PCU
NPWA1050	Word 05 TMGA PCU
NPWA1060	Word 06 TMGA PCU
NPWA1070	Word 07 TMGA PCU
NPWA1080	Word 08 TMGA PCU
NPWA1090	Word 09 TMGA PCU
NPWA1100	Word 10 TMGA PCU
NPWA1110	Word 11 TMGA PCU
NPWA1120	Word 12 TMGA PCU
NPWA1130	Word 13 TMGA PCU
NPWA1140	Word 14 TMGA PCU
NPWA1150	Word 15 TMGA PCU
NPWA1160	Word 16 TMGA PCU
NPWA1170	Word 17 TMGA PCU
NPWA1180	Word 18 TMGA PCU
NPWA1190	Word 19 TMGA PCU
NPWA1200	Word 20 TMGA PCU
NPWA1210	Word 21 TMGA PCU
NPWA1220	Word 22 TMGA PCU
NPWA1230	Word 23 TMGA PCU
NPWA1240	Word 24 TMGA PCU
NPWA1250	Word 25 TMGA PCU

Name	Designation
NPWA1260	Word 26 TMGA PCU
NPWA1270	Word 27 TMGA PCU
NPWA1280	Word 28 TMGA PCU
NPWA1290	Word 29 TMGA PCU
NPWA1300	Word 30 TMGA PCU
NPWA1310	Word 31 TMGA PCU
NPWA1320	Word 32 TMGA PCU
NPWA1330	Word 33 TMGA PCU
NPWA1340	Word 34 TMGA PCU
NPWA1350	Word 35 TMGA PCU
NPWA1360	Word 36 TMGA PCU
NPWA1370	Word 37 TMGA PCU
NPWA1380	Word 38 TMGA PCU
NPWA1390	Word 39 TMGA PCU
NPWA1400	Word 40 TMGA PCU
NPWA1410	Word 41 TMGA PCU
NPWA1420	Word 42 TMGA PCU
NPWA1430	Word 43 TMGA PCU
NPWA1440	Word 44 TMGA PCU
NPWA1450	Word 45 TMGA PCU
NPWA1460	Word 46 TMGA PCU
NPWA1470	Word 47 TMGA PCU
NPWA1480	Word 48 TMGA PCU

Name	Designation
NPWA1490	Word 49 TMGA PCU
NPWA1500	Word 50 TMGA PCU
NPWA1510	Word 51 TMGA PCU
NPWA1520	Word 52 TMGA PCU
NPWA1530	Word 53 TMGA PCU
NPWA1540	Word 54 TMGA PCU
NPWA1550	Word 55 TMGA PCU
NPWA1560	Word 56 TMGA PCU
NPWA1570	Word 57 TMGA PCU
NPWA1580	Word 58 TMGA PCU
NPWA1590	Word 59 TMGA PCU
NPWA1600	Word 60 TMGA PCU
NPWA1610	Word 61 TMGA PCU
NPWA1620	Word 62 TMGA PCU
NPWA1630	Word 63 TMGA PCU
NPWA1640	Word 64 TMGA PCU
NPWA1650	Word 65 TMGA PCU
NPWA1660	Word 66 TMGA PCU
NPWA1670	Word 67 TMGA PCU
NPWA1680	Word 68 TMGA PCU
NPWA1690	Word 69 TMGA PCU
NPWA1700	Word 70 TMGA PCU
NPWA1710	Word 71 TMGA PCU

Name	Designation
NPWA1720	Word 72 TMGA PCU
NPWA1730	Word 73 TMGA PCU
NPWA1740	Word 74 TMGA PCU
NPWA1750	Word 75 TMGA PCU
NPWA1760	Word 76 TMGA PCU
NPWA1770	Word 77 TMGA PCU
NPWA1780	Word 78 TMGA PCU
NPWA1790	Word 79 TMGA PCU

8.15. SS-PDU TM Datasheets

Link to PDF-file: TM Datasheets PDU1NORM.pdf

Name	Designation
NDMWBT52	FineOBT:SS PDU Acqs NORM
NPWA2000	LAST CMD ECHO
NPWA2010	Word 01 TMGA PDU S/S
NPWA2020	Word 02 TMGA PDU S/S
NPWA2030	Word 03 TMGA PDU S/S
NPWA2040	Word 04 TMGA PDU S/S
NPWA2050	Word 05 TMGA PDU S/S
NPWA2060	Word 06 TMGA PDU S/S
NPWA2070	Word 07 TMGA PDU S/S
NPWA2080	Word 08 TMGA PDU S/S

Name	Designation
NPWA2090	Word 09 TMGA PDU S/S
NPWA2100	Word10 TMGA PDU SS Spare
NPWA2110	Word11 TMGA PDU SS Spare
NPWA2120	Word 12 TMGA PDU S/S
NPWA2130	Word 13 TMGA PDU S/S
NPWA2140	Word 14 TMGA PDU S/S
NPWA2150	Word 15 TMGA PDU S/S
NPWA2160	Word 16 TMGA PDU S/S
NPWA2170	Word 17 TMGA PDU S/S
NPWA2180	Word 18 TMGA PDU S/S
NPWA2190	Word 19 TMGA PDU S/S
NPWA2200	Word 20 TMGA PDU S/S
NPWA2210	Word 21 TMGA PDU S/S
NPWA2220	Word22 TMGA PDU SS Spare
NPWA2230	Word23 TMGA PDU SS Spare
NPWA2240	Word 24 TMGA PDU S/S
NPWA2250	Word 25 TMGA PDU S/S
NPWA2260	Word 26 TMGA PDU S/S
NPWA2270	Word27 TMGA PDU SS Spare
NPWA2280	Word 28 TMGA PDU S/S
NPWA2290	Word 29 TMGA PDU S/S
NPWA2300	Word 30 TMGA PDU S/S
NPWA2310	Word 31 TMGA PDU S/S

Name	Designation
NPWA2320	Word 32 TMGA PDU S/S
NPWA2330	Word33 TMGA PDU SS Spare
NPWA2340	Word 34 TMGA PDU S/S
NPWA2350	Word 35 TMGA PDU S/S
NPWA2360	Word 36 TMGA PDU S/S
NPWA2370	Word 37 TMGA PDU S/S
NPWA2380	Word 38 TMGA PDU S/S
NPWA2390	Word 39 TMGA PDU S/S
NPWA2400	Word 40 TMGA PDU S/S
NPWA2410	Word 41 TMGA PDU S/S
NPWA2420	Word 42 TMGA PDU S/S
NPWA2430	Word43 TMGA PDU SS Spare
NPWA2440	Word 44 TMGA PDU S/S
NPWA2450	Word 45 TMGA PDU S/S
NPWA2460	Word46 TMGA PDU SS Spare
NPWA2470	Word47 TMGA PDU SS Spare
NPWA2480	Word48 TMGA PDU SS Spare
NPWA2490	Word49 TMGA PDU SS Spare
NPWA2500	Word50 TMGA PDU SS Spare
NPWA2510	Word51 TMGA PDU SS Spare
NPWA2520	Word 52 TMGA PDU S/S
NPWA2530	Word 53 TMGA PDU S/S
NPWA2540	Word 54 TMGA PDU S/S

Name	Designation
NPWA2550	Word 55 TMGA PDU S/S
NPWA2560	Word56 TMGA PDU SS Spare
NPWA2570	Word57 TMGA PDU SS Spare
NPWA2580	Word58 TMGA PDU SS Spare
NPWA2590	Word59 TMGA PDU SS Spare
NPWA2600	Word 60 TMGA PDU S/S
NPWA2610	Word 61 TMGA PDU S/S
NPWA2620	Word 62 TMGA PDU S/S
NPWA2630	Word 63 TMGA PDU S/S
NPWA2640	Word 64 TMGA PDU S/S
NPWA2650	Word65 TMGA PDU SS Spare
NPWA2660	Word 66 TMGA PDU S/S
NPWA2670	Word 67 TMGA PDU S/S
NPWA2680	Word 68 TMGA PDU S/S
NPWA2690	Word 69 TMGA PDU S/S
NPWA2700	Word 70 TMGA PDU S/S
NPWA2710	Word 71 TMGA PDU S/S
NPWA2720	Word 72 TMGA PDU S/S
NPWA2730	Word 73 TMGA PDU S/S
NPWA2740	Word 74 TMGA PDU S/S
NPWA2750	Word75 TMGA PDU SS Spare
NPWA2760	Word 76 TMGA PDU S/S
NPWA2770	Word 77 TMGA PDU S/S

Name	Designation
NPWA2780	Word78 TMGA PDU SS Spare
NPWA2790	Word79 TMGA PDU SS Spare
NPWA2800	Word80 TMGA PDU SS Spare
NPWA2810	Word81 TMGA PDU SS Spare
NPWA2820	Word82 TMGA PDU SS Spare
NPWA2830	Word83 TMGA PDU SS Spare
NPWA2840	Word 84 TMGA PDU S/S
NPWA2850	Word 85 TMGA PDU S/S
NPWA2860	Word 86 TMGA PDU S/S
NPWA2870	Word 87 TMGA PDU S/S
NPWA2880	Word88 TMGA PDU SS Spare
NPWA2890	Word89 TMGA PDU SS Spare
NPWA2900	Word90 TMGA PDU SS Spare
NPWA2910	Word91 TMGA PDU SS Spare
NPWA2920	Word 92 TMGA PDU S/S
NPWA2930	PDU S/S ID COUNT

8.16. PL-PDU TM Datasheets

Link to PDF-file: TM Datasheets PDU2NORM.pdf

Name	Designation
NDMWBT58	FineOBT:PL PDU Acqs NORM
NPWAA000	LAST CMD ECHO

Name	Designation
NPWAA010	Word 01 TMGA PDU P/L
NPWAA020	Word 02 TMGA PDU P/L
NPWAA030	Word 03 TMGA PDU P/L
NPWAA040	Word 04 TMGA PDU P/L
NPWAA050	Word 05 TMGA PDU P/L
NPWAA060	Word 06 TMGA PDU P/L
NPWAA070	Word 07 TMGA PDU P/L
NPWAA080	Word08 TMGA PDU PL Spare
NPWAA090	Word 09 TMGA PDU P/L
NPWAA100	Word 10 TMGA PDU P/L
NPWAA110	Word 11 TMGA PDU P/L
NPWAA120	Word12 TMGA PDU PL Spare
NPWAA130	Word13 TMGA PDU PL Spare
NPWAA140	Word 14 TMGA PDU P/L
NPWAA150	Word 15 TMGA PDU P/L
NPWAA160	Word 16 TMGA PDU P/L
NPWAA170	Word 17 TMGA PDU P/L
NPWAA180	Word 18 TMGA PDU P/L
NPWAA190	Word 19 TMGA PDU P/L
NPWAA200	Word20 TMGA PDU PL Spare
NPWAA210	Word 21 TMGA PDU P/L
NPWAA220	Word 22 TMGA PDU P/L
NPWAA230	Word 23 TMGA PDU P/L

Name	Designation
NPWAA240	Word24 TMGA PDU PL Spare
NPWAA250	Word25 TMGA PDU PL Spare
NPWAA260	Word 26 TMGA PDU P/L
NPWAA270	Word27 TMGA PDU PL Spare
NPWAA280	Word 28 TMGA PDU P/L
NPWAA290	Word 29 TMGA PDU P/L
NPWAA300	Word 30 TMGA PDU P/L
NPWAA310	Word 31 TMGA PDU P/L
NPWAA320	Word 32 TMGA PDU P/L
NPWAA330	Word33 TMGA PDU PL Spare
NPWAA340	Word 34 TMGA PDU P/L
NPWAA350	Word 35 TMGA PDU P/L
NPWAA360	Word 36 TMGA PDU P/L
NPWAA370	Word 37 TMGA PDU P/L
NPWAA380	Word 38 TMGA PDU P/L
NPWAA390	Word 39 TMGA PDU P/L
NPWAA400	Word 40 TMGA PDU P/L
NPWAA410	Word 41 TMGA PDU P/L
NPWAA420	Word 42 TMGA PDU P/L
NPWAA430	Word43 TMGA PDU PL Spare
NPWAA440	Word 44 TMGA PDU P/L
NPWAA450	Word 45 TMGA PDU P/L
NPWAA460	Word 46 TMGA PDU P/L

Name	Designation
NPWAA470	Word 47 TMGA PDU P/L
NPWAA480	Word 48 TMGA PDU P/L
NPWAA490	Word 49 TMGA PDU P/L
NPWAA500	Word 50 TMGA PDU P/L
NPWAA510	Word51 TMGA PDU PL Spare
NPWAA520	Word 52 TMGA PDU P/L
NPWAA530	Word 53 TMGA PDU P/L
NPWAA540	Word 54 TMGA PDU P/L
NPWAA550	Word 55 TMGA PDU P/L
NPWAA560	Word 56 TMGA PDU P/L
NPWAA570	Word 57 TMGA PDU P/L
NPWAA580	Word 58 TMGA PDU P/L
NPWAA590	Word59 TMGA PDU PL Spare
NPWAA600	Word 60 TMGA PDU P/L
NPWAA610	Word 61 TMGA PDU P/L
NPWAA620	Word 62 TMGA PDU P/L
NPWAA630	Word 63 TMGA PDU P/L
NPWAA640	Word 64 TMGA PDU P/L
NPWAA650	Word65 TMGA PDU PL Spare
NPWAA660	Word 66 TMGA PDU P/L
NPWAA670	Word 67 TMGA PDU P/L
NPWAA680	Word 68 TMGA PDU P/L
NPWAA690	Word 69 TMGA PDU P/L

Name	Designation
NPWAA700	Word 70 TMGA PDU P/L
NPWAA710	Word 71 TMGA PDU P/L
NPWAA720	Word 72 TMGA PDU P/L
NPWAA730	Word 73 TMGA PDU P/L
NPWAA740	Word 74 TMGA PDU P/L
NPWAA750	Word75 TMGA PDU PL Spare
NPWAA760	Word 76 TMGA PDU P/L
NPWAA770	Word 77 TMGA PDU P/L
NPWAA780	Word 78 TMGA PDU P/L
NPWAA790	Word 79 TMGA PDU P/L
NPWAA800	Word 80 TMGA PDU P/L
NPWAA810	Word 81 TMGA PDU P/L
NPWAA820	Word 82 TMGA PDU P/L
NPWAA830	Word83 TMGA PDU PL Spare
NPWAA840	Word 84 TMGA PDU P/L
NPWAA850	Word 85 TMGA PDU P/L
NPWAA860	Word 86 TMGA PDU P/L
NPWAA870	Word 87 TMGA PDU P/L
NPWAA880	Word 88 TMGA PDU P/L
NPWAA890	Word 89 TMGA PDU P/L
NPWAA900	Word 90 TMGA PDU P/L
NPWAA910	Word91 TMGA PDU PL Spare
NPWAA920	Word 92 TMGA PDU P/L

Name	Designation
NPWAA930	PDU P/L ID COUNT

8.17. PDU-Continuous TM Datasheets

Link to PDF-file: TM Datasheets PDUCONT.pdf

Name	Designation
NDMWBT54	FineOBT:SS PDU Acqs CONT
NPWAC000	LAST CMD ECHO
NPWAC010	Word01 PDU Curr Profile
NPWAC020	Word02 PDU Curr Profile
NPWAC030	Word03 PDU Curr Profile
NPWAC040	Word04 PDU Curr Profile
NPWAC050	Word05 PDU Curr Profile
NPWAC060	Word06 PDU Curr Profile
NPWAC070	Word07 PDU Curr Profile
NPWAC080	Word08 PDU Curr Profile
NPWAC090	Word09 PDU Curr Profile
NPWAC100	Word10 PDU Curr Profile
NPWAC110	Word11 PDU Curr Profile
NPWAC120	Word12 PDU Curr Profile
NPWAC130	Word13 PDU Curr Profile
NPWAC140	Word14 PDU Curr Profile
NPWAC150	Word15 PDU Curr Profile

Name	Designation
NPWAC160	Word16 PDU Curr Profile
NPWAC170	Word17 PDU Curr Profile
NPWAC180	Word18 PDU Curr Profile
NPWAC190	Word19 PDU Curr Profile
NPWAC200	Word20 PDU Curr Profile
NPWAC210	Word21 PDU Curr Profile
NPWAC220	Word22 PDU Curr Profile
NPWAC230	Word23 PDU Curr Profile
NPWAC240	Word24 PDU Curr Profile
NPWAC250	Word25 PDU Curr Profile
NPWAC260	Word26 PDU Curr Profile
NPWAC270	Word27 PDU Curr Profile
NPWAC280	Word28 PDU Curr Profile
NPWAC290	Word29 PDU Curr Profile
NPWAC300	Word30 PDU Curr Profile
NPWAC310	Word31 PDU Curr Profile
NPWAC320	Word32 PDU Curr Profile
NPWAC330	Word33 PDU Curr Profile
NPWAC340	Word34 PDU Curr Profile
NPWAC350	Word35 PDU Curr Profile
NPWAC360	Word36 PDU Curr Profile
NPWAC370	Word37 PDU Curr Profile
NPWAC380	Word38 PDU Curr Profile

Name	Designation
NPWAC390	Word39 PDU Curr Profile
NPWAC400	Word40 PDU Curr Profile
NPWAC410	Word41 PDU Curr Profile
NPWAC420	Word42 PDU Curr Profile
NPWAC430	Word43 PDU Curr Profile
NPWAC440	Word44 PDU Curr Profile
NPWAC450	Word45 PDU Curr Profile
NPWAC460	Word46 PDU Curr Profile
NPWAC470	Word47 PDU Curr Profile
NPWAC480	Word48 PDU Curr Profile
NPWAC490	Word49 PDU Curr Profile
NPWAC500	Word50 PDU Curr Profile
NPWAC510	Word51 PDU Curr Profile
NPWAC520	Word52 PDU Curr Profile
NPWAC530	Word53 PDU Curr Profile
NPWAC540	Word54 PDU Curr Profile
NPWAC550	Word55 PDU Curr Profile
NPWAC560	Word56 PDU Curr Profile
NPWAC570	Word57 PDU Curr Profile
NPWAC580	Word58 PDU Curr Profile
NPWAC590	Word59 PDU Curr Profile
NPWAC600	Word60 PDU Curr Profile
NPWAC610	Word61 PDU Curr Profile

Name	Designation
NPWAC620	Word62 PDU Curr Profile
NPWAC630	Word63 PDU Curr Profile
NPWAC640	Word64 PDU Curr Profile
NPWAC650	Word65 PDU Curr Profile
NPWAC660	Word66 PDU Curr Profile
NPWAC670	Word67 PDU Curr Profile
NPWAC680	Word68 PDU Curr Profile
NPWAC690	Word69 PDU Curr Profile
NPWAC700	Word70 PDU Curr Profile
NPWAC710	Word71 PDU Curr Profile
NPWAC720	Word72 PDU Curr Profile
NPWAC730	Word73 PDU Curr Profile
NPWAC740	Word74 PDU Curr Profile
NPWAC750	Word75 PDU Curr Profile
NPWAC760	Word76 PDU Curr Profile
NPWAC770	Word77 PDU Curr Profile
NPWAC780	Word78 PDU Curr Profile
NPWAC790	Word79 PDU Curr Profile
NPWAC800	Word80 PDU Curr Profile
NPWAC810	Word81 PDU Curr Profile
NPWAC820	Word82 PDU Curr Profile
NPWAC830	Word83 PDU Curr Profile
NPWAC840	Word84 PDU Curr Profile

Name	Designation
NPWAC850	Word85 PDU Curr Profile
NPWAC860	Word86 PDU Curr Profile
NPWAC870	Word87 PDU Curr Profile
NPWAC880	Word88 PDU Curr Profile
NPWAC890	Word89 PDU Curr Profile
NPWAC900	Word90 PDU Curr Profile
NPWAC910	Word91 PDU Curr Profile
NPWAC920	Word92 PDU Curr Profile
NPWAC930	Word93 PDU Curr Profile

8.18. Platform-Analog TM Datasheets

Link to PDF-file: TM Datasheets PFANA.pdf

Name	Designation
NACA3100	+5V ACM Board A AIU
NACA3101	+15V ACM Board A AIU
NACA3102	-15V ACM Board A AIU
NACA3110	Power Supply 1 Temp1 AIU
NACA3111	SPARE

Name	Designation
NACA3200	+5V ACM Board B AIU
NACA3201	+15V ACM Board B AIU
NACA3202	-15V ACM Board B AIU
NACA3210	Power Supply 2 Temp1 AIU
NACA3211	SPARE
NACA3300	+5V Star Tracker 1
NACA3310	CPU Temp Star Tracker 1
NACA3311	Power Supply Temp STR 1
NACA3400	+5V Star Tracker 2
NACA3410	CPU Temp Star Tracker 2
NACA3411	Power Supply Temp STR 2
NACA3500	+5V Nav Camera 1
NACA3510	CPU TEMP Nav Camera 1
NACA3511	Power Supply Temp CAM 1
NACA3600	+5V Nav Camera 2
NACA3610	CPU TEMP Nav Camera 2
NACA3611	Power Supply Temp CAM 2
NACA3710	PCB Temp WDE1
NACA3711	Temp 1 WDE1
NACA3712	Temp RWA1
NACA3720	PCB Temp WDE2
NACA3721	Temp 1 WDE2
NACA3722	Temp RWA2

Name	Designation
NACA3730	PCB Temp WDE3
NACA3731	Temp 1 WDE3
NACA3732	Temp RWA3
NACA3740	PCB Temp WDE4
NACA3741	Temp 1 WDE4
NACA3742	Temp RWA4
NDMA0100	+15V RTU S/S HK A
NDMA0101	+5V RTU S/S HK A
NDMA0102	+28V RTU S/S HK A
NDMA0103	-15V RTU S/S HK A
NDMA0104	+10V RTU S/S HK A
NDMA0110	Temp1 RTU S/S HKA CV-PS1
NDMA0111	Temp2 RTU S/S HKA TMMA_N
NDMA0200	+15V RTU S/S HK B
NDMA0201	+5V RTU S/S HK B
NDMA0202	+28V RTU S/S HK B
NDMA0203	-15V RTU S/S HK B
NDMA0204	+10V RTU S/S HK B
NDMA0210	Temp1 RTU S/S HKB CV-PS2
NDMA0211	Temp2 RTU S/S HKB TMMA_R
NDMA0700	+5V PS1 CDMU1
NDMA0701	+15V PS1 CDMU1
NDMA0710	Temp PS1 CDMU1

Name	Designation
NDMA0800	+5V PS2 CDMU1
NDMA0801	+15V PS2 CDMU1
NDMA0810	Temp PS2 CDMU1
NDMA0900	+5V PS3 CDMU2
NDMA0901	+15V PS3 CDMU2
NDMA0910	Temp PS3 CDMU2
NDMA1000	+5V PS4 CDMU2
NDMA1001	+15V PS4 CDMU2
NDMA1010	Temp PS4 CDMU2
NDMA1100	+5V PS1 SSMM
NDMA1101	+20V PS1 SSMM
NDMA1110	TEMP PS1 SSMM
NDMA1200	+5V PS2 SSMM
NDMA1201	+20V PS2 SSMM
NDMA1210	TEMP PS2 SSMM
NDMWBT00	FinObt:PL Analog Acqs
NHGAT001	PLA540_HGA-HRM Temp 1
NHGAT002	PLA541_HGA-HRM Temp 2
NHGAT003	PLA542_HGA-HRM Temp 3
NPWATH01	PLA504_PCU Therm A
NPWATH02	PLA500_PDU-BM Temp A
NPWATH03	PLA502_PDU-PM Temp A
NPWATH11	PLA505_PCU Therm B

Name	Designation
NPWATH12	PLA501_PDU-BM Temp B
NPWATH13	PLA503_PDU-PM Temp B
NSAANY01	SA-2 (-Y) THERM 1
NSAANY02	SA-2 (-Y) THERM 2
NSAANY03	SA-2 (-Y) THERM 3
NSAAPY01	SA-1 (+Y) THERM 1
NSAAPY02	SA-1 (+Y) THERM 2
NSAAPY03	SA-1 (+Y) THERM 3
NSTASDE1	PLA524_Sade Temp 1
NSTASDE2	PLA525_Sade Temp 2
NSTASDE3	PLA526_Sade Temp 3
NSTASDE4	PLA527_Sade Temp 4
NSTAXB10	PLA520_U/B-Boom Temp A
NSTAXB20	PLA521_U/B-Boom Temp B
NSTAXB30	PLA522_L/B Boom Temp A
NSTAXB40	PLA523_L/B Boom Temp B
NTSA0001	#016_MIRTE_TRP_P-C37
NTSA0002	#020_MIRME_TRP_P-C38
NTSA0003	#022_MIRUS_TRP_P-C39
NTSA0004	#043_VIRTI_TRP_P-C40
NTSA0005	#047_VIRPH_TRP_P-C41
NTSA0006	#049_VIRPM_TRP_P-C42
NTSA0007	#024_NAC__STP_P-C44

Name	Designation
NTSA0008	#027_WAC__STP_P-C45
NTSA0009	#030_NACRB_TRP_P-C46
NTSA0010	#032_WACRB_TRP_P-C47
NTSA0011	#034_OSIEL_TRP_P-C48
NTSA0012	#036_DFMS_TRP_P-C49
NTSA0013	#039_COPS_TRP_P-C50
NTSA0014	#041_RODPU_TRP_P-C51
NTSA0015	#045_VIREL_TRP_P-C52
NTSA0016	#051_RPCEL_TRP_P-C53
NTSA0017	#053_IES__TRP_P-C54
NTSA0018	#056_ICA__TRP_P-C55
NTSA0019	#059_MIP__STP-C56
NTSA0020	#062_MAGIB_STP-C57
NTSA0021	#058_LAP1_STP-C58
NTSA0022	#065_SREM_TRP_P-C59
NTSA0023	#068_ESSRB_TRP-C60
NTSA0024	#070_ESSAA_TRP_P-C61
NTSA0025	#073_ESSAB_TRP_P-C62
NTSA0026	#075_ESSEL_TRP-C63
NTSA0027	#077_MSS__TRP-C64
NTSA0028	#079_NPYPZ_TRP-C65
NTSA0029	#081_NPYMZ_TRP-C66
NTSA0030	#121_MGAS_TRP_P-C67

Name	Designation
NTSA0031	#124_MGAX_TRP_P-C68
NTSA0032	#127_LGAPZ_TRP_P-C69
NTSA0033	#130_LGAMZ_TRP_P-C70
NTSA0034	#103_BAT1_H705_1_C1
NTSA0035	#106_BAT2_H780_1-C2
NTSA0036	#109_BAT3_H730_1-C3
NTSA0037	#142_APM__H178_1-C4
NTSA0038	#155_SAPY_H756_1-C5
NTSA0039	#158_SAMY_H781_1-C6
NTSA0040	#200_MMH__H701_1-C7
NTSA0041	#206_NTO__H726_1-C8
NTSA0042	#214_Tr01_H129_1-C9
NTSA0043	#217_Tr02_H179_1-C10
NTSA0044	#220_Tr03_H329_1-C11
NTSA0045	#223_Tr04_H379_1-C12
NTSA0046	#226_Tr05_H130_1-C13
NTSA0047	#229_Tr06_H180_1-C14
NTSA0048	#232_Tr07_H330_1-C15
NTSA0049	#235_Tr08_H380_1-C16
NTSA0050	#238_Tr09_H131_1-C17
NTSA0051	#241_Tr10_H181_1-C18
NTSA0052	#244_Tr11_H331_1-C19
NTSA0053	#247_Tr12_H381_1-C20

Name	Designation
NTSA0054	#321_RW1__H703_1-C21
NTSA0055	#324_RW2__H728_1-C22
NTSA0056	#327_RW3__H753_1-C23
NTSA0057	#330_RW4__H778_1-C24
NTSA0058	#342_STR1_H704_1-C25
NTSA0059	#346_STR2_H729_1-C26
NTSA0060	#352_NAV1_H754_1-C27
NTSA0061	#356_NAV2_H779_1-C28
NTSA0062	#001_ALICE_TRP_P-C29
NTSA0063	#014_MIDAS_TRP_P-C30
NTSA0064	#007_CONAN_TRP_P-C31
NTSA0065	#009_CONEL_TRP-C32
NTSA0066	#010_COSIM_TRP_P-C33
NTSA0067	#012_GIADA_TRP_P-C34
NTSA0068	#015_MIRTE_STP-C35
NTSA0069	#104_BAT1_H705_2-C71
NTSA0070	#110_BAT3_H730_2-C72
NTSA0071	#156_SAPY_H756_2-C73
NTSA0072	#201_MMH__H701_2-C74
NTSA0073	#215_Tr01_H129_2-C75
NTSA0074	#221_Tr03_H329_2-C76
NTSA0075	#227_Tr05_H130_2-C77
NTSA0076	#233_Tr07_H330_2-C78

Name	Designation
NTSA0077	#239_Tr09_H131_2-C79
NTSA0078	#245_Tr11_H331_2-C80
NTSA0079	#322_RW1__H703_2-C81
NTSA0080	#328_RW3__H753_2-C82
NTSA0081	#353_NAV1_H754_2-C83
NTSA0082	#343_STR1_H704_2-C84
NTSA0083	#038_RTOF_TRP_P-C85
NTSA0084	#055_ICA__STP-C86
NTSA0085	#064_SREM_STP-C87
NTSA0086	#072_ESSAB_STP-C88
NTSA0087	#120_MGAS_STP-C89
NTSA0088	#126_LGAPZ_STP-C90
NTSA0089	#100_PDUSS_TRP-C91
NTSA0090	#161_SADE_TRP-C92
NTSA0091	#141_BOOMZ_STP-C93
NTSA0092	#146_HGAMA_STP_2-C94
NTSA0093	#204_MMHLO_GAU_P-C95
NTSA0094	#203_MMHHI_GAU-C96
NTSA0095	#210_NTOLO_GAU_P-C97
NTSA0096	#212_HEPY_TRP-C98
NTSA0097	#250_HEPYD_TRP-C99
NTSA0098	#252_PR1D_TRP-C100
NTSA0099	#254_RCS01_TRP-C101

Name	Designation
NTSA0100	#256_RCS03_TRP-C102
NTSA0101	#258_RCS05_TRP-C103
NTSA0102	#260_RCS07_TRP-C104
NTSA0103	#262_RCS09_TRP-C105
NTSA0104	#264_RCS11_TRP-C106
NTSA0105	#266_PR1__TRP_P-C107
NTSA0106	#268_PR2__TRP_P-C108
NTSA0107	#270_PVC03_TRP-C109
NTSA0108	#272_PVC07_TRP-C110
NTSA0109	#274_PVC09_TRP-C111
NTSA0110	#280_WIU__TRP-C112
NTSA0111	#281_TWT1_TRP-C113
NTSA0112	#283_EPC1_TRP-C114
NTSA0113	#285_TRSP1_TRP-C115
NTSA0114	#288_USO__TRP-C116
NTSA0115	#300_CDMU1_TRP-C117
NTSA0116	#302_RTUSS_TRP-C118
NTSA0117	#320_AIU__TRP-C119
NTSA0118	#334_IMU1_TRP-C120
NTSA0119	#337_SASPX_STP-C121
NTSA0120	#339_SASMX_STP-C122
NTSA0121	#341_STR1_STP-C123
NTSA0122	#349_SSTE1_TRP-C124

Name	Designation
NTSA0123	#351_NAV1_STP-C125
NTSA0124	#xxx_SPARE_01-C126
NTSA0125	#xxx_SPARE_03-C127
NTSA0126	#151_APME_TRP_1-C128
NTSA0127	#017_MIRTE_TRP_R-C37
NTSA0128	#021_MIRME_TRP_R-C38
NTSA0129	#023_MIRUS_TRP_R-C39
NTSA0130	#044_VIRTI_TRP_R-C40
NTSA0131	#048_VIRPH_TRP_R-C41
NTSA0132	#050_VIRPM_TRP_R-C42
NTSA0133	#092_NAC__STP_R-C44
NTSA0134	#093_WAC__STP_R-C45
NTSA0135	#031_NACRB_TRP_R-C46
NTSA0136	#033_WACRB_TRP_R-C47
NTSA0137	#035_OSIEL_TRP_R-C48
NTSA0138	#037_DFMS_TRP_R-C49
NTSA0139	#040_COPS_TRP_R-C50
NTSA0140	#042_RODPU_TRP_R-C51
NTSA0141	#046_VIREL_TRP_R-C52
NTSA0142	#052_RPCEL_TRP_R-C53
NTSA0143	#054_IES__TRP_R-C54
NTSA0144	#057_ICA__TRP_R-C55
NTSA0145	#xxx_SPARE_07-C56

Name	Designation
NTSA0146	#xxx_SPARE_08-C57
NTSA0147	#067_ESSRA_TRP-C58
NTSA0148	#xxx_SPARE_11-C59
NTSA0149	#336_IMU3_TRP-C60
NTSA0150	#071_ESSAA_TRP_R-C61
NTSA0151	#074_ESSAB_TRP_R-C62
NTSA0152	#076_ESSSW_TRP-C63
NTSA0153	#078_MSS__STP-C64
NTSA0154	#080_NMYPZ_TRP-C65
NTSA0155	#082_NMYMZ_TRP-C66
NTSA0156	#122_MGAS_TRP_R-C67
NTSA0157	#125_MGAX_TRP_R-C68
NTSA0158	#128_LGAPZ_TRP_R-C69
NTSA0159	#131_LGAMZ_TRP_R-C70
NTSA0160	#105_BAT1_H705_3-C1
NTSA0161	#108_BAT2_H780_3-C2
NTSA0162	#111_BAT3_H730_3-C3
NTSA0163	#144_APM__H178_3-C4
NTSA0164	#157_SAPY_H756_3-C5
NTSA0165	#160_SAMY_H781_3-C6
NTSA0166	#202_MMH__H701_3-C7
NTSA0167	#208_NTO__H726_3-C8
NTSA0168	#216_Tr01_H129_3-C9

Name	Designation
NTSA0169	#219_Tr02_H179_3-C10
NTSA0170	#222_Tr03_H329_3-C11
NTSA0171	#225_Tr04_H379_3-C12
NTSA0172	#228_Tr05_H130_3-C13
NTSA0173	#231_Tr06_H180_3-C14
NTSA0174	#234_Tr07_H330_3-C15
NTSA0175	#237_Tr08_H380_3-C16
NTSA0176	#240_Tr09_H131_3-C17
NTSA0177	#243_Tr10_H181_3-C18
NTSA0178	#246_Tr11_H331_3-C19
NTSA0179	#249_Tr12_H381_3-C20
NTSA0180	#323_RW1__H703_3-C21
NTSA0181	#326_RW2__H728_3-C22
NTSA0182	#329_RW3__H753_3-C23
NTSA0183	#332_RW4__H778_3-C24
NTSA0184	#344_STR1_H704_3-C25
NTSA0185	#348_STR2_H729_3-C26
NTSA0186	#354_NAV1_H754_3-C27
NTSA0187	#358_NAV2_H779_3-C28
NTSA0188	#002_ALICE_TRP_R-C29
NTSA0189	#090_MIDAS_TRP_R-C30
NTSA0190	#xxx_SPARE_12-C31
NTSA0191	#xxx_SPARE_05-C32

Name	Designation
NTSA0192	#011_COSIM_TRP_R-C33
NTSA0193	#013_GIADA_TRP_R-C34
NTSA0194	#018_MIROB_TRP-C35
NTSA0195	#107_BAT2_H780_2-C71
NTSA0196	#143_APM__H178_2-C72
NTSA0197	#159_SAMY_H781_2-C73
NTSA0198	#207_NTO__H726_2-C74
NTSA0199	#218_Tr02_H179_2-C75
NTSA0200	#224_Tr04_H379_2-C76
NTSA0201	#230_Tr06_H180_2-C77
NTSA0202	#236_Tr08_H380_2-C78
NTSA0203	#242_Tr10_H181_2-C79
NTSA0204	#248_Tr12_H381_2-C80
NTSA0205	#325_RW2__H728_2-C81
NTSA0206	#331_RW4__H778_2-C82
NTSA0207	#357_NAV2_H779_2-C83
NTSA0208	#347_STR2_H729_2-C84
NTSA0209	#094_RTOF_TRP_R-C85
NTSA0210	#096_LAP2_STP-C86
NTSA0211	#069_ESSAA_STP-C87
NTSA0212	#102_PCU__TRP-C88
NTSA0213	#123_MGAX_STP-C89
NTSA0214	#129_LGAMZ_STP-C90

Name	Designation
NTSA0215	#101_PDUPL_TRP-C91
NTSA0216	#140_BOOPZ_STP-C92
NTSA0217	#145_HGAMA_STP_1-C93
NTSA0218	#147_HGAMA_STP_3-C94
NTSA0219	#205_MMHLO_GAU_R-C95
NTSA0220	#209_NTOHI_GAU-C96
NTSA0221	#211_NTOLO_GAU_R-C97
NTSA0222	#213_HEMY_TRP-C98
NTSA0223	#251_HEMYD_TRP-C99
NTSA0224	#253_PR2D_TRP-C100
NTSA0225	#255_RCS02_TRP-C101
NTSA0226	#257_RCS04_TRP-C102
NTSA0227	#259_RCS06_TRP-C103
NTSA0228	#261_RCS08_TRP-C104
NTSA0229	#263_RCS10_TRP-C105
NTSA0230	#265_RCS12_TRP-C106
NTSA0231	#267_PR1__TRP_R-C107
NTSA0232	#269_PR2__TRP_R-C108
NTSA0233	#271_PVC04_TRP-C109
NTSA0234	#273_PVC08_TRP-C110
NTSA0235	#275_PVC10_TRP-C111
NTSA0236	#287_RFDU_TRP-C112
NTSA0237	#282_TWT2_TRP-C113

Name	Designation
NTSA0238	#284_EPC2_TRP-C114
NTSA0239	#286_TRSP2_TRP-C115
NTSA0240	#304_SSMM_TRP-C116
NTSA0241	#301_CDMU2_TRP-C117
NTSA0242	#303_RTUPL_TRP-C118
NTSA0243	#333_WDE__TRP-C119
NTSA0244	#335_IMU2_TRP-C120
NTSA0245	#338_SASPX_TRP-C121
NTSA0246	#340_SASMX_TRP-C122
NTSA0247	#345_STR2_STP-C123
NTSA0248	#350_SSTE2_TRP-C124
NTSA0249	#355_NAV2_STP-C125
NTSA0250	#xxx_SPARE_02-C126
NTSA0251	#xxx_SPARE_04-C127
NTSA0252	#153_APME_TRP_3-C128
NTSA0253	#152_APME_TRP_2-C129
NTSA0254	#276_CYPSM_GAU-C130
NTSA0255	#xxx_SPARE_06-C36
NTSA0256	#019_MIRSE_TRP_P-C43
NTSA0257	#154_APME_TRP_4-C129
NTSA0258	#277_CYBSM_GAU-C130
NTSA0259	#006_CONAN_STP-C36
NTSA0260	#091_MIRSE_TRP_R-C43

Name	Designation
NTTAT110	PLA530_Twta-1 EPC Temp
NTTAT120	TWTA-1 TLM A0
NTTAT130	TWTA-1 TLM IH
NTTAT210	PLA531_Twta-2 EPC Temp
NTTAT220	TWTA-2 TLM A0
NTTAT230	TWTA-2 TLM IH
NTTAUS10	USO DC CURRENT A
NTTAUS20	USO DC VOLTAGE A
NTTAUS30	USO OVEN TEMP A
NTTAUS40	USO OVEN TEMP B
NTTAUS50	USO POWER MONITOR 1A
NTTAUS60	USO POWER MONITOR 2A
NTTAUS70	PLA538_USO Unit Temp
NTTAUS80	USO LOCK STAT A
NTTAUS90	USO LOCK STAT B
NTTAX100	TRSP-1 RX CV VOLT
NTTAX110	TRSP-1 RX DC CURRENT
NTTAX120	PLA534_Trsp1 RX Temp
NTTAX130	TRSP-1 S-RF OUTPWR
NTTAX140	TRSP-1 S-TX DC CURR
NTTAX150	PLA532_Trsp1 TxS/BD Temp
NTTAX160	TRSP-1 S-TX CV VOLT
NTTAX170	TRSP-1 X-RF OUTPWR

Name	Designation
NTTAX180	TRSP-1 X-TX DC CURR
NTTAX190	PLA533_Trsp1 TxX-BD Temp
NTTAX1A0	TRSP-1 X-TX CV VOLT
NTTAX200	TRSP-2 RX CV VOLT
NTTAX210	TRSP-2 RX DC CURR
NTTAX220	PLA537_Trsp2 RX Temp
NTTAX230	TRSP-2 S-RF OUTPWR
NTTAX240	TRSP-2 S-TX DC CURR
NTTAX250	PLA535_Trsp2 TxS-BD Temp
NTTAX260	TRSP-2 S-TX CV VOLT
NTTAX270	TRSP-2 X-RF OUTPWR
NTTAX280	TRSP-2 X-TX DC CURR
NTTAX290	PLA536_Trsp2 TxX-BD Temp
NTTAX2A0	TRSP-2 X-TX CV VOLT

8.19. Platform-Non-Analog TM Datasheets

Link to PDF-file: TM Datasheets PFNONANA.pdf

Name	Designation
NDMA0301	Group 1N: individual BLD
NDMA0401	Group 1R: individual BLD
NDMA0501	Gp 1N:Indiv RSS-NSBARSS1
NDMA0502	Gp 2N:Indiv RSS-NSBARSS2

Name	Designation
NDMA0503	Gp 3N:Indiv RSS-NSBARSS3
NDMA0504	Gp 4N:Indiv RSS-NSBARSS4
NDMA0505	Group 5N: individual RSS
NDMA0506	Group 6N: individual RSS
NDMA0601	Gp 1R:Indiv RSS-NSBARSS5
NDMA0602	Gp 2R:Indiv RSS-NSBARSS6
NDMA0603	Gp 3R:Indiv RSS-NSBARSS7
NDMA0604	Gp 4R:Indiv RSS-NSBARSS8
NDMA0605	Group 5R: individual RSS
NDMA0606	Group 6R: individual RSS
NDMWBT01	FinObt:PL NonAnalog Acqs

8.20. Payload-Analog TM Datasheets

Link to PDF-file: TM Datasheets PLANA.pdf

Name	Designation
NBEAT001	Spare
NBEAT101	Spare
NCNAT001	PAY405-Consert EL Temp B
NCNAT002	PAY403-ConsertAnt Temp B
NCNAT101	PAY404-Consert EL Temp A
NCNAT102	PAY402-ConsertAnt Temp A
NCSAT001	PAY407-Cosima Temp B

Name	Designation
NCSAT101	PAY406-Cosima Temp A
NDMA2100	+15V RTU P/L HK A
NDMA2101	+5V RTU P/L HK A
NDMA2102	+15V PWR RTU P/L HK A
NDMA2103	-15V RTU P/L HK A
NDMA2104	+10V RTU P/L HK A
NDMA2110	Temp1 RTU P/L HKA CV-PS1
NDMA2111	Temp2 RTU P/L HKA TMMA_N
NDMA2200	+15V RTU P/L HK B
NDMA2201	+5V RTU P/L HK B
NDMA2202	+15V PWR RTU P/L HK B
NDMA2203	-15V RTU P/L HK B
NDMA2204	+10V RTU P/L HK B
NDMA2210	Temp1 RTU P/L HKB CV-PS2
NDMA2211	Temp2 RTU P/L HKB TMMA_R
NDMWBT02	Fine OBT:PL analog Acqs
NLTAT001	PAY435-Ssp Mss Temp 2
NLTAT002	PAY434-Ssp Mss Temp 1
NLTAT011	PAY438-SSP Temp3, YE box
NLTAT012	Spare
NLTAT013	PAY436-SSP Temp1, YE box
NLTAT014	PAY440-SSP Temp5, Civa P
NLTAT015	PAY439-SSP Temp4, PushPl

Name	Designation
NLTAT016	PAY437-SSP Temp2, PrimBa
NMDAT001	PAY411-Midas Temp B
NMDAT101	PAY410-Midas Temp A
NMRAT002	PAY413-Miro Temp 2B
NMRAT101	PAY414-Miro Temp 1A
NMRAT102	PAY412-Miro Temp 2A
NRNAT001	PAY422-RosinaDFMS Temp B
NRNAT002	PAY424-RosinaRTOF Temp B
NRNAT101	PAY421-RosinaDFMS Temp A
NRNAT102	PAY423-RosinaRTOF Temp A
NRNAT103	PAY441-RosinaCOPS Temp A
NRPAT001	PAY429-Rpc Ies Temp
NRPAT002	PAY430-Rpc Ica Temp
NRPAT003	PAY431-Rpc Mip Temp
NSEAT001	PAY432-Srem Temp
NSRAT001	PAY415-OsirisNacTemp IFP
NSRAT002	PAY416-OsirisNacTemp FD
NSRAT003	PAY419-OsirisWacTemp STR
NSRAT004	PAY417-OsirisNacTemp STR
NSRAT005	PAY418-OsirisNacTemp CCD
NSRAT006	PAY420-OsirisWacTemp CCD
NVRAT001	PAY427-VirtisOboxTempM B
NVRAT002	PAY428-VirtisOboxTempH B

Name	Designation
NVRAT101	PAY425-VirtisOboxTempM A
NVRAT102	PAY426-VirtisOboxTempH

8.21. Payload-Non-Analog TM Datasheets

Link to PDF-file: TM Datasheets PLNONANA.pdf

Name	Designation
NDMA2121	Last MLC D Rcvd RtuP/L
NDMA2301	Group 1N: individual BLD
NDMA2401	Group 1R: individual BLD
NDMA2501	Gp 1N:Indiv RSS-RSS,Com1
NDMA2601	Gp 1R:Indiv RSS-RSS,Com2
NDMWBT03	FinObt:PL NonAnalog Acqs

8.22. Transponder 1 TM Datasheets

Link to PDF-file: TM Datasheets TRSP1.pdf

Name	Designation
NDMWBT64	Fine OBT:TRSP1 Acqs
NTTA1001	Word 00 TMGA TRSP 1
NTTA1002	Word 01 TMGA TRSP 1
NTTA1003	Word 02 TMGA TRSP 1
NTTA1004	Word 03 TMGA TRSP 1

Name	Designation
NTTA1005	Word 04 TMGA TRSP 1
NTTA1006	Word 05 TMGA TRSP 1

8.23. Transponder 2 TM Datasheets

Link to PDF-file: TM Datasheets TRSP2.pdf

Name	Designation
NDMWBT66	Fine OBT:TRSP2 Acqs
NTTA2001	Word 00 TMGA TRSP 2
NTTA2002	Word 01 TMGA TRSP 2
NTTA2003	Word 02 TMGA TRSP 2
NTTA2004	Word 03 TMGA TRSP 2
NTTA2005	Word 04 TMGA TRSP 2
NTTA2006	Word 05 TMGA TRSP

9. APPENDIX 3 – POWER SUBSYSTEM DATA

9.1. Solar Array Output Power

The Solar Array output power is calculated by the so called “Power Tool (PT)”. This tool is an aid to calculate the Solar Array power output for various mission phases. The tool employs a simple thermal model of the SA linked to input parameters such as sun distance to estimate the SA power (see Annex 1 of procedure fcp-ts0270 for a short user guide of this tool).

9.2. Battery Charge-/Discharge Characteristics

The following tables and charts depict the battery charge/discharge characteristics dependant on temperature.

9.3. Supporting Documentation

See attached documents:

Unit	Document Title	Doc Number	Issue
SYSTEM	Electrical Interface Blockdiagram	BB 2480-123001A00	F
SYSTEM	Rosetta Grounding Diagram	BB 2480-123002A00	1.1
SYSTEM	Electrical ICD	RO-DSS-IF-1002	4 F
SYSTEM	Platform Functional ICD	RO-MMB-IF-3101	1
SYSTEM	Power Subsystem TM/TC ICD	RO-MMB-IF-3107	1
SYSTEM	Power Subsystem Design Description	RO-MMB-TN-3158	3
SYSTEM	Inputs To User Manual Power S/S	RO-MMB-MA-3105	1A
SYSTEM	Power Subsystem Performance Analysis	RO-MMB-TN-3206	2
SYSTEM	Power Availability Assessment for the new Rosetta Mission	RO-DSS-TN-1188	2
BATTERY	Battery User Manual	RO-AEA-MA-3049	3
BATTERY	Battery Design Description	RO-AEA-RP-3018	2
BATTERY	Battery ICD	RO-AEA-IF-3022	2
BATTERY	Li-Ion Battery Performance Report	RO-AEA-RP-3100	1
BATTERY	Battery Performance Prediction	RO-DSS-TN-1170	2A

Unit	Document Title	Doc Number	Issue
HARNESS	Harness Design Report	RO-FYS-RP-3003	A3
HARNESS	Voltage Drop Analysis	RO-MMB-TN-3205	2
PCU	PCU Design Description	RO-TER-DD-3001	4
PCU	PCU EICD	RO-TER-IF-3008	4
PCU	PCU Operations Manual	RO-TER-MA-3005	6
PL-PDU	PL-PDU Design Description	RO-FIN-DS-0001	4
PL-PDU	PL-PDU EICD	RO-FIN-IF-0001	4A
PL-PDU	PL-PDU TM/TC ICD	RO-FIN-IF-3003	1d
PL-PDU	PL-PDU EQM User Manual	RO-FIN-MA-3001	1b
SA	Solar Array Electrical Design Report	RO-FIA-AN-3001	D
SA	Solar Array ICD	RO-FOK-IF-3001	5
SA	Solar Array to APR Interface	RO-DSS-TN-1197	1
SA	Solar Array Design And Operations Description	RO-FOK-RP-0001	4
SA	Solar Array Design Description	RO-FOK-RP-3001	2
SA	Solar Array TM/TC ICD	RO-MMB-IF-3112	1
SADE	SADE Design Description	RO-AEO-AN-3014	4
SADE	SADE EICD	RO-AEO-IF-3002	6
SADE	SADE User Manual	RO-AEO-MA-3002	4
SADM	SADM Design Description	RO-KDA-DD-3001	2b
SADM	SADM EICD	RO-KDA-IF-3001	3a
SADM	SADM Operations Manual	RO-KDA-MA-3001	1a
SS-PDU	SS-PDU Design Description	RO-FIN-DS-0002	4
SS-PDU	SS-PDU EICD	RO-FIN-IF-0002	4b
SS-PDU	SS-PDU TM/TC ICD	RO-FIN-IF-3004	1e
SS-PDU	SS-PDU EM User Manual	RO-FIN-MA-3002	1a

Temperature	C/10 Rate Discharge	C/2 Rate Discharge	C Rate Discharge	2C Rate Discharge
-30	84,75	29,5833		
-20	90,25	70,8333	20,8333	
-10	95,33334	80,4	60,8333	
0	97,21975	87,444	75	40
10	98,3303	92,10888	83,5821	64,7454
20	98,85885	94,90819	89,6374	77,4
30	99,1636	96,30699	92,74077	83,697
40	99,405518	97,19382	94,27913	87,2
50	99,580142	98,13622	95,91915	90
60	99,708834	98,80492	97,03278	91,75014

Table 9-1: Battery Discharge Characteristic

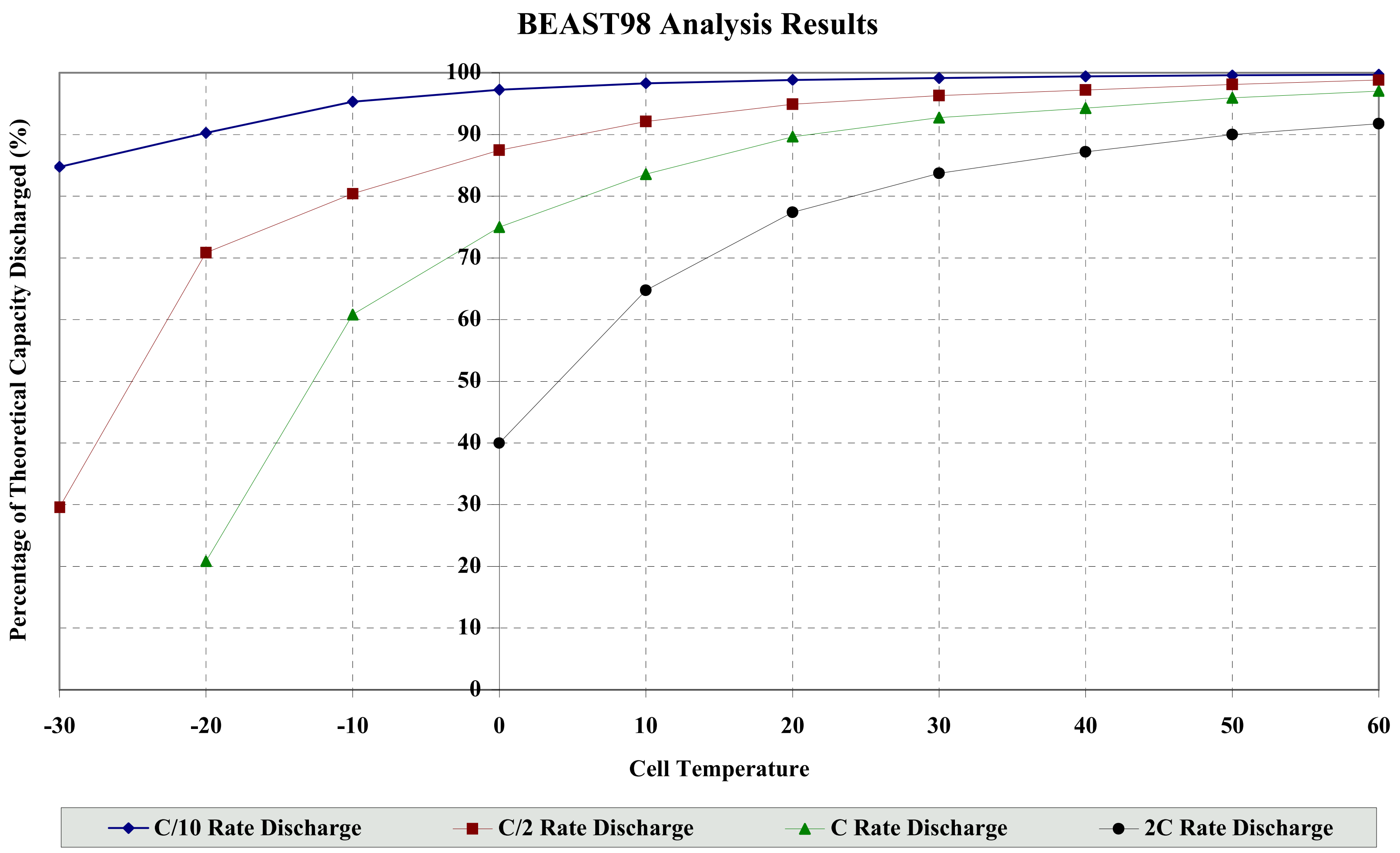


Figure 9-1: Battery Discharge Characteristic

Temperature	Taper to Zero Current	C/10 Rate Charge	C/2 Rate Charge	C Rate Charge	2C Rate Charge
-30	100	46,4035			
-20	100	76,5281			
-10	100	86,3827	23,992		
0	100	90,8092	39,9	13,7	
10	100	93,2524	54,837	27,3	
20	100	94,9635	70,445	39,1071	16,1835
30	100	96,187	78,94	49,551	25,344
40	100	96,922	83,37	60,404	33,1028
50	100	97,42	86,496	68,934	38
60	100	97,6086	87,286	71,112	41,451

Table 9-2: Battery Charge Characteristic

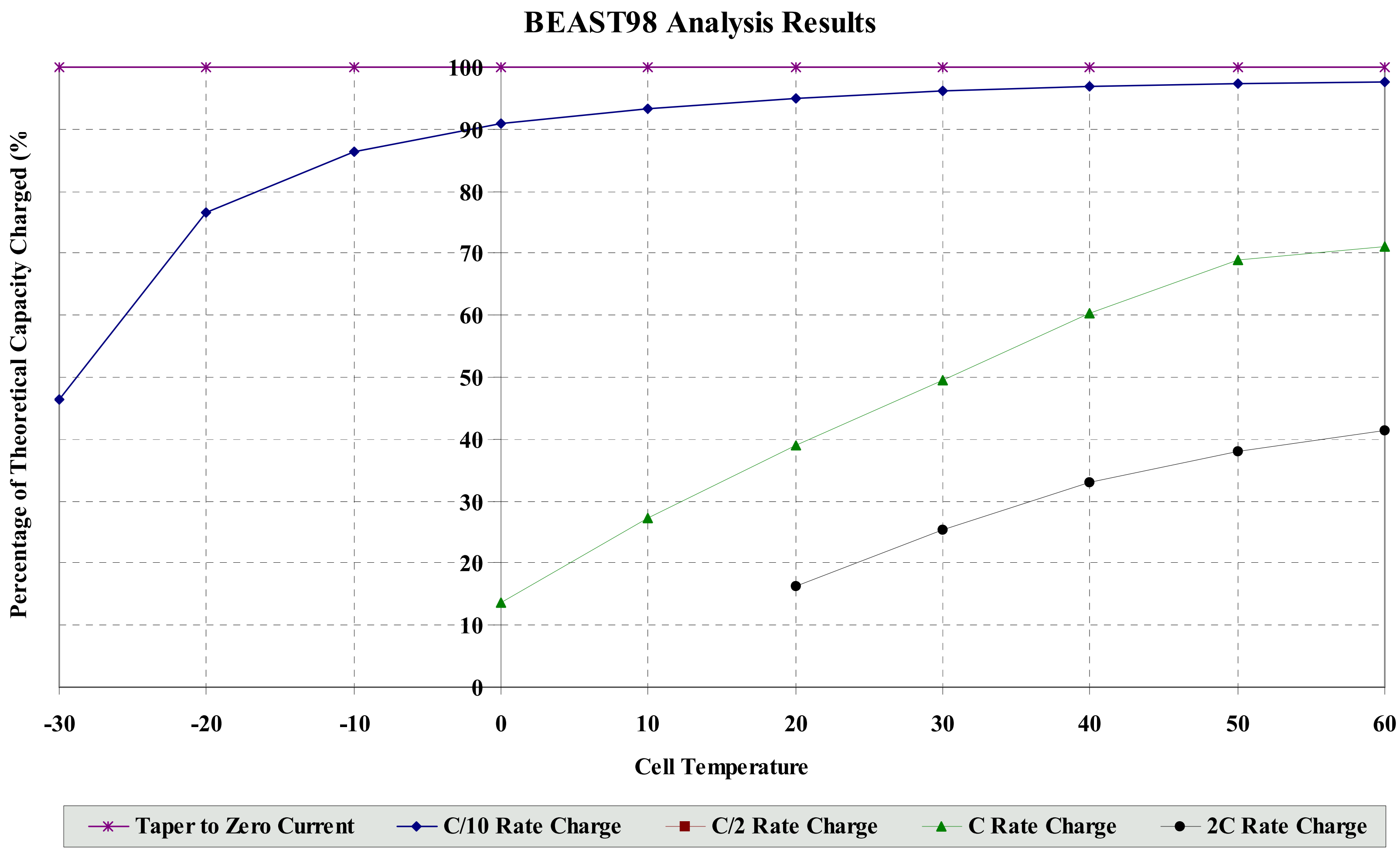


Figure 9-2: Battery Charge Characteristic

10. APPENDIX 4 – ADDITIONAL DOCUMENTATION RELATED TO PROPULSION SUBSYSTEM

See attached documents:

Unit	Document Title	Doc Number	Issue
RCS	Mission Baseline For Propulsion Subsystem Operation	RO-DSS-TN-1071	5
RCS	Propulsion Subsystem Pressure Drop Analysis	RO-MMB-AN-3002	1
RCS	Reaction Control Subsystem (RCS) Design Description	RO-MMB-DS-3103	1
RCS	Input To User Manual Propulsion Subsystem	RO-MMB-MA-3104	1
RCS	Reaction Control Subsystem Design & Operation Description	RO-MMB-RP-3204	2
RCS	Propellant –Mass Determination	RO-MMB-TN-3124	1
RCS	Propulsion Model Functional Description	RO-MMB-TN-3171	2
RCS	Pressurisation Strategy Analysis	RO-MMB-TN-3185	4
RCS	Thermal-Propellant Gauging Implementation	RO-MMB-TN-3191	1
RCS	Thermal-Propellant Gauging Test Evaluation	RO-MMB-TR-3121	A
RCS	Thermal-Propellant Gauging Test Software User Manual (contained in folder "\Flight Procedures\tpgt software")	RO-MMB-TN-3231	1
TANK	Propellant Tank Design Description	RO-DAD-TN-0001	1
TANK	Effects Of Propellant Tank Temperature Variation	RO-MMB-TN-3103	1
TANK	Formation Of Iron Nitrate Corrosion Products In The Rosetta Oxidiser Tank During Spin Stabilised Hibernation	RO-MMB-TN-3169	2

11. APPENDIX 5 – ADDITIONAL DOCUMENTATION RELATED TO THERMAL CONTROL

See attached documents:

Unit	Document Title	Doc Number	Issue
TCS	Thermal Hardware Design Description	RO-AAE-ES-3101	2
TCS	TCS Tables ICD	RO-DSS-IF-1007	1a
TCS	TCS URD	RO-DSS-RS-1038	1d
TCS	Thermal Analysis of LEOP And Commissioning Cases	RO-DSS-TN-1086	6
TCS	Thermal Analysis of Cold Mission Cases	RO-DSS-TN-1110	1c
TCS	Thermal Analysis of Special Mission Cases	RO-DSS-TN-1140	1c
TCS	Thermal Analysis Cases for CDR	RO-DSS-TN-1100	1.2
TCS	TCS Qualification Summary	RO-DSS-TN-1107	3
TCS	Asteroid Fly-By Thermal Analysis	RO-MMB-TN-3216	2
TCS	Thermal Subsystem Design Description	RO-MMB-DS-3101	7
TCS	Platform Thermal ICD	RO-MMB-IF-3106	6
TCS	TCS Heater Circuit Design	RO-MMB-TN-3152	4
TCS	TCS Inputs For User Manual	RO-MMB-TN-3198	c
TCS	FAR Thermal Analysis Report	RO-MMB-TN-3134	9
TCS	Thermal Analysis Documentation for Rosetta Churyumov-Gerasimenko Mission	RO-DSS-TN-1193	1
TCS	Thermal Analysis Report for the Churyumov-Gerasimenko Mission	RO-MMB-TN-3232	2
LOUVRE	Platform Louvres ICD	RO-SEN-IF-3001	3
LOUVRE	Platform Louvres Description	RO-SEN-TN-3001	2
LOUVRE	Louver Thermal Report	RO-SDP-RP-3101	3
PCU	PCU Thermal Analysis	RO-TER-AN-3004	3
RCS	RCS Thermal Analysis Report	RO-MMB-RP-3219	5

Unit	Document Title	Doc Number	Issue
SA	Solar Array Thermal Analysis Report	RO-FOK-RP-3003	4
SA	SA Eurostar 2000 Thermal Verification Report	E2P-AN-001-FS	3
SADE	SADE Thermal Analysis	RO-AEO-AN-3008	3
SADM	Thermal Analyse Rosetta SADM	RO-KDA-AN-3004	3
THRUSTER	Thruster Thermal Analysis Report	RO-MMB-TN-3167	2
Booms	Booms Thermal Analysis Report	RO-SEN-RP-3502	2
TT&C	HGA MA Thermal Analysis Report	RO-HTS-AN-0004	3
TT&C	S/X Band Transponder Thermal Analysis	RPT/RST/0021/ALS	7
TT&C	MGA-S Thermal Analysis	RO-CAS-TN-3010	2
TT&C	MGA-X Thermal Analysis	RO-CAS-TN-3009	1
SAS	SAS Thermal Analysis	RO-TNO-TN-2003	1

12. APPENDIX 6 – ADDITIONAL INFORMATION RELATED TO RF SUBSYSTEM

12.1. Antenna Coordinate System

High Gain Antenna Reference Axes

- The HGA zero position is as illustrated in Figures 5-4, 5-5 and 5-6.

HGA elevation rotation is limited to +30° / -165° from the reference position (except before and during deployment when elevations between –207° and +30° are allowable).

HGA azimuth rotation is limited to +80° / -260° from the reference position.

See also discussion on HGA pointing constraints in section §3.5.

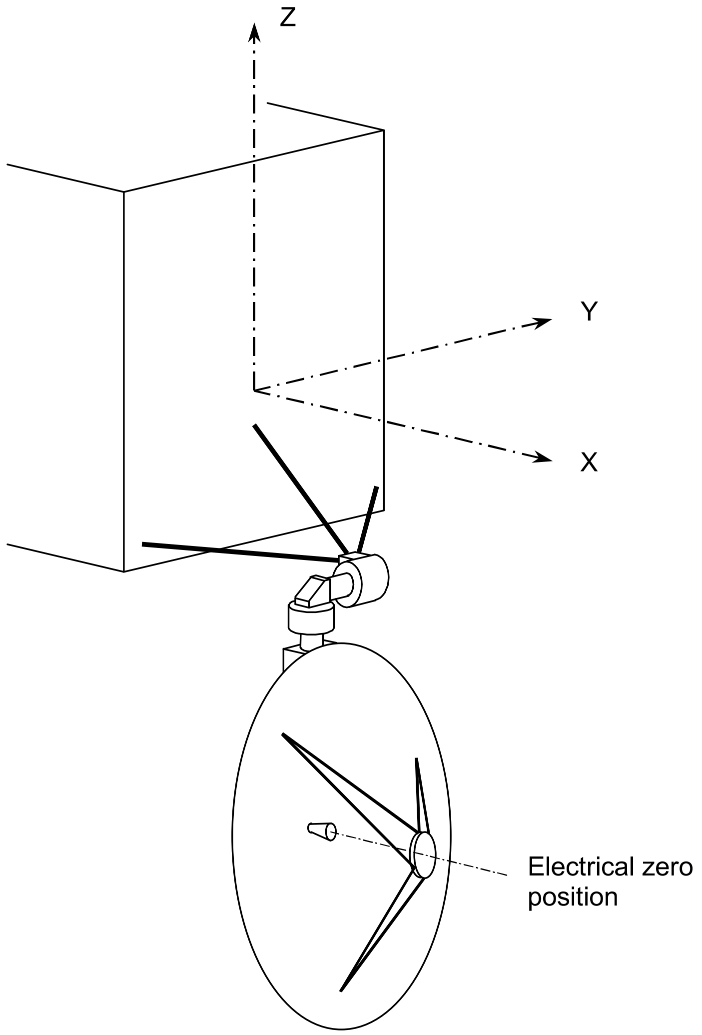


Figure 12-1: APM Electrical Zero

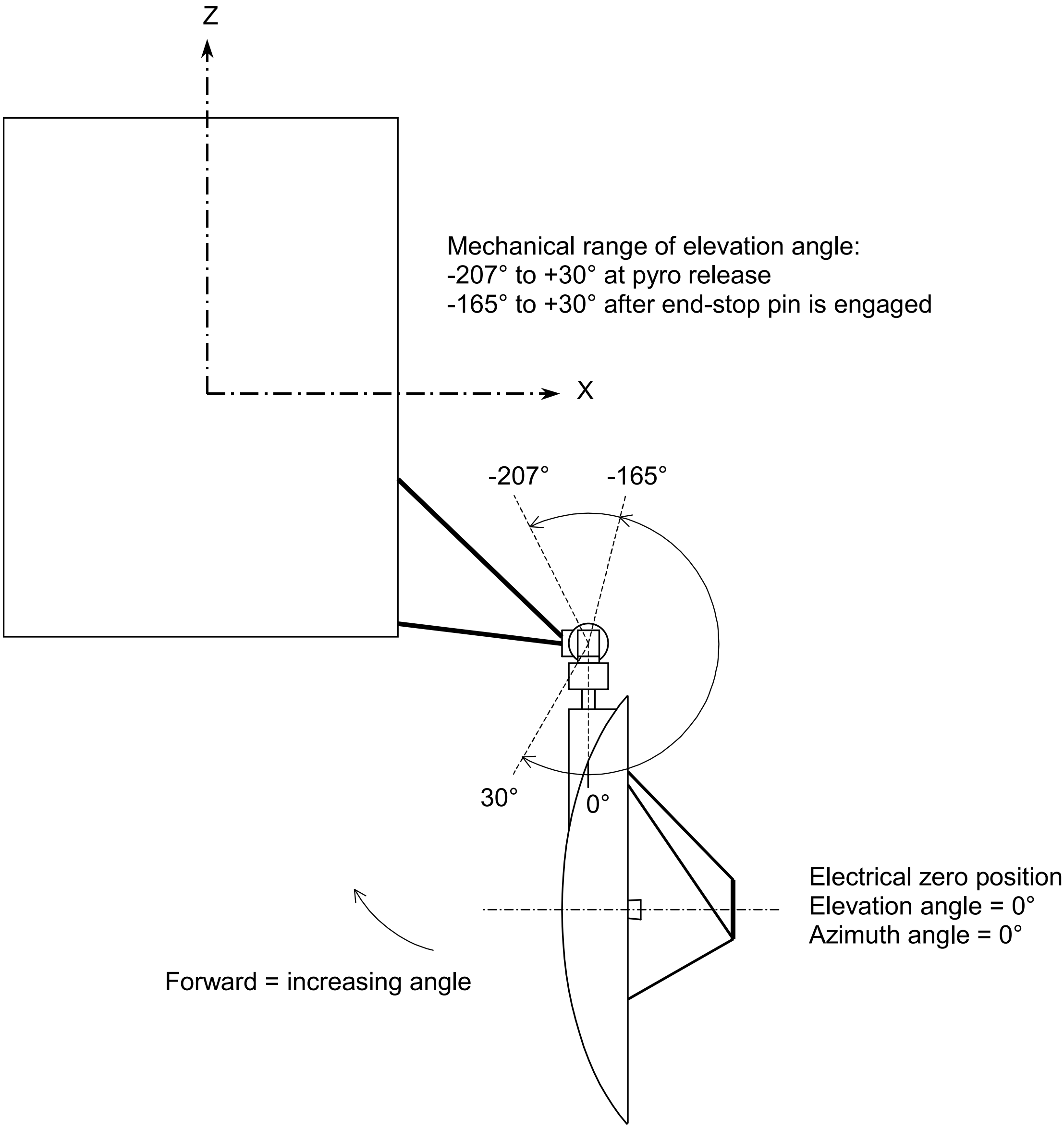
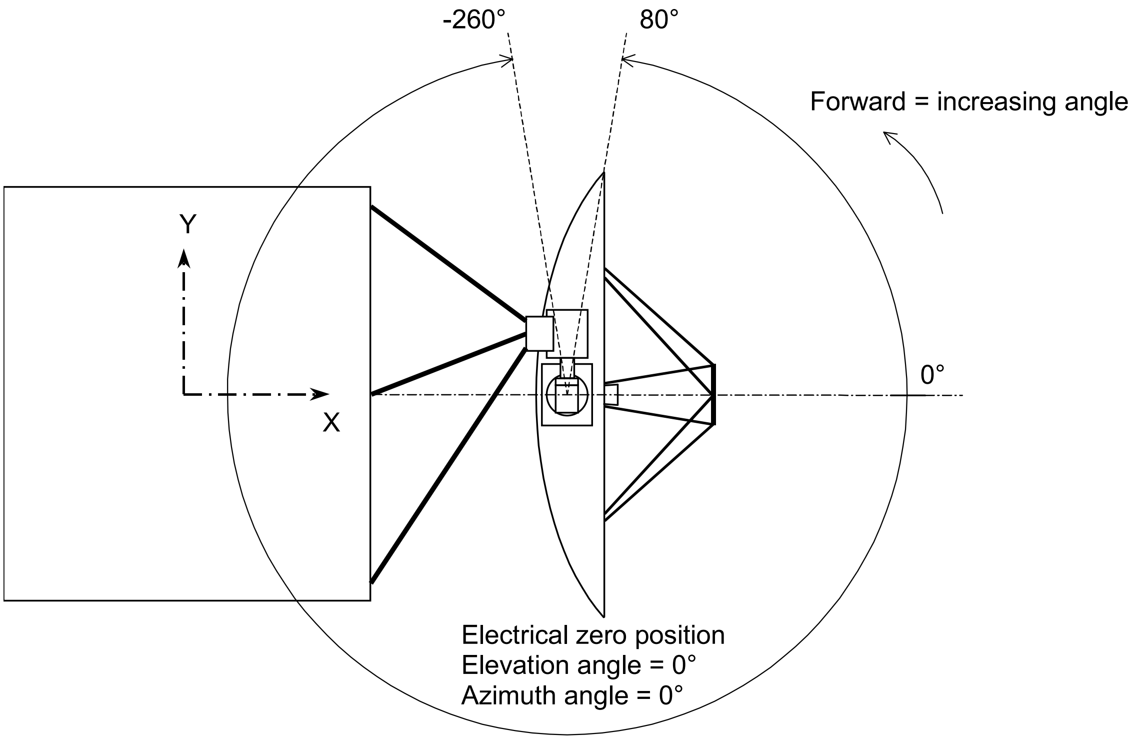


Figure 12-2: Elevation Zero



Mechanical range of azimuth angle:
-260° to +80°

Figure 12-3: Azimuth Zero

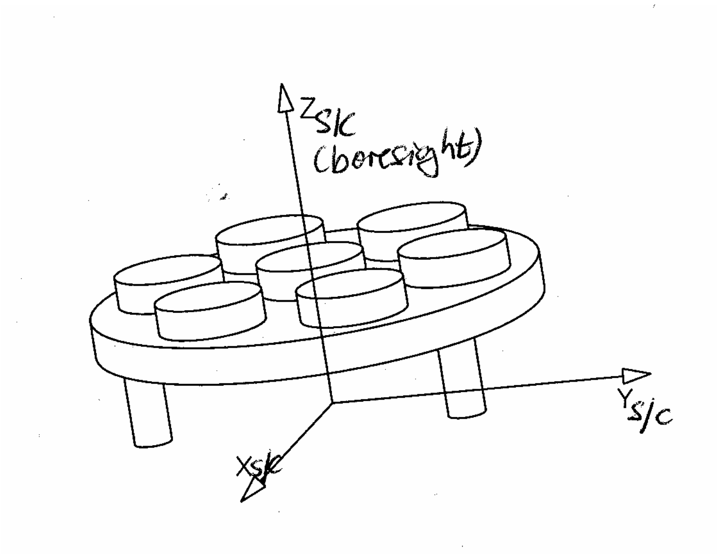


Figure 12-4: MGA-S boresight direction

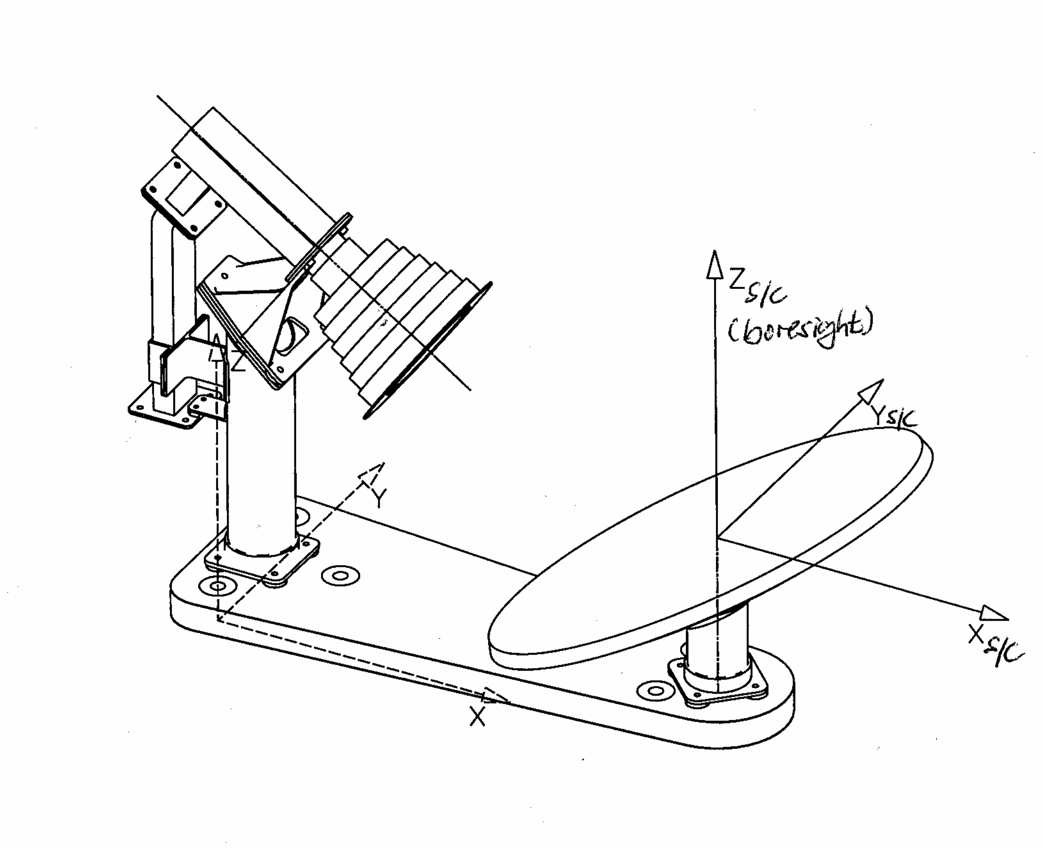


Figure 12-5: MGA-X boresight direction

12.2. Antenna Pattern

See Platform section, §5.3

12.3. RF Subsystem Characteristics

- The spacecraft telecommunication subsystem is allocated with an uplink frequency in the 2110.243 - 2117.746 MHz frequency band at S-Band, as follows:
  - S-Band : 2115.017747 MHz DSN CH 19
  - X-Band: 7168.091821 MHz DSN CH 19

- The spacecraft telecommunication subsystem is allocated for a Category B mission with a downlink frequency in the 2291.666 - 2299.814 MHz frequency band for the S-Band, as well as in the 8402.777 - 8440.802 MHz frequency band for X-Band, as follows:
  - S-Band 2296.852852 MHz DSN CH 19
  - X-Band 8421.790124 MHz DSN CH 19

- The ratio of uplink and downlink frequencies for the transponders are for a Category B Mission as follows:
  - fu/fd = 221/240 (S-/S- Band)
  - fu/fd = 221/880 (S-/X- Band)
  - fu/fd = 749/880 (X-/X- Band)
  - fu/fd = 749/240 (X-/S- Band)

- The telecommand modulation scheme is PCM/PSK/PM on a sinusoidal sub-carrier. The ranging signal directly phase modulates (PM) the uplink carrier. For simultaneous ranging and telecommand, the two signals are added prior to phase modulation of the uplink carrier.

- The telemetry modulation scheme is PCM/PSK/PM on a square wave sub-carrier. Two sub-carrier frequencies are used, one for the low bit rates and one for the high bit rates. The sub-carrier frequencies are as follows:
  - 8193 Hz for the low bit rates
  - 262144 Hz for the high bit rates

- The ranging signal in the ranging channel of the transponder directly phase modulates (PM) the downlink carrier. When simultaneous ranging and telemetry is performed, the two signals are added prior to phase modulation of the downlink carrier.

- The telemetry bit rate is switchable between 10.67 bps – 26214.4 bps in steps with a factor of 2 and odd steps. Some additional bit rates are available to optimise the data return during near comet operations.. These bit rates comprise the actual information bits including header and Read-Solomon, before convolutional encoding

- The coding is concatenated for the down link. (Reed Solomon R-S 255,223 with interleaving depth I=5 and convolutional rate ½ with constraint length K=7). Turbo Coding of rate ½ and ¼ may also be used.

- The following telecommand bit rates will be used:
  - 7.8125 bps
  - 15.625 bps
  - 250 bps
  - 1000 bps
  - 2000 bps

- The telecommand NRZ-L interface consists of following signals :
  - Bit Clock, clock signal from the subcarrier demodulator
  - Bit Stream, data from the subcarrier demodulator
  - Data Valid, indicating that the data is valid (Squelch Function)

  All inputs are in accordance with the System Interface Requirement Specification RO-DSS-IS-1001 , § 3.6.1.3

- Receiver Lock Status

  The RF-lock status is provided by the Transponder (three signals per transponder). The signals are in accordance with the System Interface Requirement Specification RO-DSS-IS-1001, § 4.1.2.7.3 (RLS)

- Each subcarrier demodulator provides two telecommand NRZ-L interfaces.

- The TT&C subsystem is compatible with the ESA ground stations and NASA DSN Network.

  For the ESA ground station(s) the ranging signal is in accordance with the Ranging Standard ESA document (ESA-PSS-04-104). The selected tone frequency is 1.048576 MHz and code length are between 16 and 20.

For the NASA DSN ground station(s) the ranging signal is in accordance with with 'Deep Space Network/Flight Project Interface Handbook NASA/JPL 810.5, Volume I: Existing DSN Capabilities, TRK-30, Revision E .

- The gain to noise temperature ratio is defined as the ratio of the receive antenna gain to the total worst case noise temperature in degree Kelvin at the reference antenna interface. This system temperature shall include 60°K equivalent noise received by the antenna, and the worst case noise of all subsequent elements in the receive section, at maximum operating temperature for each element. The (G/T) is greater than or equal to the values specified in the following table:

	X-Band Worst case	S-Band Worst case	Comments
HGA	+15.3 dB/K	+1.0 dB/K	in antenna axis
MGA	-0.9 dB/K	-13.8 dB/K	in antenna axis
LGA	N/A	-31.6 dB/K	over coverage

These performances is valid at satellite level, when antennae are mounted on the spacecraft.

- All subsystem requirements will be met and TC operations, in worst case conditions, shall be possible over the spacecraft mission for the following flux density levels for each antenna:

	LGA	MGA	HGA
Flux density S-Band	-112.1 (dBm/m²)	-129.6 (dBm/m²)	-144.6 (dBm/m²)
Flux density X-Band	N/A	-129.8 (dBm/m²)	-146.0 dBm/m²)

The command subsystem is able to withstand an in-band flux density level 136 dB higher than the minimum power flux density given from any direction without damage.

The maximum power for compatibility with the communication subsystem is 76 dB higher than the minimum power flux density. At this power level, the command subsystem ensures full performances.

- All subsystem requirements will be met and TC operations, in worst case conditions, shall be possible over the spacecraft mission for:
  - Doppler rates up to 20 Hz/s (down to min. flux density)~~) level as specified in PTPA-140)~~

- Carrier acquistion

  The probability of carrier acquistion is at least 97% at a

  - carrier sweep rate up to 20 Hz/s for min flux density levels ~~as specified in PTPA-140~~
  - carrier sweep rate up to 500 Hz/s for flux density levels at least 20 dB above those levels ~~specified in PTPA-140~~

- The axial ratio of antennae is not higher than:

	S-Band	X-Band	Comments
HGA	1.4 dB	1.4 dB	over antenna axis to θ_{3dB}° from antenna axis
MGA	2.2 dB	1.4 dB	over antenna axis to 15° from antenna axis for the S-Band and θ_{3dB}° for X-Band
LGA	5 dB	N/A	over coverage

These performances is met at satellite level, when antennae are mounted on the spacecraft.

- The θ_{3dB} over the aperture, half cone angle, is not ~~be~~ less than:

	S-Band	X-Band
HGA TX	2.06°	0.49°
HGA RX	2.21°	0.57°

These performances ~~shall be~~ are met at satellite level, when antennae are mounted on the spacecraft.

- Implementation losses are:
  - Carrier recovery : 1.0 dB
  - Ranging : 2.0 dB typically
  - Telecommand Recovery : 3.5 dB typically, up to 4.7 dB for low bit rates

- PLL bandwidth of the receiver is 20 Hz +/- 20% (double-sided) in Narrow Band mode.

- Carrier to noise ratio required in PLL bandwidth of the receiver does not exceed 10 dB.

- The ranging bandwidth ~~(double-sided)~~ is 4.2 MHz ~~6.4 Mhz max. (3dB bandwidth)~~.

- The TM modulation index is selectable in a range as specified in ESA standard, during the mission of the spacecraft. The indices are chosen by command in 'TM alone', 'Ranging alone' and 'TM + Ranging' modes.
- The following TM and Ranging Modulation Indices are selectable:

Function	Modulation Index (Rads peak)
Telemetry	0.5/0.7/0.8/0.9/1.0/1.1/1.18/1.25
Ranging	0.1/0.2/0.3/0.4/0.5/0.6/0.7

- The minimum worst case EIRP for each antenna is:

	S-Band	X-Band	Comments
HGA	+34.3 dBW	+57.3 dBW	in boresight axis
MGA	+19.8 dBW	+39.7 dBW	in boresight axis
LGA	+0.2 dBW	N/A	over coverage[1]

- The max. radiated Emissions of the HGA, MGA and LGAs is compliant to the limits as defined in §5.2.5.1 and §5.2.1.1 of RO-DSS-RS-1002 (EMC Specification).

- Carrier Phase noise

[1] LGA coverage of 86.45%

The phase noise of the unmodulated carrier, integrated between 10 Hz and 100 kHz is less than :

1. 0.7 deg RMS at S-Band
2. 3.0 deg RMS at X-Band

The USO requirement specification and basic technical parameters are defined in Table 12-1:

Output frequency		38.28 Mhz (in accordance with TT&C frequencies)
Frequency stability	Allan variance, 3s	$< 2x10^{-13}$
Phase	1 Hz	≤ -105 dBc/Hz
	10 Hz	≤ -120 dBc/Hz
	100 Hz	≤ -125 dBc/Hz
	1000 Hz	≤-142 dBc/Hz
Harmonics		< -35 dBc
Spurious output		< -108 dBc

Table 12-1: Quartz USO technical Parameters

12.2. RF Link Budgets

see Annex 10.

12.3. Ranging Calibration Data

See RO-DSS-TN-1156, iss. 2.1, §3.6

12.4. Further supporting information

See attached documents:

Unit	Document Title	Doc Number	Issue
TTC	TTC Subsystem TM/TC ICD	RO-MMB-IF-3108	2
TTC	TTC Subsystem User Manual	RO-MMB-MA-3102	2
TTC	TTC Subsystem Design Description	RO-MMB-TN-3113	5
TTC	TT&C Subsystem Analysis	RO-MMB-TN-3202	2
TTC	Input on Solar Noise Link Performance	RO-DSS-TN-1132	1
TTC	TT&C Inputs to Flight Dynamics Database	RO-DSS-TN-1156	2.1
TTC	Rosetta Acquisition Procedure	RO-DSS-TN-1180	2
TTC	Parametric Study on TT&C Link Budgets New Mission	RO-DSS-TN-1185	1
TTC	Establishing TM/TC when Rosetta is in MGA strobing	RO-DSS-TN-1195	2
APM	APM User Manual	RO-ETL-MA-0087	1.1
APME	APME Design Description	RO-ETL-RP-0003	2
APME	APME ICD	RO-ETL-IF-0001	1.8
HGA	HGA Design Description	RO-SES-TN-3017	4
LGA	S-Band Antenna 95° Single Port	P-SAA-TNT-0005-SE	9
MGA	MGA-X Antenna Design Description	RO-CAS-RP-3000	3
MGA	MGA-S Antenna Design Description	RO-CAS-RP-3001	3
RFDU	RFDU Design Description	RO-AEO-DD-3001	3
RFDU	RFDU Interface Data-Sheet	RO-AEO-IF-3006	1
RFDU	RFDU User Manual	RO-AEO-MA-3001	4
TRANSPONDER	S/X Band Transponder ICD	RO-ALS-IF-0018	7
TRANSPONDER	S/X Band Transponder User Manual for EQM & FM	RO-ALS-MA-0092	4
TRANSPONDER	S/X-Band Transponder Design Report	RO-ALS-RP-0002	8

Unit	Document Title	Doc Number	Issue
TRANSPONDER	S/X Band Transponder TM/TC Description	RO-ALS-TN-0053	6
TWTA	TWTA Interface Data Sheets	RO-AET-IF-1016	1 Rev. 1
TWTA	TWTA User Handbook	RO-AET-MA-1018	1 Rev.2
TWTA	X-Band TWTA Design Description	RO-AET-TN-1017	1
USO	USO Design Description	RO-TIM-DS-3003	3
USO	USO EICD	RO-TIM-IF-3002	4.4
USO	USO Operations Manual	RO-TIM-MA-3001	3.1
WIU	WIU Design Description	RO-AEO-DD-3002	3
WIU	WIU Interface Data-Sheet	RO-AEO-IF-3005	2
WIU	WIU User Manual	RO-AEO-MA-3003	5

13. APPENDIX 7 – FAILURE AND CONTINGENCY ANALYSIS

See attached documents:

Unit	Document Title	Doc Number	Issue
SYSTEM	Rosetta Hazard Analysis	RO-DSS-AN-1002	3
SYSTEM	Radiation Analysis	RO-DSS-AN-1004	3a
SYSTEM	Rosetta Reliabilty Analysis	RO-DSS-AN-1005	3
SYSTEM	System Level Fmeca	RO-DSS-AN-1006	5
SYSTEM	Rosetta Single Point Failure List	RO-DSS-LI-1008	5
SYSTEM	Rosetta SEU Functionality Analysis	RO-DSS-TN-1099	4
SYSTEM	Platform FMECA	RO-MMB-RP-3174	2
SYSTEM	Generic Interface FMECA	RO-MMT-RP-2016	2
SADE	SADE FMECA	RO-AEO-AN-3012	4
PL-PDU	PL-PDU FMECA	RO-FIN-RP-0004	2
SS-PDU	SS-PDU FMECA	RO-FIN-RP-0005	2
SA	SA FMECA	RO-FOK-AN-3018	3
HGAMA	HGAMA FMECA	RO-HTS-AN-0001	1b
SADM	SADM FMECA	RO-KDA-AN-3001	2b
RCS	RCS FMECA	RO-MMB-RP-3102	4
THERMAL	Thermal FMECA	RO-MMB-RP-3108	3
POWER	Power FMECA	RO-MMB-RP-3124	3
TTC	TTC FMECA	RO-MMB-RP-3129	2
BOOMS	Experiment Booms FMECA	RO-SEN-AN-3502	2
PCU	PCU FMECA	RO-TER-AN-3002	5
PCU	PCU Worst Case Analysis	RO-TER-AN-3006	2
SSMM	SSMM Data Integrity	RO-DSS-TN-1109	2

14. APPENDIX 8 – ON-BOARD SOFTWARE

14.1. Software Memory Budget

See Annex 10.

14.2. Program Code Listing

See Flight Tape: RO-DSS-DP-1006, issue 3

- ~~DMS SW~~
- ~~AOCMS SW~~
- ~~SSMM SW~~
- ~~STR SW~~
- ~~CAM SW~~
- ~~PMFW~~

14.3. Data Areas

Unit	Data Area
SSMM	PROM, EEPROM, RAM, Memory Modules,
STR, CAM	PROM, EEPROM, RAM
PM-Firmware	PROM, RAM
DMS, AOCMS	PROM, EEPROM, RAM, SGM-EEPROM, SGM-RAM

14.4. Software Development/Maintenance Environment Description

Product	Document Name	Ref.- Number	Quantity
Logiscope	Installing And Managing	RO-RST-DOC-001	3
	Support Center User's Guide	RO-RST-DOC-002	3

Product	Document Name	Ref.- Number	Quantity
ATTOL UniTest	Installation Guide	RO-RST-DOC-003	3
	Folder Containing Delivery Notes And License Information Addressed To DSS	RO-RST-DOC-004	1
	Folder Containing Delivery Notes And License Information Addressed To CAPTEC	RO-RST-DOC-005	1
	Folder Containing Delivery Notes And License Information Addressed To TERMA	RO-RST-DOC-006	1
HoodNICE	Release Guide	RO-RST-DOC-007	3
	Installation & Maintenance Guide	RO-RST-DOC-008	3
	Reference Manual	RO-RST-DOC-009	3
	Hoodnice Version Transition Support	RO-RST-DOC-010	1
	Tape Content	RO-RST-DOC-011	3
	4 Sheets Sticked Together (License Information, Delivery Form, Error Report, Eval. Form) Addressed To Dss	RO-RST-DOC-012	1
	4 Sheets Sticked Together (License Information, Delivery Form, Error Report, Eval. Form) Addressed To Captec	RO-RST-DOC-013	1
	4 Sheets Sticked Together (License Information, Delivery Form, Error Report, Eval. Form) Addressed To Terma	RO-RST-DOC-014	1
Ada TLD	Configured Separatly, When Delivery Has Been Done By TLD	n/a	n/a
ClearCase	Letter (One Page)	RO-RST-DOC-025	3
	Clearcase Technical Bulletin	RO-RST-DOC-026	3
	Products License Agreement	RO-RST-DOC-027	3

Product	Document Name	Ref.- Number	Quantity
	Clearcase And Multisite Release Notes V3.2.1	RO-RST-DOC-028	3
	Clearcase And Multisite Release Notes	RO-RST-DOC-029	3
	Clearcase Product Family Installation Notes	RO-RST-DOC-030	3
	Clearcase Quick Reference	RO-RST-DOC-031	3
	Clearcase/Clearddts Integration	RO-RST-DOC-032	3
	Clearcase Concepts Manual	RO-RST-DOC-033	3
	Clearcase Administrator's Manual	RO-RST-DOC-034	3
	Clearcase User's Manual	RO-RST-DOC-035	3
	Clearcase Reference Manual	RO-RST-DOC-036	3
	Clearcase V3 Migration Guide	RO-RST-DOC-037	3

Table 14-1: SDE Documentation

Product	Description	Version	Media Type	Ref. Number	Quantity
Logiscope	CD contains Logiscope product	2.0	CD-ROM	RO-RST-MEDIA-001	3
	Floppy Disk contains license key file for Ws. ro_ws4	n/a	1.44" FD	RO-RST-MEDIA-002	1
	Floppy Disk contains license key file for Ws. ro_ws5	n/a	1.44" FD	RO-RST-MEDIA-003	1
	Floppy Disk contains license key file for Ws. ro_ws6	n/a	1.44" FD	RO-RST-MEDIA-004	1
ATTOL UniTest	CD contains ATTOL UniTest product	3.3a	CD-ROM	RO-RST-MEDIA-005	3
	Floppy Disk contains license key & install key file for Ws.:ro_ws4	n/a	1.44" FD	RO-RST-MEDIA-006	1

Product	Description	Version	Media Type	Ref. Number	Quantity
	Floppy Disk contains license key & install key file for Ws.:ro_ws5	n/a	1.44" FD	RO-RST-MEDIA-007	1
	Floppy Disk contains license key & install key file for Ws.:ro_ws6	n/a	1.44" FD	RO-RST-MEDIA-008	1
HoodNICE	Tape contains the HoodNICE product	2.3.4	QIC-11	RO-RST-MEDIA-009	3
	Floppy Disk contains license key file for Ws.:ro_ws4	n/a	1.44" FD	RO-RST-MEDIA-010	1
	Floppy Disk contains license key file for Ws.:ro_ws5	n/a	1.44" FD	RO-RST-MEDIA-011	1
	Floppy Disk contains license key file for Ws.:ro_ws6	n/a	1.44" FD	RO-RST-MEDIA-012	1
Ada TLD	configured separatly, when delivery has been done by TLD	92SA005	CD-ROM	RO-SBI-MEDIA-002	3
ClearCase	CD ClearCase Rel. 3.2	3.2	CD-ROM	RO-RST-MEDIA-018	3
	CD ClearCase Rel. 3.2.1	3.2.1	CD-ROM	RO-RST-MEDIA-019	3
	Floppy Disk contains license key file for Ws.:ro_ws4	n/a	1.44" FD	RO-RST-MEDIA-020	1
	Floppy Disk contains license key file for Ws.:ro_ws5	n/a	1.44" FD	RO-RST-MEDIA-021	1
	Floppy Disk contains license key file for Ws.:ro_ws6	n/a	1.44" FD	RO-RST-MEDIA-022	1

Table 14-2: CIDL - Media of Tools Bundle 1, except Tool Ada TLD

Product	Document Name	Ref.- Number	Quantity
Windows 98	Getting Started Microsoft Windows 98	RO-RST-DOC-113	4
	Registration Card	RO-RST-DOC-114	4
ADDS-21020-SW-PC	Registration Form	RO-RST-DOC-135	4
	ADSP-2106x Compactor Reference Manual	RO-RST-DOC-136	4

Product	Document Name	Ref.- Number	Quantity
	ADSP-21000 Family Development Tools Release Note	RO-RST-DOC-137	4
	Software License Agreement	RO-RST-DOC-138	4
	ADSP-21000 Family C Runtime Library Manual	RO-RST-DOC-139	4
	ADSP-21000 Family C Tools Manual	RO-RST-DOC-140	4
	ADSP-21000 Family Assembler Tools & Simulator Manual	RO-RST-DOC-141	4
	ADSP-21020 User's Manual	RO-RST-DOC-142	4

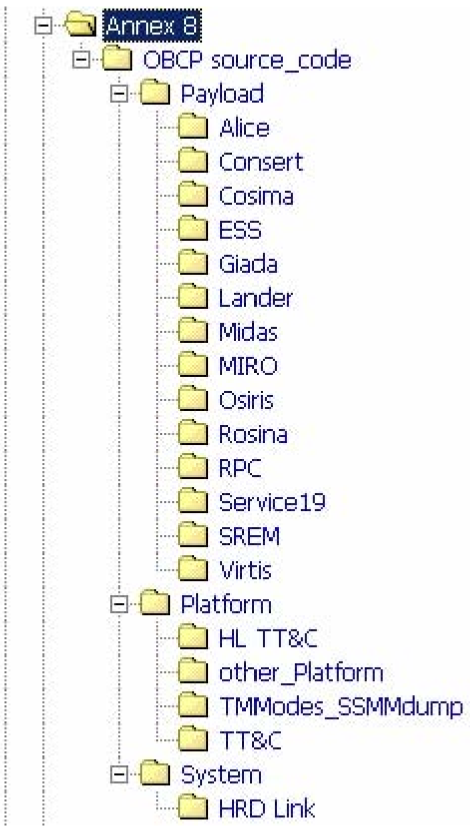
Table 14-3: CIDL - Documentation of SVF-PC Tools

14.5. Software Maintenance Documentation attached

Unit	Document Title	Doc Number	Issue
SYSTEM	OEDIPE Rosetta Users Manual	RO-MMT-MA-2022	1
SYSTEM	Rosetta Spacecraft Control Language	RO-MMT-TN-2042	2.1
SYSTEM	System Autonomy Software User Requirements Document	RO-DSS-RS-1016	9
SYSTEM	OBCP Users Manual	RO-DSS-MA-1002	1b
OBCP	OBCP Status 27.08.2003		
OBCP	OBCP URD Generation Guide	RO-DSS-TN-1092	5a
OBCP	System Level OBCPs URD	RO-DSS-RS-1019	10e
OBCP	Platform OBCPs URD	RO-DSS-RS-1020	4b
OBCP	Low Level OBCPs URD	RO-DSS-RS-1021	1
OBCP	OSIRIS Experiment OBCPs URD	RO-DSS-RS-1022	2b

Unit	Document Title	Doc Number	Issue
OBCP	ALICE Experiment OBCPs URD	RO-DSS-RS-1023	1g
OBCP	VIRTIS Experiment OBCPs URD	RO-DSS-RS-1024	1e
OBCP	MIRO Experiment OBCPs URD	RO-DSS-RS-1025	3b
OBCP	ROSINA Experiment OBCPs URD	RO-DSS-RS-1026	3a
OBCP	COSIMA Experiment OBCPs URD	RO-DSS-RS-1028	3
OBCP	MIDAS Experiment OBCPs URD	RO-DSS-RS-1029	2a
OBCP	CONSERT Experiment OBCPs URD	RO-DSS-RS-1030	2a
OBCP	GIADA Experiment OBCPs URD	RO-DSS-RS-1031	2b
OBCP	RPC Experiment OBCPs URD	RO-DSS-RS-1032	2c
OBCP	SREM Experiment OBCPs URD	RO-DSS-RS-1033	1c
OBCP	ESS / Lander OBCPs URD	RO-DSS-RS-1034	1d
SADE	SADE Software URD	RO-DSS-RS-1036	6.1
APME	APME Software URD	RO-DSS-RS-1037	6
OBCP	TT&C Related OBCP URD	RO-DSS-RS-1040	4.8
OBCP	High Level TT&C OBCP URD	RO-DSS-RS-1047	4.7
OBCP	HRD Link OBCPs URD	RO-DSS-RS-1048	2h
OBCP	TM Mode & SSMM Dump OBCPs URD	RO-DSS-RS-1050	1g
SDE	SDE User Manual	RO-SBI-MA-1001	1.4
SVF	SVF Design Specification	RO-TER-DS-1000	1
SVF	SVF Architectural Design Document	RO-TER-DS-1001	1a
SVF	Rosetta SVF Aocms Environment Simulation Architectural Design	RO-TER-DS-1008	2d
SVF	SVF SSMM Environment Simulation ADD	RO-TER-DS-1009	1a
SVF	SVF STR Environment Simulation ADD	RO-TER-DS-1011	1b
SVF	SVF CAM Environment Simulation ADD	RO-TER-DS-1012	1a
SVF	SVF SME Architectural Design Document	RO-TER-DS-1013	1
SVF	SVF CDMS Environment Simulation ADD	RO-TER-DS-1014	2
SVF	SVF User Manual	RO-TER-MA-1001	9
SVF	SVF Build And Installation Manual	RO-TER-MA-1008	8
SVF	SVF Distributed SILD Manual	RO-TER-MA-1010	3a
SVF	SVF SME User Manual	RO-TER-MA-1002	1

Additionally, OBCP Software source code is available in Annex 8 but can be accessed only by navigating with a file manager directly on the CD.



Folder Structure of Annex 8 - "Software Sources" Directories

15. Appendix 9 – Spacecraft Configuration Drawings

The various configuration drawings can be accessed via hyperlinks from the Configuration Table below.

File Location	Title	Doc Number
	Overall System Drawings	
2480-100 004A00B RO Alignmt Mirror.pdf	Location of Alignment Mirrors	2480-100 004A00 Issue B
2480-200 001A00C Location of Units.pdf	Location of Units	2480-200 001A00 Issue C
2480-321 100A00 Reaction Wheel IF.pdf	Reaction Wheel Interface	2480-321 100A00 Issue A
2480-323 100A00B Star Tracker IF.pdf	Star Tracker Interface	2480-323 100A00 Issue B
2480-325 100A00B NAV CAM IF.pdf	NAV CAM Interface	2480-325 100A00 Issue B
2480-500 100A00B RO AR5 Clearances.pdf	Rosetta Ariane 5 Clearances	2480-500 100A00 Issue B
2480-500 101A Umbilical Purge Portloc.pdf	Umbilical and Purge Port Location	2480-500101A00 Issue B
2480-500 102A00 Purge IF AR5.pdf	Purge Interface Ariane 5	2480-500 102A00 Issue A
RO-AEO-IF-3001i5.pdf	SADE Interface Control Drwaing	RO-AEO-IF-3001 Issue 5
Structure\2480_100001A 00-1.pdf	Rosetta Launch Configuration 1	2480-100 001A00 Issue A
Structure\2480_100001A 00-2.pdf	Rosetta Launch Configuration 2	2480-100 001A00 Issue A
Structure\2480_100001A 00-3.pdf	Rosetta Launch Configuration 3	2480-100 001A00 Issue A
Structure\2480_100001A 00-4.pdf	Rosetta Launch Configuration 4	2480-100 001A00 Issue A
Structure\2480_100001A 00-5.pdf	Rosetta Launch Configuration 5	2480-100 001A00 Issue A
Structure\2480_100002A 00-1.pdf	Rosetta Flight Configuration 1	2480-100 002 A00 Issue A
Structure\2480_100002A 00-2.pdf	Rosetta Flight Configuration 2	2480-100 002 A00 Issue A
Structure\2480_100002A 00-3.pdf	Rosetta Flight Configuration 3	2480-100 002 A00 Issue A
Structure\2480_100002A 00-4.pdf	Rosetta Flight Configuration 4	2480-100 002 A00 Issue A
Structure\2480_100002A 00-5.pdf	Rosetta Flight Configuration 5	2480-100 002 A00 Issue A
Structure\2480_100002A 00-6.pdf	Rosetta Flight Configuration 6	2480-100 002 A00 Issue A
Structure\2480_100002A 00-7.pdf	Rosetta Flight Configuration 7	2480-100 002 A00 Issue A
Structure\2480_100002A 00-8.pdf	Rosetta Flight Configuration 8	2480-100 002 A00 Issue A
Structure\2480_100001A00-4 (Boom).pdf	Boom Location	
Structure\ro8k601-1.pdf	Overall Configuration (+x,+y,+z faces)	RO8k601-1 Issue 2
Structure\ro8k601-2.pdf	Overall Configuration (-x,-y,-z faces)	RO8k601-2 Issue 1
Structure\ro8k605-1.pdf	PSM +Z Panel (+z face)	RO8k605-1 Issue 3
Structure\ro8k605-2.pdf	PSM +Z Panel (-z face)	RO8k605-2 Issue 3
Structure\ro8k617.pdf	HGA	RO8k617 Issue 2
Structure\ro8k625-1.pdf	Integrated +X Panel (-x face)	RO8k625-1 Issue 1
Structure\ro8k625-2.pdf	Integrated +X Panel (+x face)	RO8k625-2 Issue 1
Structure\ro8k625-3.pdf	Integrated +X Panel (-x face)	RO8k625-3 Issue 1
Structure\ro8k626-1.pdf	BSM -X Panel (+x face)	RO8k626-1 Issue 2
Structure\ro8k626-2.pdf	BSM -X Panel (-x face)	RO8k626-2 Issue 2
Structure\ro8k628-1.pdf	BSM +Y Panel (-y face)	RO8k628-1 Issue 2
Structure\ro8k628-2.pdf	BSM +Y Panel (+y face)	RO8k628-2 Issue 2
Structure\ro8k629-1.pdf	BSM -Y Panel (-y face)	RO8k629-1 Issue 2
Structure\ro8k629-2.pdf	BSM -Y Panel (+y face)	RO8k629 Issue 2
Structure\ro8k631.pdf	PSM +X Shear Panel	RO8k631 Issue 1

File Location	Title	Doc Number
Structure\ro8k632.pdf	PSM -X+Y Shear Panel	RO8k632 Issue 1
Structure\ro8k633.pdf	PSM -X-Y Shear Panel	RO8k633 Issue 1
Structure\ro8k634.pdf	PSM +Y Shear Panel	RO8k634 Issue 1
Structure\ro8k635.pdf	PSM -Y Shear Panel	RO8k635 Issue 1
Structure\ro8k636-1.pdf	Internal Deck (+z face)	RO8k636-1 Issue 1
Structure\ro8k636-2.pdf	Internal Deck (-z face)	RO8k636-2 Issue 1
Structure\ro8k642-1.pdf	PSM +Y Panel (-y face)	RO8k642-1 Issue 2
Structure\ro8k642-2.pdf	PSM +Y Panel (+y face)	RO8k642-2 Issue 1
Structure\ro8k643-1.pdf	PSM -Y Panel (+y face)	RO8k643-1 Issue 2
Structure\ro8k643-2.pdf	PSM -Y Panel (-y face)	RO8k643-2 Issue 2
Payload Interface Drawings		
Payload\2480-411 100A00B ALICE IF.pdf	ALICE Interface	2480-411 100A00 Issue B
Payload\2480-412 100A00B MIRO IF.pdf	MIRO Interface	2480-412 100A00 Issue B
Payload\2480-413 100A00 VIRTIS IF.pdf	VIRTIS Interface (Optics)	2480-413 100A00 Issue A
Payload\2480-413 200A00B VIRTIS EL IF.pdf	VIRTIS Electronics Interface	2480-413 200A00 Issue B
Payload\2480-413 300A00C VIRTIS PEM H IF.pdf	VIRTIS PEM H Interface	2480-413 300A00 Issue C
Payload\2480-413 400A00C VIRTIS PEM M IF.pdf	VIRTIS PEM M Interface	2480-413 400A00 Issue C
Payload\2480-414 100A00B OSIRIS WAC IF.pdf	OSIRIS WAC Interface	2480-414 100A00 Issue B
Payload\2480-414 200A00 OSIRIS NAC IF.pdf	OSIRIS NAC Interface	2480-414 200A00 Issue A
Payload\2480-414 300A00B OSIRIS EL IF.pdf	OSIRIS Electrical Interface	2480-414 300A00 Issue B
Payload\2480-414 400A00B OSIRIS WAC CRB IF.pdf	OSIRIS WAC CRB Interface	2480-414 400A00 Issue B
Payload\2480-414 500A00 OSIRIS NAC CRB IF.pdf	OSIRIS NAC CRB Interface	2480-414 500A00 Issue A
Payload\2480-417 100A00 COSIMA IF.pdf	COSIMA Interface	2480-417 100A00 Issue A
Payload\2480-418 100A00 MIDAS IF.pdf	MIDAS Interface	2480-418 100A00
Payload\2480-419 100A00 ROSINA DFMS IF.pdf	ROSINA DFMS Interface	2480-419 100A00
Payload\2480-419 200A00 ROSINA RTOF IF.pdf	ROSINA RTOF Interface	2480-419 200A00
Payload\2480-419 300A00 ROSINA COPS IF.pdf	ROSINA COPS Interface	2480-419 300A00
Payload\2480-419 400A00 ROSINA DPU IF.pdf	ROSINA DPU Interface	2480-419 400A00
Payload\2480-420 100A00B CONSERT IF.pdf	CONSERT Interface	2480-420 100A00
Payload\2480-421 100A00B GIADA IF.pdf	GIADA Interface	2480-421 100A00
Payload\2480-423 100A00B RPC IES IF.pdf	RPC IES Interface	2480-423 100A00
Payload\2480-424 100A00B MAG LAP 2 IF.pdf	MAG LAP 2 Interface	2480-424 100A00
Payload\2480-425 100A00C RPC ICA IF.pdf	RPC ICA Interface	2480-425 100A00
Payload\2480-426 100A00B MIP LAP1 IF.pdf	RPC MIP-LAP1 Interface	2480-426 100
Payload\2480-427 100A00 RPC-PIU IF.pdf	RPC-PIU Interface	2480-427 100A00
Payload\RO-DSS-TN-1179i1.pdf	Lander Configuration summary	RO-DSS-TN-1179
Payload\RO- LAN- DW- 3500i2.pdf	Lander drawings	RO-LAN-DW-3500
Payload\2480-450 000A00 LANDER IF.pdf	LANDER Interface	2480-450 000A00
Payload\2480-450 100A00B LANDER MSS IF.pdf	LANDER MSS Interface	2480-450 100A00
Payload\2480-450 200A00 LANDER ESS IF.pdf	LANDER ESS Interface	2480-450 200A00
Payload\2480-450 210A00 B.pdf	ESS PROCESSOR Interface	2480-450 210A00
Payload\2480-450 220A00 ESS TXRX FILTE UNT IF.pdf	ESS TXRX FILTE UNT Interface	2480-450 220A00
Payload\2480-450 230A00 ESS SWITCH BOX IF.pdf	ESS SWITCH BOX Interface	2480-450 230A00
Payload\2480-450 240A00 C.pdf	ESS TXRX ANTENNA Interface	2480-450 240A00
Payload\2480-461 100A00C SREM IF.pdf	SREM Interface	2480-461 100A00

File Location	Title	Doc Number
Propulsion Subsystem Drawings		
Propulsion\ro2k603-1.pdf	RCS MLI	RO2k603-1 Issue 1
Propulsion\ro2k603-2.pdf	RCS MLI	RO2k603-2 Issue 1
Propulsion\ro2k613-1.pdf	RCS Thermal Hardware	RO2k613-1 Issue 2
Propulsion\ro2k613-2.pdf	RCS Thermal Hardware	RO2k613-2 Issue 2
Propulsion\ro2k613-3.pdf	RCS Thermal Hardware	RO2k613-3 Issue 2
Propulsion\ro2k613-4.pdf	RCS Thermal Hardware	RO2k613-4 Issue 2
Propulsion\ro2k613-5.pdf	RCS Thermal Hardware	RO2k613-5 Issue 2
Propulsion\ro2k614-1.pdf	RCS Thermal Hardware	RO2k614-1 Issue 1
Propulsion\ro2k614-2.pdf	RCS Thermal Hardware	RO2k614-2 Issue 1
Propulsion\ro2k614-3.pdf	RCS Thermal Hardware	RO2k614-3 Issue 1
Propulsion\ro2k614-4.pdf	RCS Thermal Hardware	RO2k614-4 Issue 1
Propulsion\ro2k614-5.pdf	RCS Thermal Hardware	RO2k614-5 Issue 1
Propulsion\ro2k614-6.pdf	RCS Thermal Hardware	RO2k614-6 Issue 1
Propulsion\ro2k614-7.pdf	RCS Thermal Hardware	RO2k614-7 Issue 1
Propulsion\ro2k614-8.pdf	RCS Thermal Hardware	RO2k614-8 Issue 1
Propulsion\ro2k614-9.pdf	RCS Thermal Hardware	RO2k614-9 Issue 1
Propulsion\ro2k615-1.pdf	Propellant Tank Thermal Hardware	RO2k615-1 Issue 1
Propulsion\ro2k615-2.pdf	Propellant Tank Thermal Hardware	RO2k615-2 Issue 1
Propulsion\ro2k615-3.pdf	Propellant Tank Thermal Hardware	RO2k615-3 Issue 1
Propulsion\ro2k615-4.pdf	Propellant Tank Thermal Hardware	RO2k615-4 Issue 1
Propulsion\ro2k615-5.pdf	Propellant Tank Thermal Hardware	RO2k615-5 Issue 1
Propulsion\ro2k615-6.pdf	Propellant Tank Thermal Hardware	RO2k615-6 Issue 6
Propulsion\ro2k616-1.pdf	Tank Pipework Thermal Hardware	RO2k616-1 Issue 1
Propulsion\ro2k616-2.pdf	Tank Pipework Thermal Hardware	RO2k616-2 Issue 1
Propulsion\ro2k616-3.pdf	Tank Pipework Thermal Hardware	RO2k616-3 Issue 1
Propulsion\ro2k616-4.pdf	Tank Pipework Thermal Hardware	RO2k616-4 Issue 1
Propulsion\ro2k616-5.pdf	Tank Pipework Thermal Hardware	RO2k616-5 Issue 1
Propulsion\ro2k617-rcs layout.pdf	Thruster Positions	RO2k617 Issue 1
Propulsion\ro8k625.pdf	Integrated +X Panel (-x face)	RO8k625 Issue 2
Thermal Subsystem Drawings		
Thermal\C062389 (1).pdf	RCS Core Assembly	c062389 Issue 1
Thermal\C062389 (2).pdf	RCS Core Assembly	c062389 Issue 1
Thermal\RO8K605 (1).pdf	FM PSM +Z Panel (+Z face)	ro8k605 Issue 1
Thermal\RO8K605 (2).pdf	FM PSM +Z Panel (-Z face)	ro8k605 Issue 1
Thermal\RO8K617.pdf	HGA Requirements	ro8k617 Issue 1
Thermal\RO8K625.pdf	Integrated +X Panel (-X face)	ro8k625 Issue 1
Thermal\RO8K626 (1).pdf	FM BSM -X Panel (+X face)	ro8k626 Issue 1
Thermal\RO8K626 (2).pdf	FM BSM -X Panel (-X face)	ro8k626 Issue 1
Thermal\RO8K628.pdf	FM BSM +Y Panel (-Y face)	ro8k628 Issue 01
Thermal\RO8K629.pdf	FM BSM -Y Panel (+Y face)	ro8k629 Issue 1
Thermal\RO8K636 (1).pdf	FM Internal Deck (-Z face)	ro8k636 Issue 1
Thermal\RO8K636 (2).pdf	FM Internal Deck (+Z face)	ro8k636 Issue 1
Thermal\RO8K642.pdf	FM PSM +Y Panel (-Y face)	ro8k642 issue 1
Thermal\RO8K643.pdf	FM PSM -Y Panel (+Y Face)	ro8k643 iss01

File Location	Title	Doc Number
TT&C Subsystem Drawings		
TT&C\RO2k300.pdf	Waveguide Interface	RO2k300 Issue 2
TT&C\RO-AEO-IF-3004.pdf	WIU Internal Interfaces Control Drawing	AEO-IF-3004 Issue 7
TT&C\2000570-003.pdf	LGA Interface Control Drawing	200 0570-003 Issue F
TT&C\MGX00AD0000P02.pdf	MGA-X Interface Control Drawings	MGX00AD0000P02
TT&C\MGS00HD0000P03	MGA-S Interface Control Drawings	MGS00HD0000P03
TT&C\2001708-001.pdf	HGA Interface Control Drawing	2001708-001 Issue A
TT&C\1GI008848 H01.pdf	TWTA ICD Drawing	1GI008848 H01
TT&C\1GI008847 H01.pdf	EPC ICD Drawing	1GI008847 H01
TT&C\4174477.pdf	TWT ICD Drawing	4174477
TT&C\RO-AEO-IF-3003.pdf	RFDU Interface Control Drawing	RO-AEO-IF-3003
TT&C\RO-TIM-KO-3007i5.pdf	USO Mechanical Drawings	RO-TIM-KO-3007 Issue 5

16. APPENDIX 10 – SYSTEM BUDGETS

16.1. Budget Summary

16.1.1. Mass Budget Summary

The dry mass budget is provided in the Annex, ref: RO-DSS-RP-1017.

This is for information only, because a measured value for the total spacecraft dry and wet mass is available now, derived from the propellant loading activities performed in Nov. 2001 in Kourou.

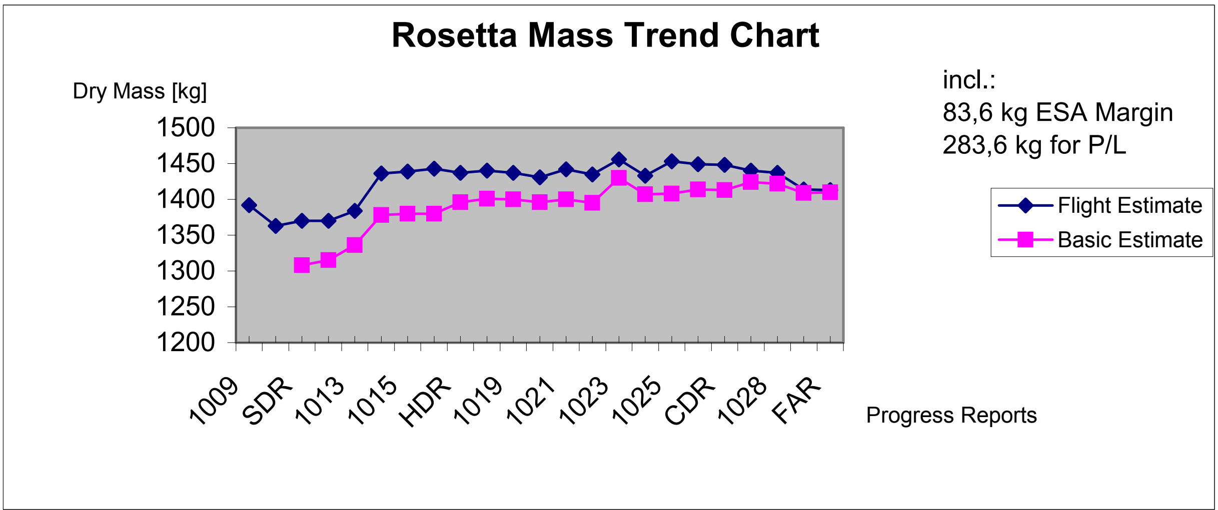
Meanwhile the dry mass increased slightly:

- + 0.64 kg for new STR-B bracket including screws
- + 0.2 kg for payload.

The launch mass will be increased by this amount, so that the overall budget for the launch configuration is as follows:

- dry mass: 1340.35 kg
- helium mass: 5.4 kg
- propellant mass: 1719.1 kg (as before)
- resulting total launch mass: 3064.83 kg

The S/C wet mass budget is provided in the Propellant Budget, RO-DSS-RP-1014. This is not fully in line with this new launch mass, but the difference is negligible.



16.1.2. Power Budget Summary

The new mission profile to the comet Churyumov-Gerasimenko exhibits some changes with respect to the power situation:

- the maximum Sun distance is now 5.33 AU
- the minimum Sun distance is now 0.88 AU
- the mission duration is 500 days longer.

As a consequence, the power situation became rather critical, i.e. the required 10% margin could not be demonstrated everywhere.

Therefore it was agreed to reassess the solar array radiation degradation for selected critical points in the mission, instead of continuing with the over-pessimistic figures for end-of-life.

As a result, the power budget has now higher margins for all operational modes and distances compared to the old Wirtanen mission.

Especially before the deep space hibernation, the operational constraints are now much less severe. For example, the use of the reaction wheels at transition to Safe Mode need not be inhibited prior to DSHM.

After hibernation the solar array output power is expected to be about 65 W less than before, which corresponds to more than 10% of the required power. However, all required operations are possible with 10% margin up to 4.5 AU, which is the planned hibernation exit distance.

After the second Earth fly-by the minimum Sun distance is reached. For this close-to-Sun case it is recommended to disable the MPPT in order to improve the voltage margin, but no problem is expected.

Based on these data, the power budget demonstrates the feasibility of the mission with respect to the availability of power for all nominal operational modes.

.For details it is referred to the Power Budget Report, RO-DSS-RP-1015.

16.1.3. Propellant Budget Summary

Changes since FAR

The launch window for the mission to comet Wirtanen has been missed due to problems with Ariane 5. Therefore a new mission, to comet Churyumov-Gerasimenko, has been defined, with the following new Delta-V allocations (ref. PR/4622/JvC):

Deep space manoeuvres + RVMs	1688 m/s
Launch window and flight tapes	10 m/s
Interplanetary navigation	75 m/s
Asteroid fly-by	20 m/s
Near comet operations	120 m/s
Launcher injection correction	147 m/s
Contingency	75 m/s
S/C failures (45 m/s)	

Other contingencies (30 m/s)	
Total Delta-V	2135 m/s

Table 4.1-1: Global Delta-V Allocations

This new mission is about 500 days longer in total. Part of this time, about 160 days, is an extension of the deep space hibernation phase, but about 340 additional days are spent in active operational modes, resulting in more overall consumption for attitude control.

The mass budget had changed slightly: due to a change in STR B viewing direction an additional bracket was introduced, which was estimated at about 0.4-0.5 kg. Therefore the S/C dry mass was assumed to increase from 1339.52 kg to 1340.0 kg. The propellant budget was calculated on this basis, without adjusting the total launch mass.

Meanwhile the bracket has been manufactured and weighed, and the mass of the payload changed slightly, see section 16.1.1, resulting in a total mass increase of 0.83 kg. This final adjustment was not reflected in the propellant budget calculations. However, this can be considered negligible; it is in the order of the measurement accuracy anyway.

The following table summarises the results of the propellant budget calculations. The budget shows positive margins for the nominal and contingency cases.

Reference Scenario	**Penalty**	**Margin (remaining Delta-V at end of Mission)**
Nominal Mission		**62.2 m/s**
+ one of the following contingencies:		
▪ Use of redundant propulsion system		**48.7 m/s**
▪ HGA blocked at Begin of Life		**34.7 m/s**
▪ HGA blocked at the comet *		**17.5 m/s**

* if this failure occurs, inefficient vectoring manoeuvre strategies have to be avoided as far as possible; the quoted figure is based on an average efficiency of 70.3% for all remaining manoeuvres with improved strategy

16.1.4. Link Budget summary

The link budgets have been computed as defined in ESA PSS-04-105, that means including nominal, adverse, favourable, mean - 3 sigma and worst case RSS (Root Sum Square). All the link budgets have been established for 10 degrees of elevation.

Detailed information is given in RO-DSS-TN-1025, issue 8.1. The following table presents the obtained results **without ranging** wrt:

- the mandatory performance requirements (**bold text**, as given in the system requirement specification),
- the verification requirements (standard text, as given in the SGICD)

The downlink results are valid for non-coherent transponder operation with a ground station receiver loop bandwidth of 3Hz in S-Band and 10Hz in X-Band. Superior performance is given in coherent mode. Those results are presented in **RO-DSS-TN-1182, 'Space/Ground Coherent Downlink Budgets'** (Ground station receiver loop bandwidth of 0.3Hz in S-Band and X-Band).

Legend :
High : **High** link budget margin, more than 5 dB additional to the required margin
O.K. : Link budget margin is **O.K.**
small : Link budget margin just in the range of the required margin or a little bit **small**er
low ! : Link budget margin requirement not met , **low** margin but no negative margin
No !! : Link budget margin requirement not met , negative margin**, no** link possible

UPLINK	S-Band		
	LGA[1]	**MGA**	**HGA**
Kourou 15m	15.625 bps / 0,16 AU : O.K	15.625 bps / 1.25 AU : O.K	1000 bps / 1.01 AU :O.K.
New Norcia	**7.8125 bps /1.1 AU : O.K.** 15.625 bps / 1.1 AU: O.K.. **1000bps /0.025AU: high**	**15.625 bps / 6.25 AU: O.K.**	**2000bps / 4.5AU : o.k.** 1000 bps / 5.5 AU : O.K.
DSN 34 m (BWG)	15.625 bps / 1.1 AU : O.K.	15.625 bps / 6.25 AU : O.K.	1000 bps / 5.5 AU : O.K
DSN 70m	**7.8125 bps / 6.5 AU : high** 15.625 bps / 6.25 AU : high	-	-
UPLINK	**X-Band**		
	LGA	**MGA**	**HGA**
Kourou 15m	-	15.625 bps / 1.45 AU : O.K	2000 bps / 1.03 AU : O.K
New Norcia	-	**15.625 bps / 6.25 AU : high**	**2000bps / 4.5AU : high** 2000 bps / 5.5 AU : high
DSN 34 m (BWG)	-	15.625 bps / 6.25 AU : high	2000 bps / 5.5 AU : high

[1] The results for the LGA correspond to a coverage of 88.64%

UPLINK	S-Band		
DSN 70m	-	15.625 bps / 6.25 AU : high	-

Table 16-1: Uplink performance summary

DOWNLINK	S-Band		
	LGA[1]	**MGA**	**HGA**
Kourou 15m	10.67bps / 0.029 AU :O.K. **16 bps / 0.04 AU : low !**	16 bps / 0.289 AU : O.K.	1024bps / 0.4184 AU:O.K.
New Norcia	10.67bps / 0.2 AU : No ! **256bps / 0.025 AU :O.K.**	16 bps / 1.0 AU : low !	1024 bps / 0.8 AU : O.K.
DSN 34 m	-	-	-
DOWNLINK	**X-Band**		
Kourou 15m	-	16 bps / 1.03 AU : O.K.	4096 bps / 2.09 AU : O.K.
New Norcia	-	**16 bps / 4.0 AU : small**	4096 bps / 4.2 AU **4096 bps / 4.5 AU : O.K.** **(5461.33/4.5 AU : o.k.)**
DSN 34 m (BWG)	-	16 bps / 4.0 AU : o.k.	4096 bps / 4.2 AU : high (5461.33/4.2 AU : o.k.)

Table 16-2: Downlink performance summary

CONCLUSIONS

Links Without Ranging (Table 16-1 & Table 16-2)

- All performance requirements of the system requirement specification can be met, except following downlinks in non-coherent mode :
  →

  → S-Band DL to Kourou 16 bps/0.04 AU via LGA

[1] The results for the LGA correspond to a coverage of 86.45%

→ X-Band DL to New Norcia 16 bps/4.0 AU via MGA (carrier recovery margin is 2.85 dB).

In coherent mode, the downlink performance is compliant in any case.

Coverage of LGA links @ 3dB link margin :

Link	Coverage @ 3dB margin	Remark
DL 16 bps to Kourou at 0.04AU, (ref. to TTCS-195)	~50 %	98% in coh. mode
DL 256 bps to New Norcia at 0.025AU, (ref. to TTCS-190)	> 99 %	
UL 1000bps from New Norcia at 0.025 AU, (ref. to TTCS-190)	100%	
UL 7.8125 bps from DSN 70m at 6.5 AU, (ref. to TTCS-192) UL 7.8125bps from New Norcia at 1.1 AU, (ref. to TTCS-192)	> 99% 98%	

Ranging Only

- Ranging via the LGAs with the ESA ground station is limited to 0.095 AU (S/S-Band)
- Ranging via the MGA with the ESA ground station is limited to 0.95 AU in S/S-Band and 3.67 AU in S/X-Band. 4.44 AU are possible in X/X-Band
- Ranging via the HGA with the Kourou 15m ground station is possible up to 5.65 AU (X/X-Band) .
- Ranging via the HGA with the New Norcia ground station is possible to > 6.25 AU with high margin in (S/X-Band and X/X-Band)

TM/TC and simultaneous Ranging

- Links via the LGAs are limited by ranging, they are possible only for near earth.
- TM/TC and Ranging via the LGAs with the New Norcia station at 0.025 AU is possible for TC = 1000 bps and TM = 256 bps.
- Links via the MGA are also limited by ranging.
  Using New Norcia G/S in X/X-Band , the requirement of 4AU / 16 bps can be met with ranging. Using DSN 70m G/S in X/X-Band , 16 bps in up- and downlink with ranging is possible up to 6.25 AU with low margin (0.89dB for DL carrier recovery).
- With the HGA , all required links can be performed with simultaneous ranging,.

16.1.5. Pointing Budget Summary

A summary of the pointing budget status against the requirements is given in Table 16-3. The detailed budget can be found in the attached document (RO-DSS-RP-1016)

The spacecraft pointing requirements are concerned with the following:

- Delta-V magnitude and direction accuracy
- SSP ejection velocity magnitude and direction accuracy
- HGA boresight pointing accuracy
- Pointing accuracy of the solar array axis and the solar array rotation
- APE during asteroid and comet detection, asteroid fly-by and comet observation
- RPE during asteroid and comet detection, asteroid fly-by and comet observation
- AMA during asteroid fly-by and comet observation

All the pointing requirements are met apart from two. These are the solar array rotation accuracy (worst case accuracy of 1.3° against a requirement of 0.1°) and the AMA of the payload line of sight during comet observation (worst case accuracy currently predicted to be 36.63" against a requirement of 12"). The first of these non-compliances can be handled at system level with no adverse effects. The second non-compliance is mainly due to the orientation of the star tracker on the spacecraft – its boresight is at 90° to the payload line of sight, so errors around the star tracker line of sight, (the axis with the poorest measurement performance), directly affect the AMA of the payload line of sight.

The following tables summarise the pointing budgets.

PINT	TITLE	SPECIFICATION	COMPLIANCE	PERFORMANCE AND COMMENTS
001	APE of delta-V	0.5° half cone	C	Axial delta-V using OCM: 0.45° Vectored delta-V using OCM: 0.33° (with at least two burns) Small delta-V using NM-WDP: 0.22° (with at least two burns) Touch-up delta-V prior to SSP separation: 0.16°
	Delta-V amplitude	1% for delta-V ≥ 10 mm/s; 0.1 mm/s for delta-V ≤ 10 mm/s.	C	For the touch-up delta-V prior to SSP separation, error ≤ 0.0826% for delta-V ≥ 10 mm/s and error ≤ 0.0826 mm/s for delta-V ≤ 10 mm/s. For all other delta-V manoeuvres, compliance is assured by one or two correction manoeuvres. (Ground measures the achieved delta-V and computes the correction manoeuvre).
002	Asteroid and comet detection	0.3° half cone	C	Requirement applied to payloads that are calibrated in flight. Worst case half cone APE = 0.038° for Virtis.
004	Asteroid fly-by: APE of payload LoS	0.3° half cone	C	Requirement applied to payloads that are calibrated in flight (PL-C payloads). For NAVCAM which is used for guidance, half cone APE = 0.141°. All other PL-C payloads are within specification. Worst case half cone APE = 0.275° for second NAVCAM.
007	Comet observation: APE of payload LoS	0.1° half cone	C	Requirement applied to payloads that are calibrated in flight. Worst case half cone APE = 0.028° for Virtis. Note an allowance of 0.01° is included for the total guidance error from ground.
009	SSP ejection	0.1° half cone for velocity vector	C	Half cone error = 0.070°.
		0.5° roll around velocity vector	C	Roll error = 0.017°.
		0.5% amplitude of velocity vector	C	Amplitude error = 0.103%.
011	APE of HGA (X-band down-link)	0.15° half cone	C	Assumes in-flight calibration of the HGA boresight to an accuracy of 0.05° for the X-band down-link. Half cone APE = 0.148°.

PINT	TITLE	SPECIFICATION	COMPLIANCE	PERFORMANCE AND COMMENTS
013	APE of solar array axis of rotation	5° half cone	C	Requirement applies when the payloads are operational. Worst case depointing occurs during asteroid fly-by. Half cone APE = 0.325°.
014	Solar array rotation control	0.1°	PC	When spacecraft is inertially pointing and quiescent, (asteroid and comet detection, and SSP separation), the specification is met. Worst case control error = 0.060°. At all other times, the specification is not met. Worst case control errors are: Comet observation phase: 0.231°. Asteroid fly-by phase: 0.867°. Turn and burn delta-V: 1.261° Vectored delta-V: 0.692 ***Note (1): The array pointing is compatible with spacecraft power requirements and will be taken into account in the AOCMS FDIR.*** ***Note (2): The disturbance torques arising from array depointing are accommodated within the AOCMS design.*** ***Note (3): The control performance during inertial, quiescent periods will allow the array angles to be set up to within 0.1° in order to minimise disturbance torques.*** ***Note (4): It will not be possible to remove the non-compliances during the other phases.*** ***An RFW, (RO-DSS-RW-1018, issue 1), has already been accepted on this subject (with slightly different pointing errors). This RFW has now been re-issued, at issue 2, with the finalised assessment of the pointing errors.***
020	Asteroid and comet detection: RPE of payload LoS	3×10^{-4} deg over 2 seconds, half cone	C	Half cone RPE = 1.35×10^{-4} deg over 2 seconds.

PINT	TITLE	SPECIFICATION	COMPLIANCE	PERFORMANCE AND COMMENTS
021	Asteroid and comet detection: RPE around payload LoS	6×10^{-3} deg over 2 seconds	C	Roll around payload LoS RPE = 1.15×10^{-4} deg over 2 seconds.
022	Asteroid fly-by: RPE of payload LoS	3×10^{-3} deg over 1 seconds, half cone	C	Half cone RPE = 0.996×10^{-3} deg over 1 second, at closest approach.
023	Asteroid fly-by: RPE around payload LoS	2×10^{-2} deg over 1 seconds	C	Roll around payload LoS RPE = 0.974×10^{-2} deg over 1 second.
024	Comet observation: RPE of payload LoS	3×10^{-4} deg over 1 seconds, half cone	C	Half cone RPE peak value = 7.47×10^{-4} deg over 1 second. The specified peak value of 3×10^{-4} deg is exceeded for < 4.9% of the profile.
025	Comet observation: RPE around payload LoS	6×10^{-3} deg over 1 second	C	Roll around payload LoS RPE = 0.575×10^{-3} deg over 1 second.
030	Asteroid fly-by: AMA of payload LoS	1' half cone, for tracking rates of 1.5°/sec	C	Worst case half cone AMA = 49.98" for VIRTIS, based on prediction of the thermo-elastic distortion with an accuracy of 40%. Note that the maximum tracking rate is 0.28°/sec for both asteroids.
031	Comet observation: AMA of payload LoS	12" for rates up to 10'/sec	NC	Requirement applied to payloads that are calibrated in flight (PL-C payloads). Worst case non-compliance is for VIRTIS with an expected AMA of 36.63" (2σ) half cone, based on prediction of the thermo-elastic distortion with an accuracy of 40%. Once in orbit, refinements of the thermal model are possible to improve the prediction of the thermo-elastic distortion and hence improve the AMA. The anticipated improvement to the AMA for VIRTIS will be a reduction from 36.63" (2σ) to 30.09" (2σ). ***An RFW, (RO-DSS-RW-1021), has been issued on this subject.***

PINT	TITLE	SPECIFICATION	COMPLIANCE	PERFORMANCE AND COMMENTS
	Comet observation: AMA around payload LoS	60" for rates up to 10'/sec	C	Worst case roll around payload LoS AMA = 85.49" for VIRTIS.

Note: C = Compliant. NC = Non-Compliant. PC = Partially Compliant.

Table 16-3: Summary of pointing budgets

16.1.6. On Board Software Memory and CPU Load Budget

The On Board Software budget is derived from the actual values given from the various data packages of the subcontractors for the TR/R or FA/R. For more details please refer to the unit related Budget reports:

DMS Software RO-MMT-RP-2014 issue 4.2 (status FA/R)

AOCMS Software RO-MMT-RP-2031 issue 5 (status FA/R)

PM Firmware RO-SES-TN-2062 issue 5 (status PA/R)

SSMM Software RO-SES-TN-2082 issue 3 (status TR/R)

STR&NavCam Software RO-GAL-RP-2021 issue 5 (status FA/R)

16.1.6.1. DMS and AOCMS Software

The 4 CDMS Processor Modules (PM) are designed to host the DMS and the AOCMS Software. The role of each PM is defined according to the Hardware reconfiguration logic and the PM Firmware. The PM Firmware decides at power-on of the PM from which source (PROM or EEPROM or SSMM) the related Mission Software Image (DMS SW or AOCMS SW) shall be loaded. This Software is started after loading and takes over the control of the PM.

The memory budget of the DMS and AOCMS common elements is ilsted in the following table:

CMDS Memory Budget MA 31750	Code (kwords$_{16\ bits}$)	Data (kwords$_{16\ bits}$)
PROM Cassette (incl. margin for TM packet structure) (for details see [RO-MMT-RP-2014] chapter 5.3) PROM Cassette total	196 DMS image 145 AOCMS image 16 stored OBCP 377 of 512 → 73%	
PM EEPROM total	377 of 512 → 73%	
SGM RAM total		20 of 64 → 32%
SGM EEPROM total		10 of 64 → 16%

The memory budget for these storages is above the 70% limit. The CPU budget needs close monitoring of all changes which might be implemented in the future.

16.1.6.1.1. DMS Memory Budget

DMS Memory Budget MA 31750	Code ($kwords_{16\ bits}$)	Data ($kwords_{16\ bits}$)
DMS PM RAM	122	213 data + 126 OBCP
DMS PM RAM total		461 of 512 → 90%

16.1.6.1.1.1. DMS CPU Budget

CPU Load Budget DMS SW (MA 31750)	CPU load over a 1 second period
DMS scenario A	87.5 %
DMS scenario B	95.3 %
DMS worst case	95.3 %

16.1.6.1.1.2. DMS Budget Assessment

The DMS RAM memory budget is above the required 80%.

The CPU load is high and it is still a matter of concern. It further needs close monitoring of all changes which might be implemented in the future.

16.1.6.1.2. AOCMS Memory Budget

AOCMS Memory Budget MA 31750	Code ($kwords_{16\ bits}$)	Data ($kwords_{16\ bits}$)
AOCMS PM RAM	93.7	79.4
AOCMS PM RAM total		177 of 512 → 35%

16.1.6.1.2.1. AOCMS CPU Budget

CPU Load Budget AOCMS SW (MA 31750)	CPU load over a 1 second period
AOCMS nominal case (SAM, SHM, NM)	58.1 %
AOCMS worst case	80.8 %
AOCMS worst case	80.8 %

16.1.6.1.2.2. AOCMS Budget Assessment

The AOCMS memory budget is well within the requirements.

The worst case CPU load is high. It further needs close monitoring of all changes which might be implemented in the future.

16.1.6.1.3. SSMM Software

SSMM Memory Budget

SSMM Memory Budget DSP21020	Code ($kwords_{48\ bits}$)	Data ($kwords_{32\ bits}$)
SSMM RAM for Init Software	13	3 data + 1 stack
SSMM RAM for Nominal Software	69	83 data + 31 stack 114 of 128 → 89%
SSMM RAM total	82 of 128 → 64%	118 of 128 → 92%
SSMM EEPROM for PFM (Nominal Software)		103 of 128 → 80%

16.1.6.1.3.1. SSMM CPU Load Budget

SSMM CPU Load Budget DSP21020	Value
Total CPU utilization based on a Deadline Analysis (incl. data compression using RICE algorithm, which is the worst case)	91%

16.1.6.1.3.2. SSMM Data Transfer Rates

The limiting factor for the SSMM data transfer rates for the Instruments is the DMS-SSMM link, which has priority. It is dependent on the variation of the actual DMS link rate and on the packet sizes. SES measured typically packet transfer rates in there qualification tests (using packets of size 1576 bytes on the DMS link) These values comply to the requirements.

DMS: 414 kbps

Instr1: 5.0 Mbps

Instr2: 3.2 Mbps

Instr3: 3.2 Mbps

16.1.6.1.3.3. SSMM Filesystem Budget

SSMM Filesystem Budget (DSS assumption)	Data (Mega Byte8 bits)	Data (Mega bit)
Plain files:		
8 DMS SW images (512 kB) to be loaded from SSMM at boot-up (main + redundant file for each PM)	4	32
OBCPs (200 a 8 kByte) (main + redundant file)	3.2	26
Mission Timeline (max. 3000 Cmds stored in 60 files a 512 TM packets each containing one max. TCs a 264 Byte)	8.1	64.9
100 TC packet command files for operational needs (each files+copy a 50 TCs a 256kB) 8 for DMS(512 kB) EEPROM image 8 for AOCMS(512 kB) EEPROM image 2 for STR(512 kB) EEPROM image 2 for CAM(512 kB) EEPROM image	5 4 4 1 1	120
Large file transfer files (4096) each file a 234 Byte uses a filesystem-data-block a 4 kByte	16	128
PL context files (max. 67) (incl. copy) (1 file per PL PID a 4 kByte)	0.5	4.3
Sub-Total	47	376
SSMM internal overhead:		
I-Nodes Each Word Group contains 512 I-Node-Blocks (i.e. in total 30 720 blocks)	120	960
Internal file #FFFC, #FFFD, #FFFE and #FFFF with size 2*5120 Byte and 2*110 kByte	0.234	
Internal Plain file with size 110 kByte 60 free/bad block lists (1 per Word Group)	0.234	
Sub-Total	121	964
Picture files:		
20 NavCam pictures Sub-Total	40	320
Total for all files	208	1660

TM S/C Housekeeping files:		
Avionics HK AVG for 2 days	8kbit/s	1 382
Platform HK AVG for 2 days	8kbit/s	1 382
Total AV+PF HK		***2 764***
Total SSMM filesystem used for NON-experiment data		***4 424 Mbit***
Total SSMM filesystem size (end of life) taking also a single failure into account (1 Memoryboard i.e. 5 Gbit lost) usable for Experiment data		***<u>20 Gbit</u>***
Total SSMM filesystem free for experiment data usage (file size can be allocated in 4 kByte blocks)		***15.7 Gbit*** ➔ 78.4% Free for P/L Data
This leads to the following time period, which can be recorded without interruption. (taking an average Experiment data rate of 50 kbps and an average AV+PF HK rate of 16 kbps)		***➔ 4 867 min.*** ***➔ 81 hours*** ***➔ 3.4 days***

Note 1: Due to the memory segmentation of 4 kByte-Blocks it is recommended for file creation to use multiples of 4 kBytes. This memory segmentation is already taken into account in the above list.

Note 2: The I-Node overhead is also considered in the above list.

Note 3: The Compression Ratio depends on the data contents. If the Experiments provide their data in a "compact" format, the RICE compression will not have a high compression ratio.
Currently the compression gain of memory-space is seen as additional margin.

16.1.6.1.3.4. SSMM Budget Assessment

The SSMM RAM memory budget is above the required 80%. The high value is acceptable because it is based on real measured values and because it contains a big data stack of 33 $kwords_{32bit}$.

The worst case CPU load is high. The 91% CPU load is a measured value of a worst case scenario. The bottleneck is the DMS-SSMM-link. Since this link has high priority and since the software tasks are assigned with different priorities, the consequence of a further increase of the data rate of this DMS-SSMM-link would be a bit rate decrease of the other IEEE1355 links.

The SSMM filesystem is using 14.2% for the nominal operations, which offers a big free area of 85.8% to store the experiment data.

16.1.6.1.4. Startracker

16.1.6.1.4.1. Startracker Memory Budget

Memory Budget (old SDR) STR SW (DSP21020)	Code (kwords$_{48\ bits}$)	Data (kwords$_{32\ bits}$)
STR RAM	90	69
Star Catalogues		46
STR RAM total	90 of 128 → 69%	119 of 128 → 91%
STR EEPROM total	171 of 256 → 65%	

16.1.6.1.4.2. Startracker CPU Budget

CAM SW (DSP21020) Mode	Period (msec)	Measured CPU Load
Standby	1 000	30% (peak 30%)
Cartography Mode	15 000	28% (peak 93%)
Commanded Star Tracking Mode	400	37% (peak 83%)
Autonomous Acquisition and Coarse Attitude Determination	5 000	81% (peak 93%)
Autonomous Acquisition and Fine Attitude Determination	500	59% (peak 97%)
CCD Health Status	500	10% (peak 58%)
CAM worst case CPU load		81%

16.1.6.1.4.3. Startracker Budget Assessment

The STR memory budget is well within the required limits. It is based on detailed real measurements in a representative scenario.

The overall worst case scenario of 81% CPU usage is high. It is base on measured value of a worst case scenario. It further needs close monitoring of all changes which might be implemented in the future.

16.1.6.1.5. Navigation Camera

16.1.6.1.5.1. Navigation Camera Memory Budget

Memory Budget (old SDR) CAM SW (DSP21020)	Code (kwords48 bits)	Data (kwords32 bits)
CAM RAM total	74 of 128 → 56%	65 of 128 → 49%
CAM EEPROM total	100 of 256 → 38%	

16.1.6.1.5.2. Navigation Camera CPU Budget

CAM SW (DSP21020) Mode	Period (msec)	CPU Load
Standby	1 000	30% (peak 30%)
Image Mode	35 000	7% (peak 48%)
Point Target Tracking Mode	625	23% (peak 83%)
Asteroid Mode (SDP enabled)	2500	87% (peak 95%)
Asteroid Mode (SDP disabled)	2500	79% (peak 87%)
STR worst case CPU load		87%

16.1.6.1.5.3. Navigation Camera Budget Assessment

The Navigation Camera software memory and CPU Load budget is well within the required limits. It is based on detailed analysis and resulting in a representative scenario.

The overall worst case scenario of 87% CPU usage is high. It is based on measured value of a worst case scenario. The CPU budget needs close monitoring of all changes which might be implemented in the future.

16.1.6.1.6. Traffic Budget Summary

The traffic to and from the DMS S/W is the sum of all TC and TM packets to be executed and generated onboard. The analysis on this traffic is presented in RO-DSS-TN-1048, "DMS On-Board Traffic Estimation", which is applicable document for the On-board S/W.

The resulting figures are repeated below.

TC Packets	69/sec for 12.5 sec 45sec for 15 sec 21/sec for 1 min 8/sec for 200 sec
TM Packets (i.e. HK, Events, Acknowledges)	117/sec for 1 sec 99/sec for 5 sec 63/sec for 15 sec 51/sec for 1 min 26/sec for 200 sec

The main contributors driving the DMS CPU load are:

TC Packets	
Uplink of MTL commands	
insert at the end	8 TC/sec
others	1 TC/sec
MTL execution commands(delayed)	24 TC/sec
TCs from OBCPs/Aps	19TC/sec
FDIR and monitoring	18TC/sec
TM Packets	
Acknowledges from executed commands	69
TM form Payload (12 science, 5 HK,4events)	21
Events from other applications	14
HK packets(5 DMS/system, 5 AOCMS, 1 STR, 1 CAM, 1 SSMM)	13

In addition the following main limits have to be respected:

Maximum size of “normal” MTL	3000 TC
Maximum size of “short” MTL	117 TC
Maximum number of events for event monitoring	300
Maximum number of parameter monitorings to be loaded	480
Maximum number of parameter monitorings to be active at the same time	180
Maximum number of SIDs available in DMS S/W	43
Maximum number of HK packets to be generated in the same 1 Hz cycle (phasing is possible)	5
Maximum number of parallel time synchronisations	17
Maximum number of parallel connection tests	20
Maximum number of parallel context transfer	
context file per P/L	1
context (P/L to SSMM) per P/L	1
context (SSMM to P/L) per P/L (6 requests can be queued)	1
Information distribution (maximum PIDs per command)	5
Execution rate for TC Files (TC7sec)	1

16.2. Budget Details

For budget details, see the following attached documents:

Unit	Document Title	Doc Number	Issue
SYSTEM	System Budget Summary 'Old'	RO-DSS-TN-1119	2
SYSTEM	Rosetta Platform Technical Budgets Report	RO-MMB-RP-3106	5
DMS	Channel Budget	RO-DSS-RP-1018	3
DMS	DMS On-Board Traffic Estimation	RO-DSS-TN-1048	2

Unit	Document Title	Doc Number	Issue
EMC	Rosetta Magnetic Analysis	RO-DSS-AN-1003	7
EMC	Magnetic Data For Rosetta S/C Units	RO-DSS-TN-1097	3
EMC	Rosetta Platform Radiation Summary	RO-MMB-RP-3220	a
MASS	Mass Budget	RO-DSS-RP-1017	4
MASS	Mass Properties	RO-DSS-TN-1141	7
MASS	Platform Mass Summary	RO-MMB-TN-3153	6
POINTING	Pointing Budget	RO-DSS-RP-1016	4
POINTING	HGAMA FM Pointing Budget	RO-HTS-RP-0002	4a
POWER	Power Budget	RO-DSS-RP-1015	8
PROPELLANT	Propellant Budget	RO-DSS-RP-1014	6
SADAM	SADAM Budget Report	RO-KDA-RP3001	2a
TTC	Rosetta Frequency Plan	RO-DSS-PL-1010	4
TTC	Platform Frequency Plan	RO-MMB-PL-3109	3
TTC	Space / Ground Link Budgets S/X Band	RO-DSS-TN-1025	8.1
TTC	Parametric Study On TT&C Link Budget	RO-DSS-TN-1066	3
TTC	TM Information Bit Rates Throughout The Mission	RO-DSS-TN-1136	1
TTC	Influence Of Solar Noise On Link Budgets	RO-DSS-TN-1132	1

17. APPENDIX 11 – ADDITIONAL DOCUMENTATION RELATED TO MECHANICAL SUBSYSTEM

See attached documents:

Unit	Document Title	Doc Number	Issue
SYSTEM	Spacecraft Mechanical/Thermal ICD	RO-DSS-IF-1201	3
SYSTEM	Rosetta FM Platform MICD	RO-MMB-IF-3104	11
SYSTEM	Input To Mechanisms User Manual	RO-MMB-MA-3103	2
SYSTEM	Flight Model Dynamic Analysis With Deployed Appendages	RO-MMB-TN-3196	2
SYSTEM	Structure FM Sub-System Design Description	RO-PFC-TN-3033	1
SYSTEM	Thermoelastic Distortion & Pointing Asssessment	RO-MMB-TN-3139	3
SYSTEM	Micro-Vibration Analysis Report	RO-MMB-TN-3143	4
SYSTEM	RW Disturbances At MIDAS I/F	RO-DSS-TN-1133	1
SYSTEM	Stowed Structure Flight Model Description	RO-MMB-TN-3194	3
BOOMS	Experimental Booms Subsystem TM/TC ICD	RO-MMB-IF-3110	1
BOOMS	Experiment Booms Technical Description	RO-SEN-TN-3501	2
BOOMS	Experiment Booms – Deployment Mechanism Design Description And Analysis	RO-SEN-TN-3503	1
BOOMS	Booms UM	RO-SEN-MA-3505	1
HGAMA	HGAMA Design Description	RO-HTS-DD-0001	2b
HGAMA	HGAMA ICD	RO-HTS-IF-0001	2d
HGAMA	HGAMA User Manual	RO-HTS-PR-0011	3
HGAMA	HGAMA MICD	RO-MMB-IS-3104	5
SADE	SADE Mechanical Analysis	RO-AEO-AN-3007	2
SADM	Disturbance Torque Analysis Rosetta SADM	RO-KDA-AN-3003	2a

18. APPENDIX 12 – MISCELLANEOUS DOCUMENTS

Further operational relevant documentation is collected in Annex 12:

Document	Doc Number	Issue
RFDDB ICD	RO-DSS-IF-1004	9
RFDDB Parameter Definition	RO-DSS-TN-1087	10
Payload Accommodation	RO-DSS-TN-1045	3
Environmental Disturbance Torques	RO-DSS-TN-1077	1
Rosetta Coordinate Systems	RO-DSS-TN-1081	6d
Venting Of Rosetta Spacecraft	RO-DSS-TN-1098	2
Rosetta FM Platform Equipment ICDs	RO-MMB-IF-3105	7
Platform Design Report	RO-MMB-RP-3162	3
Analysis Of SSP Separation	RO-DSS-TN-1043	2
An Approach For Meeting The Delta-V Accuracy Requirements	RO-DSS-TN-1091	1
Estimate Of Thruster Impact Onto Experiments And HGA	RO-DSS-TN-1093	3a
Operational Constraints Due To Plume Impingement On The HGA	RO-DSS-TN-1108	3
Plume Impingement Analysis on the Rosetta Spacecraft	MOB.NT.CT.3680142.00	1
Finalisation of the Strategy for meeting The Delta-V Accuracy Requirements For SSP Separation	RO-DSS-TN-1172	1
Modifications To The Touch-Up Delta-V Strategy Described In Ro-Dss-Tn-1115, To Avoid Transverse Rate Errors	RO-DSS-TN-1131	1
Fuel Penalty for Dogleg and vect. Manoeuvres	RO-DSS-TN-1165	1
Spacecraft Orientation Geometry For The Stochastic Delta-V Manoeuvres	RO-DSS-TN-1142	1
Deep Space Operations Timeline	RO-DSS-TN-1178	1
Use Of The Baseline Survival Mode Design On A Rosetta Mission To Churyumov-Gerasimenko	RO-DSS-TN-1184	2
URD for EEPROM SW Changes for Use of modified SSAP in DSHM	RO-DSS-RS-1049	2
Proposed Straegy to cope with Power Bus Undervoltage	RO-DSS-TN-1145	2
Rosetta Event/Parameter Monitoring Lists	RO-DSS-TN-1155	2d

Document	Doc Number	Issue
LGA and MGA Strobing on the Rosetta Mission to Churyumov Gerasimenko	RO-DSS-TN-1192	2
STR Straylight Investigation	RO-DSS-TN-1194	2
Radiation Impact Comet Churyumov Gerasimenko	RO-DSS-TN-1199	1

Appendix 13 – Operations Preparations & Support TNs

(These TNs have been delivered after formal issue of RUM 5.1 however they shall be considered as official inputs of the UM)

RO-DSS_TN-1200_2 Mars Eclipse Investigations

RO-DSS-TN-1209_1 Possible Operational Solutions to APM Hot Case Problem

RO-DSS-TN-1210_1 APM in-flight thermal verification

RO-DSS-TN-1211_2 Asteroid fly-bys

RO-DSS-TN-1212_1 Lander_Separation_Test_Investigations

RO-DSS-TN-1213_1 Lander_Separation_Strategy

RO-DSS-TN-1214_1 Earth flyby3 Investigations1

RO-DSS-TN-1216_1 Deep Space Hibernation

RO-DSS-TN-1053_2 Definition of the Rosetta Purging System

RO-MMB-TFX-1385-00 PFM Purge System