HERSCHEL/PLANCK Orbit Data and Access Software ICD

DMS Document: PT-CMOC-FD-ICD-2101-OPS-GFI
Herschel Ground Segment Document: HGS-ICD-020/HGS-ICD-027
Planck Ground Segment Document: PGS-ICD-005/PGS-ICD-018/PGS-ICD-036

Version: Issue 1.1

02/05/2007

Orbit data and access software are provided by Flight Dynamics to support the analysis of scientific data. The interface is described in this document.

Signatures

	Signature	Date		
Custodian:	Frank Budnik 2007.12.05 11:48:02 +01'00'		F. Budnik	OPS-GFI
Agreed:		Digitally signed by Gianpiero di Girolamo (via cjw) DN: CN = Gianpiero di Girolamo (via cjw), C = DE, O = ESOC, OU = OPS-GDS Date: 2007.12.21 12:36:19 +01'00'	G. Di Girolamo	OPS-GDS
	Digitally signed by Kevin Galloway DN: cn=Kevin Galloway, c=NL, o=ESA/ESTEC, ou=RSSD, email=kgallowa@rssd.esa.int Date: 2007.12.04 09:50:32 +01'00'		K. Galloway	HSC
	Damien Texier 2007.11.19 16:25:01 +01'00'		M. McKinnell	PSO
	Laurent Vibert 2007.09.07 18:28:43 +02'00'		C. Mercier	DPC/HFI
	Digitally signed by Andrea Zacchei Date: 2007.11.24 14:51:03 +01'00'		A. Zacchei	DPC/LFI
Approved	Gottlob Gienger 2007.12.13 17:36:36 +01'00'		G. Gienger	OPS-GFT
	CN = Uwe Feucht, C = DE, OU = ESA 2007.12.18 11:47:44 +01'00'		U. Feucht	OPS-GF
Released:			J. Dodsworth	OPS-OA

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4. PAGE	5. PARAGRAPH	6. REASON FOR CHANGE
All	All	New Document Reference
1	1, 1.1, 1.2	Rearrangement of text
1	1.1	Clarification of users vs. systems, JPL Horizons system and MCS removed
1	1.2	Clarification about applicability to mission phases
2	1.3, 1.4	Update of document references
3	1.5	List of Acronyms added
5	2.3	S/W constraint added
5	2.5	Delivery of first orbit file occurs 6 months before launch

7, 8	3.1	Requirements from [AD.4] and [AD.5] added
8	3.3	Requirements on off-line delivery added
9	3.4	Requirements from [AD.4] and [AD.5] added
11	4.1	Description of recipient of products and of type of transfer added
11	4.4	Reference added
13	5.1	Explanation added
13	5.3	Reference to FTS file naming convention added
13, 14	5.4 to 5.10	Reference added
15	6.3	Summary of transferred data and reference added
15	6.4	Error correction: long term orbit file extends up to 2 years into the future
20	8.1.3	Clarification on program usage
21, 22	8.2.2, 8.2.4	Error correction: description of parameter ITSCAL added
22	8.2.6	Description of error code for access to invalid binary files added
25	8.5.1, 8.5.3 and 8.5.4	Clarification on the usage of the sample routine READOF

Document Change Record		DCR NO	3
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2a. DMS DOCUMENT REFERENCE:		PT-CMOC-FD-ICD-2101-OPS-GFI	
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4. PAGE	5. PARAGRAPH	6. REASON FOR CHANGE
i,ii	Signatures & Distribution List	Updated signature and distribution list
1,2,3,13, 15,17-18, 19-20	1.1, 1.2,1.4, 1.5, 5.1,6.3,7, 8	Tailored to the additional delivery of OEMs according to the CCSDS standard; clarification that the delivered access software is NOT usable for an OEM

7- 9	3	Adapted requirements to the latest versions of [AD.2], [AD.4], and [AD.5].
2	1.3 - 1.4	Updated list of applicable and reference documents
13, 15	5.3, 6.4	File name convention changed
1, 3, 11	1.2, 1.5, 4.1 & 4.3	New interface to JPL/Horizons via NHSC added
5, 15-16	2.5, 6.4, 6.5	Clarified destinations and validity and delivery period of long and short term orbit files.
17	7.2	Added date and time of end of orbit reconstruction/start of orbit prediction as comment to the header of the orbit files
5, 13, 15, 28	2.3, 5.3, 6.3, 8.6	Software is updated to FORTRAN 95 standard; Software archive is not transferred via FTS

Table of Contents

1. *Introduction*

1.1 *Purpose*

The ICD describes the orbit data that are made available to the users by Flight Dynamics (OPS-GF). The interface consists of data files and software files. Actual orbit data are delivered regularly in data files. Thereby two different flavours of data files are distinguished: the Flight Dynamics ASCII orbit file (from now on referred to as FD orbit file) and the Orbit Ephemeris Message (OEM) which is the international agreed standard on orbital data exchange.

For the FD orbit file the access to the data is established through the access software which is delivered as FORTRAN source code in the software files. The interface to the orbit data is defined by the description of the calling sequences of the access software. The format of the FD orbit files is not defined in the ICD, as it is completely transparent to the user.

For the OEM no access software is delivered. The format of the OEM is not detailed in this ICD but is defined in [RD.5].

1.2 *Scope*

The ICD is written for all users (systems) that need to have access to orbital data for the missions HERSCHEL and PLANCK:

- FD (FDS);
- HSC (HCSS) and NHSC;
- PSO;
- Data processing centres for Planck HFI and LFI instruments.

The HSC and NHSC receive the orbital data as OEM. All other parties receive the orbital data as FD orbit file (incl. access software).

The ICD is applicable to both missions, HERSCHEL and PLANCK.

The ICD is applicable for all mission phases starting with LEOP (the software archive is delivered only once before launch, and if an update of the software is required).

1.3 *Applicable Documents*

	Document Project ID / Author	Title / Affiliation	Issue	Date
[AD.1]	QMS-EIMO-GSEG-DRD-1207-OPS	ESOC QMS Document Requirements Definition for Flight Dynamics Documentation		
	A. Schütz, R. E. Münch	OPS-GF	Issue 1.5	May 2006
[AD.2]	PT-CMOC-FD-RC-2001-OPS-GFT	HERSCHEL/PLANCK Flight Dynamics Requirements Compilation		
	G. Gienger et. al.	OPS-GFT	Issue 3.2	July 2006
[AD.3]	PT-CMOC-FD-IA-2002-OPS-GFT	HERSCHEL/PLANCK Flight Dynamics Implementation Analysis		
	G. Gienger	OPS-GFT	Issue 1.1	February 2005
[AD.4]	FIRST/FSC/DOC/0117	HERSCHEL Ground Segment Interface Requirements Document		
	HGSSE Group		Issue 2.5	April 2006
[AD.5]	PLANCK/PSO/2002-003	PLANCK Ground Segment Interface Requirements Document		
	PGSSG	ESA/PSO	Issue 3.0	October 2004

1.4 *Reference Documents*

	Document Project ID / Author	Title / Affiliation	Issue	Date
[RD.1]	FIRST/HSC/DOC/0150	HERSCHEL Ground Segment list of ICDs		
	HGSSE Group		Issue 1.9	April 2006
[RD.2]	Planck/PSO/2004-008	Planck Ground Segment Low-Level ICD List and Requirements Compliance Matrix		
	M. McKinnell	SCI-SA	Issue 1.0	October 2004
[RD.3]	PT-CMOC-MDSICD- 3107-OPS-GDS	HP FTS ICD		
	G. Di Girolamo	OPS-GDS	Issue 1.5	February 2007
[RD.4]	Astronomy and Astrophysics	Time Scales in the JPL and CfA Ephemerides		
	E. Standish	JPL, Pasadena	Vol 333, pp381-389	1998
[RD.5]	CCSDS 502.0-B-1	Recommendation of space data system standards: orbit data messages		
	CCSDS	N/A	Blue Book	September 2004

1.5 Acronym List

AOS	Acquisition of Signal
CCSDS	Consultative Committee for Space Data Systems
DDS	Data Distribution System
DPC	Data Processing Centre
FCT	Flight Control Team
FD	Flight Dynamics
FDS	Flight Dynamics System
FTS	File Transfer System
HCSS	Herschel Common Science System
HSC	Herschel Science Centre
ICD	Interface Control Document
JPL	Jet Propulsion Laboratory
LEOP	Launch and Early Orbit Phase
LOS	Loss of Signal
MJD	Modified Julian Day
MOC	Mission Operations Centre
N/A	Not Applicable
NHSC	NASA Herschel Science Centre
OEM	Orbit Ephemeris Message
PSO	Planck Science Office
SPK	Spacecraft and Planet Kernel
STDM	Spacecraft Trajectory Data Message
TDB	Barycentric Dynamical Time
WIMPY	World-map with Station-predictions

2. *Operational Assumptions and Constraints*

2.1 *Communications*

N/A

2.2 *Hardware*

N/A

2.3 *Software*

The software is written in FORTRAN programming language, compliant with the FORTRAN 95 ANSI standard (there are only three minor exceptions in lower level routines: non standard declaration statements REAL*8 and INTEGER*4 and conversion function DFLOAT). The software shall run on any computer with a FORTRAN95 compiler.

2.4 *User*

N/A

2.5 *Timing*

The first orbit file is delivered six months before launch. Updates of the short term orbit file are delivered on a weekly basis after orbit determinations. Updates of the long term orbit file are delivered on a monthly basis after trajectory optimisations.

The access software source code archive is delivered already before launch to allow testing by the users. New versions are only delivered in case a software update is required.

3. Requirements

3.1 Functional Requirements

The following requirements from [AD.2] shall be fulfilled:

R3.5.1.0-16: High level access routines shall allow users to retrieve the position and velocity of each spacecraft. Details of these interfaces shall be contained in the appropriate ICD.

R3.5.1.0-17 Orbit products and auxiliary data required for orbit and attitude control purposes, station scheduling and operations and spacecraft commanding shall be available once per week.

R3.5.1.0-18: The orbit determination and prediction subsystem shall be able to regularly generate the following products:

- Orbit reconstitution and prediction files
- STDM
- WIMPY
- Orbit events files, e.g. AOS/LOS times using the station horizon mask
- Orbit ephemeris messages for JPL/Horizons system.

R3.5.1.0-19 Orbit determination and prediction subsystem shall be able to predict Earth and Moon eclipses and Moon occultation.

R3.5.1.0-20 Orbit product contents and format shall be specified in the appropriate ICD.

R3.5.1.0-21 An automatically generated message shall be sent to FCT, HSC, DPCs and PSO to indicate when updated orbit products are available.

R3.5.1.0-22 Long-term orbit prediction file spanning next 6 months shall be available at launch and on request (for PLANCK, a long term orbit prediction for the up-coming survey will be made available to PSO based on the best knowledge of the expected performance of the orbit maintenance strategy and, in the case of the first survey, the expected orbit at injection to allow long term planning of the scanning strategy).

R3.5.1.0-23 Orbit prediction file covering 2-months shall be available every week.

R4.3.2.1-1: For use in the attitude and mission planning software, two files shall be produced:

- short term spanning two months
- long term spanning two years

R4.3.2.1-2: These files shall be implemented on the FDS (in binary format) and also converted to ASCII format and transferred to the HSC/PSO and DPC as a necessary input for their software

R5.6.0.0-4: All internal and external subsystem attitude and orbit interfaces shall use the equatorial J2000.0 coordinate system with the following exception: for Planck, all attitude information is expressed w.r.t. the ecliptic system of J2000.0, which is more suitable for the scanning law.

The following requirements from [AD.4] shall be fulfilled[1]:

FGS-IR-3.1-120: The MOC shall make available the spacecraft orbit predicted data to the HSC.

FGS-IR-3.1-130: The MOC shall notify the HSC of the availability of spacecraft predicted orbit data updates for a given operational period.

FGS-IR-3.1-140: The HSC shall pull spacecraft predicted orbit data updates from the MOC.

FGS-IR-3.1-350: The MOC shall make available the spacecraft reconstituted orbit data to the HSC.

FGS-IR-3.1-360: The MOC shall notify the HSC of the availability of new spacecraft reconstituted orbit data for a given operational period.

FGS-IR-3.1-370: The HSC shall pull spacecraft reconstituted orbit data from the MOC.

The following requirements from [AD.5] shall be fulfilled[2]:

PGS-IR-4.1-280 The MOC shall make available the S/C reconstituted orbit data to the DPCs and PSO.

PGS-IR-4.1-290 The MOC shall notify the DPCs and the PSO of the availability of new S/C reconstituted orbit data for a given operational period.

PGS-IR-4.1-295 The DPCs and PSO shall pull S/C reconstituted orbit data from the MOC.

PGS-IR-4.1-300 The longest interval for delivery of this data is nominally one week from event.

PGS-IR-4.7-100 The MOC shall make available the S/C orbit predicted data (future predictions) to the PSO. The PSO will use these data for future scanning law planning. The data are expected to be provided in the same format as for reconstituted orbit data.

PGS-IR-4.7-110 The MOC shall notify the PSO of the availability of S/C predicted orbit data updates for a given operational period.

PGS-IR-4.7-120 The PSO shall pull S/C predicted orbit data updates from the MOC.

3.2 On-Line Delivery Requirements

N/A

3.3 Off-Line Delivery Requirements

The following requirements from [AD.2] shall be fulfilled:

R4.2.0.0-1: The FDS shall support a file transfer system comparable in terms of function and interface with the XMM-NEWTON/ INTEGRAL file transfer system. Destination shall be either the Data Disposition System or the SCOS 2000 File Archive System, which shall perform the distribution to the recipients.

1. They have been mapped into those from [AD.2]
2. They have been mapped into those from [AD.2]

R4.2.0.0-2: The FDS shall support electronic notification, to the intended recipients of FDS products, of the availability of such products - the range of notification mechanisms to be defined in [RD.28]. Said mechanisms will also cover warnings (this does not exclude verbal notification during critical operations when FD staff are on-console).

R4.2.0.0-9 The FDS shall provide (weekly) spacecraft orbit data messages to the JPL Horizons system in a CCSDS standard format.

R4.2.0.0-11: The FDS shall support an interface for distribution of reconstituted and predicted orbit data.

R4.2.0.0-27: FD shall deliver software to access reconstituted and predicted orbit data, test data and data updates.

3.4 Performance Requirements

The following requirements from [AD.2] shall be fulfilled:

R3.5.2.0-1 [1]The subsystem shall be able to determine the orbit once a week with the accuracy provided in the following table

	Herschel	**Planck**
position (3σ)	36.3 km	20 km
velocity (3σ)	1 m/s	1 m/s

R3.5.2.0-2 [2]The subsystem shall be able to predict the orbit once a week with the accuracy provided in the following table

	Herschel	**Planck**
position (3σ)	72.5 km	500 km
velocity (3σ)	1 m/s	3 km/s

The following requirement from [AD.4] shall be fulfilled[3]:

FGS-IR- 3-1-145: The position and velocity of the spacecraft shall be predicted to an accuracy of not worse that 72.5 km and 1 m/s.

FGS-IR-3.1-375 The position and velocity of the spacecraft shall be reconstructed to an accuracy of not worse than 36.3 km and 1 m/s.

The following requirements from [AD.5] shall be fulfilled[4]:

PGS-IR-4.1-305 The reconstructed position accuracy shall be 20 km (TBC) and the recon-

1. At the time of writing these requirements are under review and will be probably relaxed .
2. At the time of writing these requirements are under review and will be probably relaxed.
3. They have been mapped into those from [AD.2]
4. They have been mapped into those from [AD.2]

structed velocity accuracy shall be better than 1 m/s with respect to the used reference system.

PGS-IR-4.7-130 The position and velocity of the S/C shall be predicted at any time to an accuracy better than 500 km and 3 km/s with respect to the Earth.

4. *Interface Characteristics*

4.1 *Interface Location and Medium*

The HERSCHEL/FDS and PLANCK/FDS are parts of the Mission Operations Centres (MOC) at ESOC, Darmstadt.

The HSC will be located at ESAC (Spain).

The NHSC will be located at Caltech in Pasadena, CA (USA).

The PSO will be located at ESTEC (Netherlands).

The DPC/HFI will be located in Paris (France).

The DPC/LFI will be located in Trieste (Italy).

The data is distributed electronically.

4.2 *Hardware Characteristics and Limitations*

N/A

4.3 *Data Source, Destination and Transfer Mechanism*

Data source is the FDS related to the mission, i.e. HERSCHEL/FDS or PLANCK/FDS.

Destinations are the MCS data archive and the HSC or the PSO and DPC's, depending on the mission.

The transfer mechanism is the HERSCHEL/PLANCK File Transfer System.

A further destination for HERSCHEL and PLANCK orbital data is the NHSC for the purpose of including them into the JPL/Horizons system. NHSC receives orbital data in form of an OEM from the FDS. The transfer mechanism between FDS and NHSC is FTP. The FDS transfers the HERSCHEL and PLANCK OEMs to the account hporbit on the FTP server nhscdmz1.ipac.caltech.edu which is located at NHSC. After transfer the FDS notifies the following NHSC staff via email about the delivery:

- HERSCHEL orbit file: Babar Ali (babar@ipac.caltech.edu) and Dario Fadda (fadda@ipac.caltech.edu);
- PLANCK orbit file: Babar Ali (babar@ipac.caltech.edu) and Bill Reach (reach@ipac.caltech.edu).

NHSC converts the OEM to the format required by JPL/Horizons (SPK format). The conversion and transfer of orbital data to JPL/Horizons is in the full responsibility of NHSC and not scope of this ICD.

4.4 *Node and Device Addressing*

This is addressed in [RD.3].

4.5 *Relationship with other Interfaces*

The following interfaces between Flight Dynamics and HSC, PSO will make use of the orbit access s/w and orbit files:
- Herschel/Planck attitude utilities and separation angle function;
- Herschel/Planck attitude constraint checker;
- Herschel/Planck slew time and path predictors.

5. Access

5.1 Programs Using the Interface Data

Access to the FD orbit files is done via the supplied access routines (see section 8). The access to an OEM is the responsibility of the recipient.

5.2 Failure Protection, Detection and Recovery Procedures

See [RD.3]

5.3 File Naming Conventions

The files have the following naming convention:

File	File Name	Extension
Short Term FD Orbit File	xyyyymmdd_vvvv	SOF
Long Term FD Orbit File	xyyyymmdd_vvvv	LOF
Short Term OEM	xyyyymmdd_vvvv	SOE
Long Term OEM	xyyyymmdd_vvvv	LOE
Access Software Source Code Archive	xyyyymmdd_vvvv	OAS

where

- - x is the spacecraft identifier: x = H for Herschel; x = P for Planck;
- - yyyymmdd is the creation date of the file;
- - vvvv is the version number of the file. Updates of the files on the same date will have different version numbers.

Each orbit data file is sent via the FTS wrapped up in a tar file. The naming convention of the wrapper files are provided in [RD.3].

The orbit access software archive is provided via the Flight Dynamics FTP server.

5.4 Storage and File Deletion Requirements

For nominal operations, only the latest version of the orbit files (short term and long term) are required.

5.5 Security Requirements

N/A

5.6 Data Integrity Checks

Flight Dynamics Test and Validation will check and authorise each orbit file and the supplied access routines.

5.7 Backup Requirements

The HPMCS will provide an archive including access to the auxiliary data products for 10 years after the end of the mission.

5.8 Input/Output Protocols, Calling Sequences

N/A

5.9 Synchronisation Requirements

N/A

5.10 Error Handling

See [RD.3]

6. Detailed Interface Specifications

6.1 Data Structure

N/A

6.2 Generation Method

FD orbit files and OEMs are generated by the HERSCHEL/PLANCK Flight Dynamics orbit determination subsystem.

6.3 Data Passed Across the Interface & Transfer Direction

- short term FD orbit file / OEM;
- long term FD orbit file / OEM;
- access software source code archive.

For the transfer directions of orbit data files see [RD.3]. The access sofware archive is provided by FDS on the FDS FTP server and can be pulled by the relevant parties from there.

6.4 Size and Frequency of Transfers

Typical sizes of the files are:

- - 2000 KB long term FD orbit file (LOF);
- - 500 KB long term OEM (LOE);
- - 200 KB short term FD orbit file (SOF);
- - 50 KB short term OEM (SOE);
- - 700 KB software source code archive (OAS).

Versions of the short term files are delivered weekly, versions of the long term files once before launch and subsequently once per month. The software archive is delivered only once before launch (and if an update of the software is required).

The time span covered by each version of the long term orbit file extends from launch up to end of mission.

The time span covered by each version of the short term orbit file extends from launch up to 2 months into the future.

6.5 Summary

The following table summarises the destinations of orbit files of different flavour and validity period. Thereby the delivery frequency and file sizes of the previous two sections do apply.

Table 1: Destinations of orbit files of different flavour and validity period.

	SOF	LOF	SOE	LOE
	HERSCHEL			
HSC	-	-	X	X
NHSC	-	-	-	X
	PLANCK			
PSO	-	X	-	-
DPC/HFI	X	X	-	-
DPC/LFI	X	X	-	-
NHSC	-	-	-	X

7. Data Definition (Files)

FD delivers two flavours of orbit files which are both in ASCII:

- FD orbit file;

- Orbit Ephemeris Message (OEM).

7.1 File Characteristics

7.1.1 FD orbit files & software source code archive

The FD orbit files (SOF and LOF) are ASCII files. The ASCII file is **not** intended to be read directly by the user, but to be converted into binary format which can be read with the access software. Therefore, the definition of the ASCII format is not provided here.

The software source code archive (OAS) is a tar archive that contains several ASCII files. The archive shall be extracted, e.g. using the ‘tar’ command: ‘tar -xvf <filename>’. One of the extracted ASCII files is a ‘readme’ file that contains information about the software, its usage and installation.

7.1.2 OEM

The OEMs (SOE and LOE) are ASCII files. The OEM format is described in [RD.5]. No software is delivered for accessing or converting an OEM.

7.2 Header Records

7.2.1 FD orbit files

Two commentary lines are added to the header (each preceded by the word “COMMENT”). One gives the date and time when the orbit reconstruction ends and the orbit prediction starts and the other gives the version of the planetary ephemerides to which the orbital data is consistent with. The rest of the file header is of no relevance to this interface and is not further detailed here.

7.2.2 OEM

The header is defined in [RD.5]. All obligatory keywords are used as described therein. The keyword ORIGINATOR is set to ESOC.

Two commentary lines are added to the header. One gives the date and time when the orbit reconstruction ends and the orbit prediction starts and the other gives the version of the planetary ephemerides to which the orbital data is consistent with.

7.3 Data Records

7.3.1 FD orbit files

N/A

7.3.2 OEM

The OEM metadata is defined in [RD.5]. All obligatory keywords are used as described therein. Some of them have fixed values which are:

OBJECT-NAME = HERSCHEL or PLANCK;

OBJECT-ID = until launch 9999-999X; after launch as given in [RD.5];

CENTER_NAME = EARTH;

REF_FRAME = EME2000;

TIME_SYSTEM = TDB.

In addition the following non-obligatory two keywords are used:

INTERPOLATION = LAGRANGE;

INTERPOLATION_DEGREE = 8.

The OEM data is given as defined in [RD.5].

7.4 File Example

7.4.1 FD orbit files

N/A

7.4.2 OEM

```
CCSDS_OEM_VERS = 1.0
CREATION_DATE  = 2006-05-31T13:16:28
ORIGINATOR     = ESOC

COMMENT Start of prediction / end of reconstruction: 2008-02-29T13:51:01 TDB
COMMENT Orbit data are consistent with planetary ephemeris DE-405


META_START
OBJECT_NAME          = HERSCHEL
OBJECT_ID            = 9999-999X
CENTER_NAME          = EARTH
REF_FRAME            = EME2000
TIME_SYSTEM          = TDB
START_TIME           = 2008-02-29T13:50:50.989755
STOP_TIME            = 2008-02-29T13:57:27.706562
INTERPOLATION        = LAGRANGE
INTERPOLATION_DEGREE = 8
META_STOP

2008-02-29T13:51:01.006402        6647.147017         243.931002        -781.861415   -0.573975   10.613836   -2.321356
2008-02-29T13:51:11.036076        6640.946227         350.365646        -805.090941   -0.662491   10.609877   -2.310753
2008-02-29T13:51:21.077559        6633.849545         456.878724        -828.239770   -0.750952   10.604498   -2.299837
2008-02-29T13:51:31.133090        6625.853790         563.479588        -851.309647   -0.839330   10.597698   -2.288609
2008-02-29T13:51:41.205144        6616.955254         670.179938        -874.302782   -0.927600   10.589476   -2.277073
2008-02-29T13:51:51.296295        6607.149731         776.992461        -897.221558   -1.015737   10.579831   -2.265231
2008-02-29T13:52:01.409188        6596.432522         883.930380        -920.068419   -1.103716   10.568764   -2.253086
2008-02-29T13:52:11.546514        6584.798430         991.007265        -942.845836   -1.191513   10.556277   -2.240641
2008-02-29T13:52:21.711007        6572.241758        1098.236946        -965.556282   -1.279103   10.542369   -2.227899
2008-02-29T13:52:31.905440        6558.756296        1205.633463        -988.202221   -1.366464   10.527042   -2.214863
2008-02-29T13:52:42.132629        6544.335318        1313.211042       -1010.786104   -1.453569   10.510298   -2.201536
2008-02-29T13:52:52.395427        6528.971570        1420.984084       -1033.310360   -1.540396   10.492139   -2.187921
2008-02-29T13:53:02.696732        6512.657264        1528.967159       -1055.777402   -1.626921   10.472569   -2.174021
2008-02-29T13:53:13.039486        6495.384062        1637.175004       -1078.189615   -1.713119   10.451589   -2.159839
2008-02-29T13:53:23.426677        6477.143072        1745.622525       -1100.549367   -1.798966   10.429204   -2.145380
2008-02-29T13:53:33.861343        6457.924832        1854.324802       -1122.858997   -1.884440   10.405417   -2.130646
2008-02-29T13:53:44.346576        6437.719297        1963.297094       -1145.120825   -1.969515   10.380232   -2.115642
2008-02-29T13:53:54.885522        6416.515829        2072.554845       -1167.337144   -2.054169   10.353654   -2.100370
```

8. Data Definition (Software Routines)

This section is NOT applicable for OEMs but only for FD orbit files.

The access software reads the data only from binary direct access files. To allow the transfer of data between machines which are not binary compatible, orbit data are made available in ASCII format. The access software source code archive contains:
- a utility (as2bin.f) to convert the orbit file from ASCII to binary format on the target platform.
- a library of subroutines and functions to be compiled and linked into the user application (OASW)
- a sample program to demonstrate the usage of orbit (readof.f) data retrieval.
(The archive contains additionally a sample program to demonstrate the usage of attitude data retrieval. This feature is not applicable for HERSCHEL and PLANCK.)

The times scale of the orbit files is barycentric dynamical time (TDB), for its definition see [RD.4].

The time format of the orbit files is MJD2000 which is a continuous time format used at ESOC. The time in this format is given in days since the reference epoch 2000 January 1, 0 hours. (Note that the reference epoch is **not** J2000.0 = January 1, 2000 12h but January 1, 2000 0h!).

The reference frame is the mean Earth equator frame of equinox J2000.0 (= 2000 January 1, 12h TDB = JD 2451545.0 TDB).

Orbital data are provided as geocentric states in the reference frame.

To access an orbit state at a certain epoch from a FORTRAN application program the following steps are necessary:

- 3 top level FORTRAN subroutines (rofcl.f, rofop.f and rofrr.f) and a series of low level subroutines have to be transferred from the DDS. The subroutines have to be compiled on the target platform and linked together with the application program.
- An orbit file covering a period which contains the desired epoch has to be transferred and converted into binary format by using the FORTRAN program as2bin.f.
- The application program has to open the orbit file by a call to rofop.f.
- By a call to subroutine rofrr.f the state is found.
- After retrieval of all required states the orbit file is closed by a call to subroutine rofcl.f.

The design of the software allows the user to access several (up to 8) orbit files at the same time. For this he has to call rofop.f with every file he wants to open as input in the calling sequence. Of course for each call a new unit has to be provided. From the calls to rofop.f the user gets for every orbit file a corresponding internal identifier which he can use to retrieve an orbit state from the respective orbit file.

The low level subroutines are only called by top level subroutines and thus remain invisible to the user.

A description of the top level subroutines, the conversion routine as2bin.f and the example program readof.f is provided in the following sections.

8.1 Program as2bin

8.1.1 Routine Name and Description

AS2BIN: Converts an orbit file from ASCII format into binary format.

8.1.2 Calling Sequence

N/A

8.1.3 Input Parameters

The following input parameters are prompted by the program on the command line:

File name of existing orbit file in ASCII format that is to be converted.
File name of not existing orbit file in binary format to be generated.

8.1.4 Output Parameters

N/A

8.1.5 Return Codes

N/A

8.1.6 Restrictions on use

The orbit file to be converted must have a valid ASCII format as delivered by the FDS.

8.2 Subroutine rofop

8.2.1 Routine Name and Description

ROFOP: Opens an orbit file and gives relevant information

8.2.2 Calling Sequence

Name	Format	Dimension	Input/Output
IUNIT	INTEGER	1	Input
FNAME	CHARACTER*132	1	Input
IORDER	INTEGER	1	Input
NVARS	INTEGER	1	Output
IFRAME	INTEGER	1	Output
IBODY	INTEGER	1	Output
ITSCAL	INTEGER	1	Output
TBEG	DOUBLE PRECISION	1	Output
TEND	DOUBLE PRECISION	1	Output
IF	INTEGER	1	Output
IER	INTEGER	1	Output

8.2.3 Input Parameters

Name	Content
IUNIT	Unit to where orbit file shall be opened
FNAME	Name of orbit file to be opened
IORDER	Requested order of interpolation, here always 8 shall be used

8.2.4 Output Parameters

Name	Content
NVARS	Number of variables stored in orbit file, here always 6

Name	Content
IFRAME	Identification of reference frame, here always 0 (=mean equator and equinox of J2000.0)
IBODY	Identification of default central body for output state, here always 3 (=Earth)
ITSCAL	Identification of time scale, here always 0 (=TDB)
TBEG	Start time of orbit file (MJD2000 format, TDB time scale)
TEND	End time of orbit file (MJD2000 format, TDB time scale)
IF	File identifier of orbit file for subsequent use in routines 'rofrr' and 'rofcl'
IER	Return code: 0 = no error 1 = unable to open file 2 = unable to read additional parameters 3 = too many files open

8.2.5 Return Codes

See output parameter IER in previous section.

8.2.6 Restrictions on use

The orbit file to be opened must have a valid binary format as generated by 'as2bin'.
If a user program tries to open a file with invalid binary format using subroutine ROFOP, the error code 1 (=unable to open file) is returned.

8.3 Subroutine rofrr

8.3.1 Routine Name and Description

ROFRR: Retrieves state from orbit file

8.3.2 *Calling Sequence*

Name	Format	Dimension	Input/Output
IF	INTEGER	1	Input
TIME	DOUBLE PRECISION	1	Input
STATE	DOUBLE PRECISION	6	Output
IFRAME	INTEGER	1	Output
IBODY	INTEGER	1	Output
IER	INTEGER	1	Output

8.3.3 *Input Parameters*

Name	Content
IF	File Identifier of orbit file as returned by rofop
TIME	Epoch of state which is requested in MJD2000 time format and TDB time scale

8.3.4 *Output Parameters*

Name	Content
STATE	Orbit state of S/C: first 3 parameters = position in km last 3 parameters = velocity in km/s
IFRAME	Identification of reference frame, here always 0 (=mean equator and equinox of J2000.0)
IBODY	Identification of central body for output state, here always 3 (=Earth)

Name	Content
IER	Return code: 1 = TIME too early 2 = TIME too late 3 = TIME in a gap 4 = error getting additional parameters 5 = error can't read block header 6 = invalid identifier

8.3.5 Return Codes

For definition, see output parameter IER in previous section.

8.3.6 Restrictions on use

A valid orbit file in binary format must have been opened before using 'rofop'.

8.4 Subroutine rofcl

8.4.1 Routine Name and Description

ROFCL: Closes an orbit file previously opened with rofop

8.4.2 Calling Sequence

Name	Format	Dimension	Input/Output
IF	INTEGER	1	Input
IER	INTEGER	1	Output

8.4.3 Input Parameters

Name	Content
IF	File Identifier of orbit file as returned by rofop

8.4.4 *Output Parameters*

Name	Content
IER	Return code: 0 = no error 1 = unable to close file 2 = invalid identifier

8.4.5 *Return Codes*

See output parameter IER in previous section.

8.4.6 *Restrictions on use*

The orbit file to be closed must have been opened before using ‘rofop’.

8.5 *Program readof*

8.5.1 *Routine Name and Description*

READOF: Sample program to demonstrate the usage of the access software. This is a simple test program to be invoked from a command shell with all input and output provided on the command line.

8.5.2 *Calling Sequence*

N/A

8.5.3 *Input Parameters*

The following input parameters are prompted by the program on the command line:

File name of existing orbit file in binary format as generated by ‘as2bin’.
Unit number to where orbit file shall be opened.
Epoch of state that is requested in MJD2000 time format and TDB time scale.

The program enters a loop when requesting the epoch such that more than one state can be retrieved. If the epoch 0 is typed at the prompt, the program exits the loop.

8.5.4 *Output Parameters*

For each requested epoch, the orbital state is printed by the program to standard output on the command line.

8.5.5 Return Codes

N/A

8.5.6 Restrictions on use

The orbit file to be used must have a valid binary format as generated by ‘as2bin’.

8.6 Running environment

The software code is compliant with the FORTRAN 95 ANSI standard (there are only three minor exceptions in lower level routines: non standard declaration statements REAL*8 and INTEGER*4 and conversion function DFLOAT). The software shall run on any computer with a FORTRAN95 compiler.