Integral

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Mission Extension Operations Review, 2012

Spacecraft Status

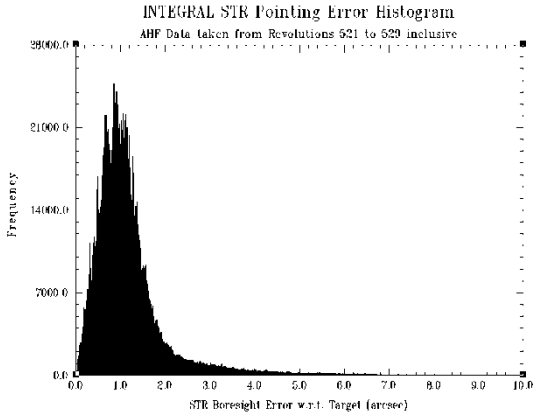
- From MEOR 2010
  - Changes only
  - Areas not mentioned in this presentation, assume currently no change

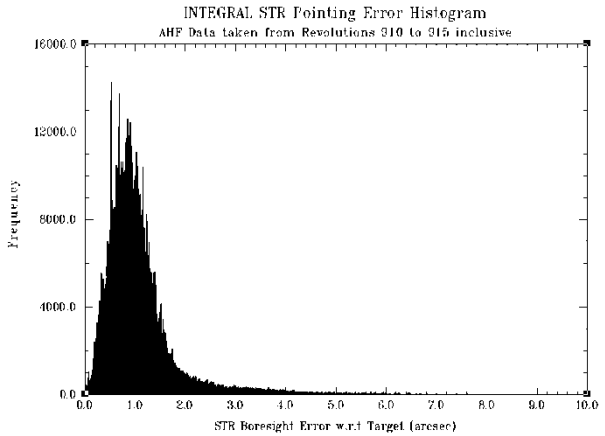
Summary of Subsystem Statuses

- Attitude and Orbital Control Subsystem (AOCS)
  - All prime units in use, full redundancy available – no change, slight STR degradation
  - Sufficient margin on limited lifetime units – no change
  - Sufficient fuel – no change
- Electrical Power Subsystem (EPS)
  - All prime units in use, full redundancy available – no change
  - Array degradation less than predicted, sufficient margin – degradation has increased due to low perigee, sufficient margin still available
  - No noticeable battery degradation
- On Board Data Handling Subsystem (OBDH)
  - All prime units in use, full redundancy available – no change
- Radio Frequency Subsystem (RFS)
  - All prime units in use, full redundancy available – no change
  - Link margin sufficient – no change
- Thermal Control Subsystem (TCS)
  - All prime units in use, full redundancy available – no change
- **Currently no Hardware issues which could limit lifetime** – no change

AOCS / RCS - Hardware

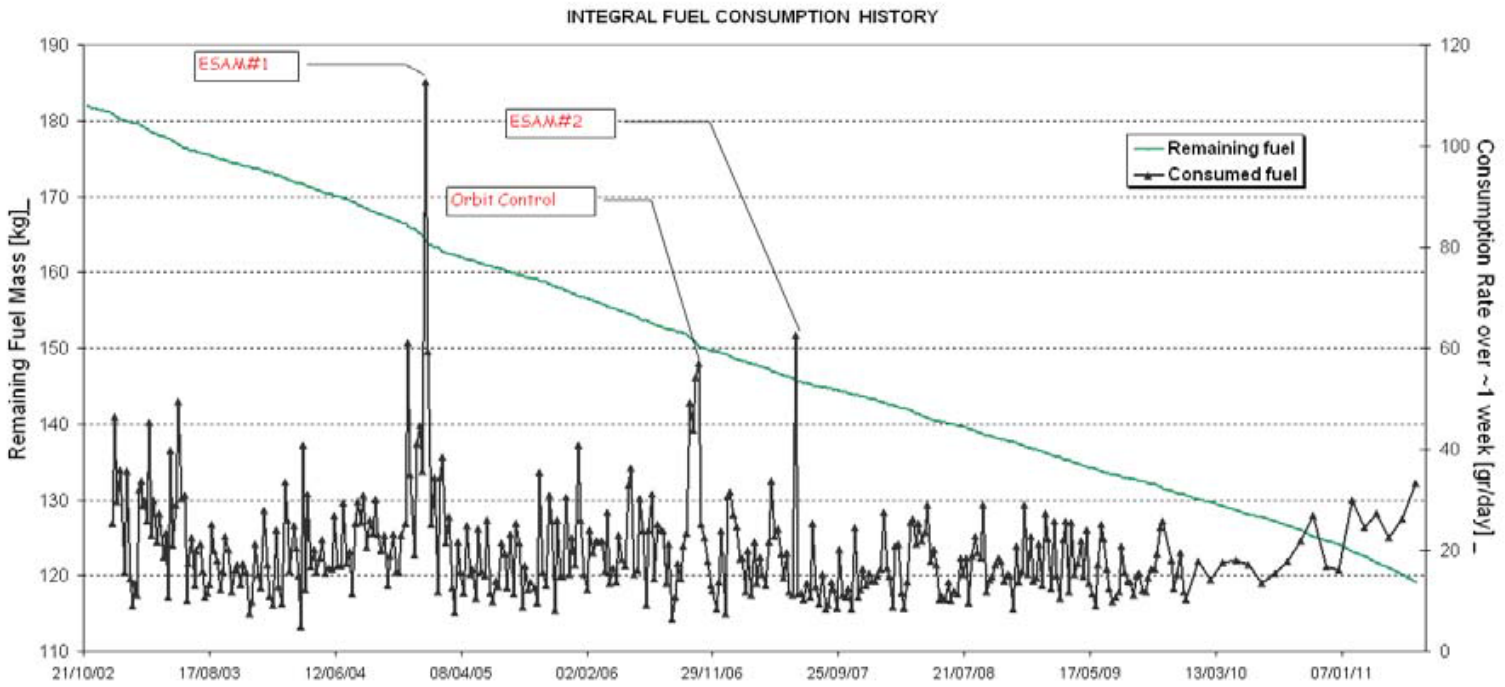
- Star Tracker shows **only slight degradation**, 5 blemish pixels plus another 4 suspect (out of 110000 total) – now 21 suspect (probably due to Proton exposure at low perigee), use of on board blemish pixel table is being investigated, STR2 still available
- No memory patches in ACC or STR - – no change
- AOCS performance is **well within specifications**:
  - Periodic calibrations of Sensors and Actuators display consistent results – no change
  - Two emergency mode entries (ESAM) to date, both fully recovered – no change
- Pointing and Slew performance is well within specifications and effectively **unchanged since last MEOR**. – no change





AOCS / RCS – Fuel Consumption

- Fuel Consumption rate remains unchanged
  - Remaining Fuel 30/4/2010: 128.5kg (now 115.4) estimated
  - Lifetime at current usage: **14.5 years more** (incl. 3,5% uncertainty and 1 ESAM per year) – no change
  - Capacity to be verified using P.V.T method as XMM – done, in line with estimate

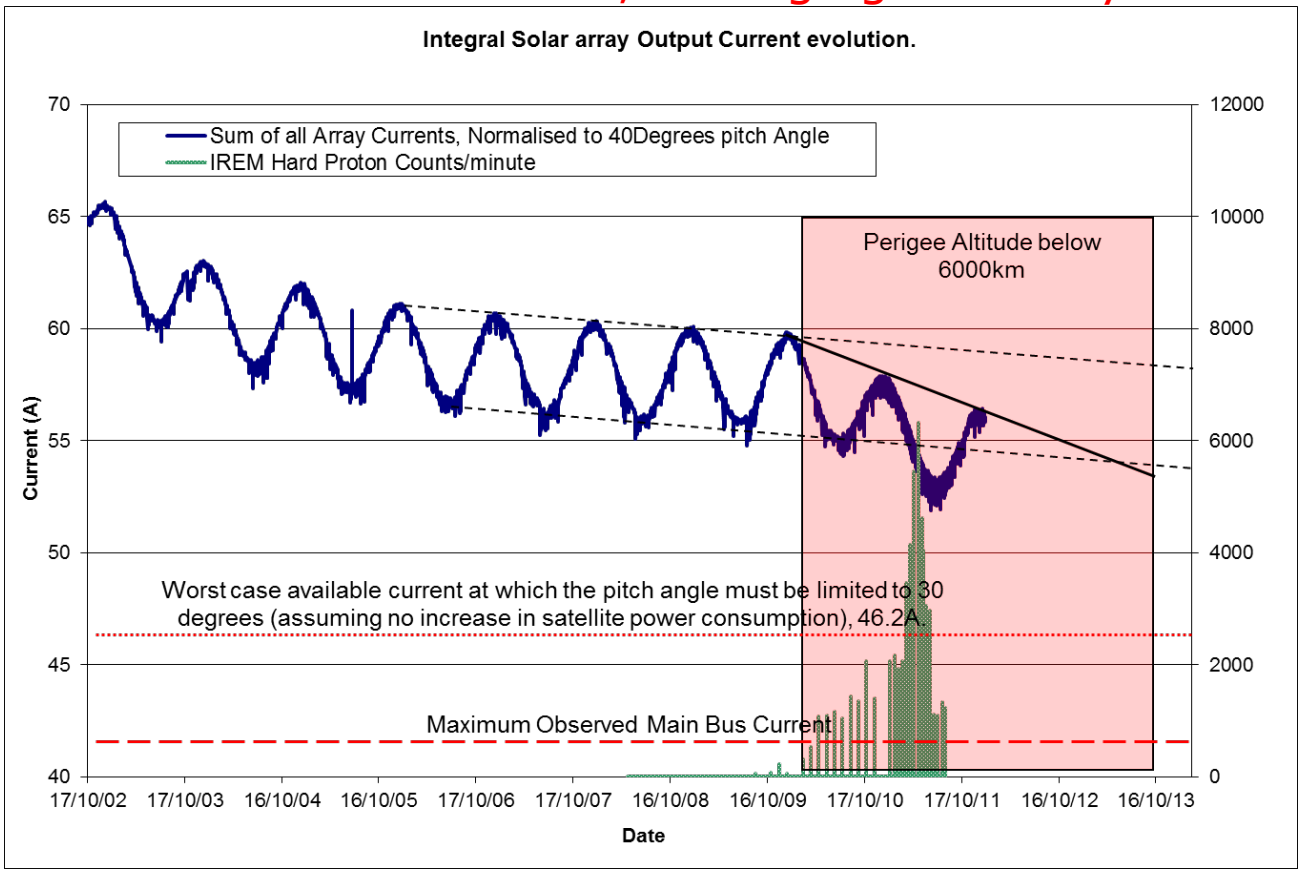


AOCS / RCS - Anomalies

- RMU-A LCL switch-off (occurred 2x) due to SEU in SPDU:
  - Critical, as RMU used for rate control in emergency mode
  - Mitigated by OBM entry which will switch the RMU on again within 24 seconds.
- 2 ESAM entries:
  - Both times ESAM executed nominally
- 2 memory corruptions affecting units selection in Failure Detection Electronics
- Increase in Loss of guide Star Events during perigee, probably due to intense proton radiation, probably temporary phenomenon.
- No significant new anomalies

EPS Hardware – Solar Arrays

- Linear projection of worst case power output at current rate shows **generous power margin at end of 2014**
- Effect of proton belts passage is unknown – see "Areas of Concern". - now visible, damaging but not yet constraining

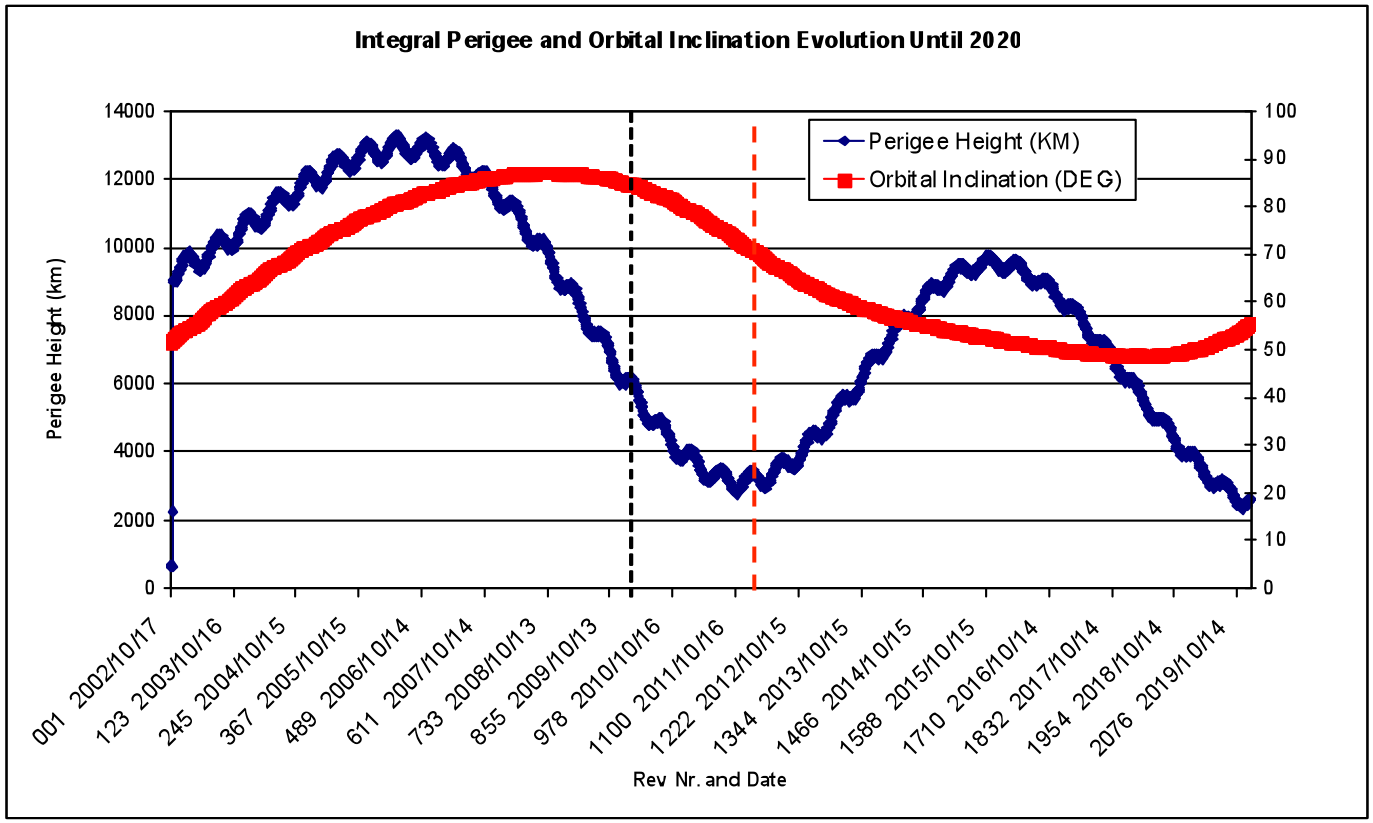


RFS - Hardware

- Due to the evolving perigee altitude Integral will start to break ITU regulations in late 2010. => transmitter to be switched off and back on via time-tagged command every perigee. – now done every revolution.
  - Outside ground station visibility => **no impact on operations**
- **Transmitter 2 functionality** re-verified in March 2010
- RFDN switching strategy is to cycle the use of RF switches at a frequency of about once per year (to maximize the use of both switches in their BOL state):
  - Rate of switching is about 270/year.
  - Switchings to date are:
    - SWA: 978 (1245)
    - SWT: 1039 (1336)
  - During the test campaign pre-launch, identical switches were successfully tested for up to **10000** hot switchings
    - Minor degradation observed after 4000 switchings, but Performance still within requirements.

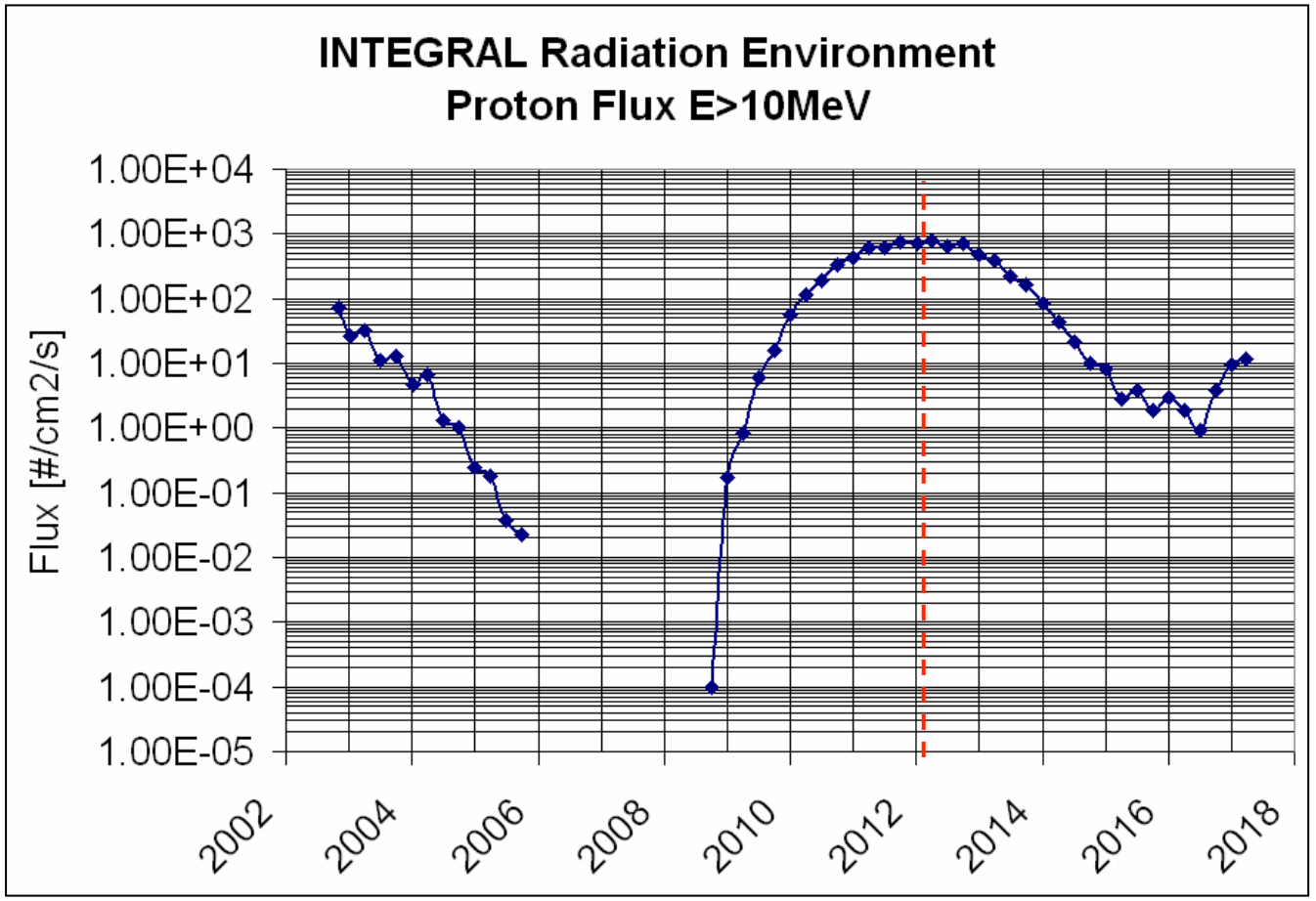
Areas of Concern – Radiation Environment

- Perigee altitude falls to **2800km in late 2011**.
  - Minimum perigee passed
- Inclination drops from 87deg to about 55deg in late 2014



Areas of Concern – Radiation Environment

- Leading to a large increase in **Proton radiation** Exposure



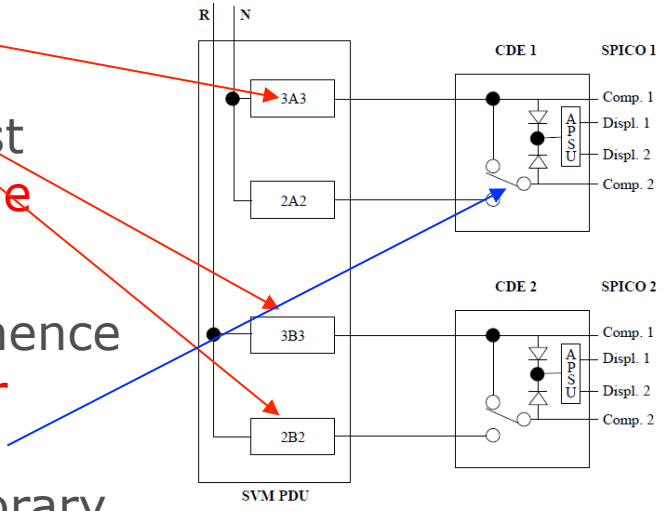
Predicted flux based on AE-8 and AP-8 models

Areas of Concern – Radiation Environment

- SVM units total dose to exceed qualification levels:
  - By end of 2012, by maximum 6%
  - By end of 2014, by 30 – 35%
- Qualification Limit is 1.5 * calculated dose for nominal 5 year extended mission
- The above statements also apply to the **electronic components of the Payload** as they were developed under the same conditions as the platform units
- Increased rate of SEUs or degradation / failure of components may occur
  - **Use of redundant units**
  - **Force changes in operational strategy / procedures**
- **So far little effect seen:**
  - **Increased Array degradation**
  - **Increased STR suspect blemish pixels**
  - **No increase in SEUs**
  - **PLM???**

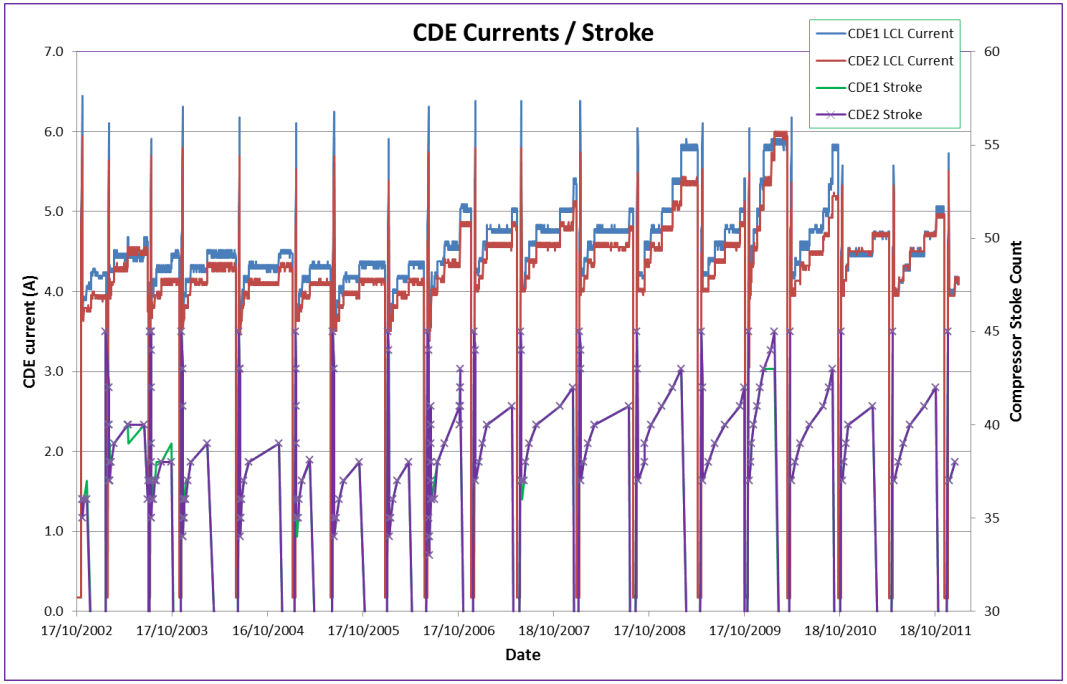
SPI Cryocooler

- Compressor Drive Electronics (CDE) power supply configuration:
  - CDE1 (Master) powered via 1 LCL
  - CDE2 (Slave) powered via 2 LCLs
  - 2-LCL configuration of CDE2 more robust
  - LCL1 also now powered in twin LCL mode
- Anomalies affecting Cryocooler:
  - CDE1 power relay command failure -> hence CDE1 still powered only via 1 LCL- sensor failure
  - CDE2 LCL switched off by SEU ->temporary degradation in performance, recovered at annealing
- Cryocooler has behaved absolutely nominally to date



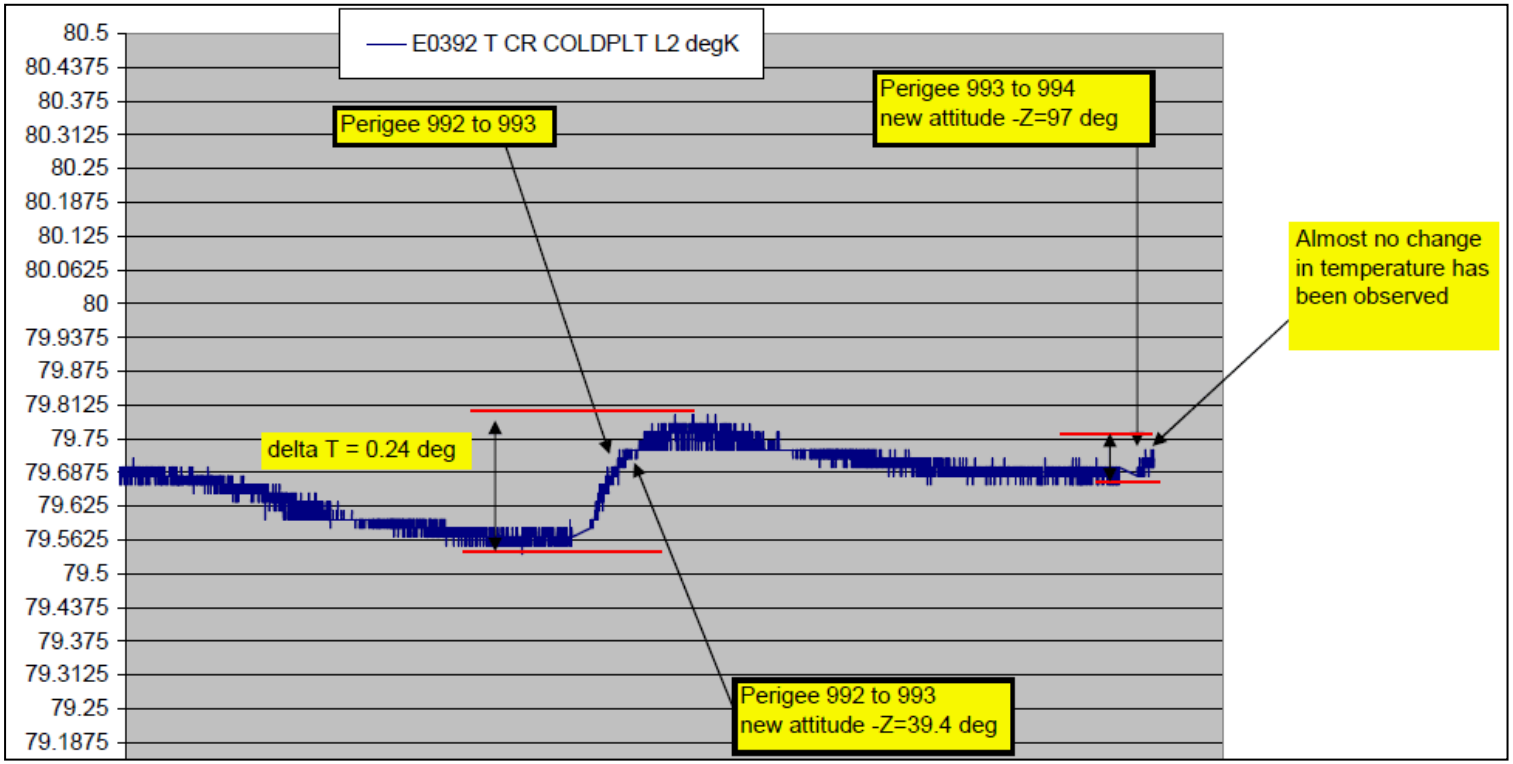
SPI Cryocooler

- CDE power consumption vs stroke setting remains stable
- Seasonal temperature increase at perigee, combination of earth albedo / low perigee - Mitigated by selecting special perigee attitude.
- CDE LCL current stable also at high stroke
  - **Can continue 80K operations (maximise time between annealings)**
  - CDE LCL current stable also at high stroke
  - CDE power consumption vs stroke setting remains stable



SPI Cryocooler

- Seasonal temperature increase at perigee, combination of earth albedo / low perigee –
  - Mitigated by selecting special perigee attitude.
  - Effect will decrease as perigee height raises
  - Probably not necessary with perigee above 6000km

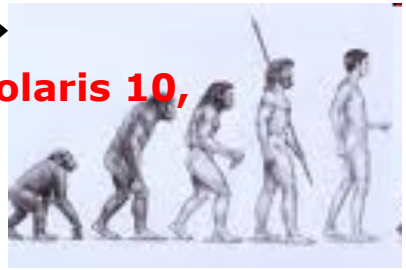


Instruments
Summary and Conclusions

- All instruments' health is nominal – no change
- Full redundancy is still available – no change
- All instruments can be operated using nominal procedures – no change
- SPI Cryocooler operations are stable – no change
- Minor performance degradation, not impacting overall science return (see C. Winkler, P. Kretschmar)
- No effects of proton belts seen so far on any instrument – no change??tbc
- Good and close co-operation with all PI teams – no change
  - E.g. Relocation of IBIS DPE equipment at ESOC, which will facilitate onboard SW maintenance
- Telemetry bandwidth margin is sufficient and will probably improve with new solar cycle – no change
- **No open issues for continued operations** – no change

Integral MOC - Data Systems

- Proposed **MCS Evolution** →



  - Migrate Current S2K 3.1 based MCS to **LINUX SLES11, now Solaris 10, virtualisation**
- Justification:
  - SPARC processor clients can no longer be purchased
  - **S2K 3.1** designed to run under both **Solaris and LINUX**
  - LINUX compatible Hardware **costs much lower** than Sun
  - **Integral MCS has been built against LINUX (SLES9) and runs**
    - some errors in mission specific applications
  - SLES11 OS and Hardware supported until **at least 2016 (Solaris 10 longer)**
  - **Commonality** of HW OS and COTS with many other ESOC missions
  - Very low porting effort in combination with XMM, ROS, MEX, VEX
  - Virtualisation allows use of common facilities and Gaia facilities
- We will take this opportunity to **reduce the amount of computer hardware** (~20 processors XMM / INT combined):
  - Sharing with XMM and Use of more powerful modern processors
- Development Cost / Effort to be **shared with XMM**
- Simulator Evolution is covered in XMM presentation
  - Possible emulator solution – VMS emulation

Integral MOC - FCT

- Integral and XMM FCTs combined and reduced in line with MEOR 2007 recommendation:

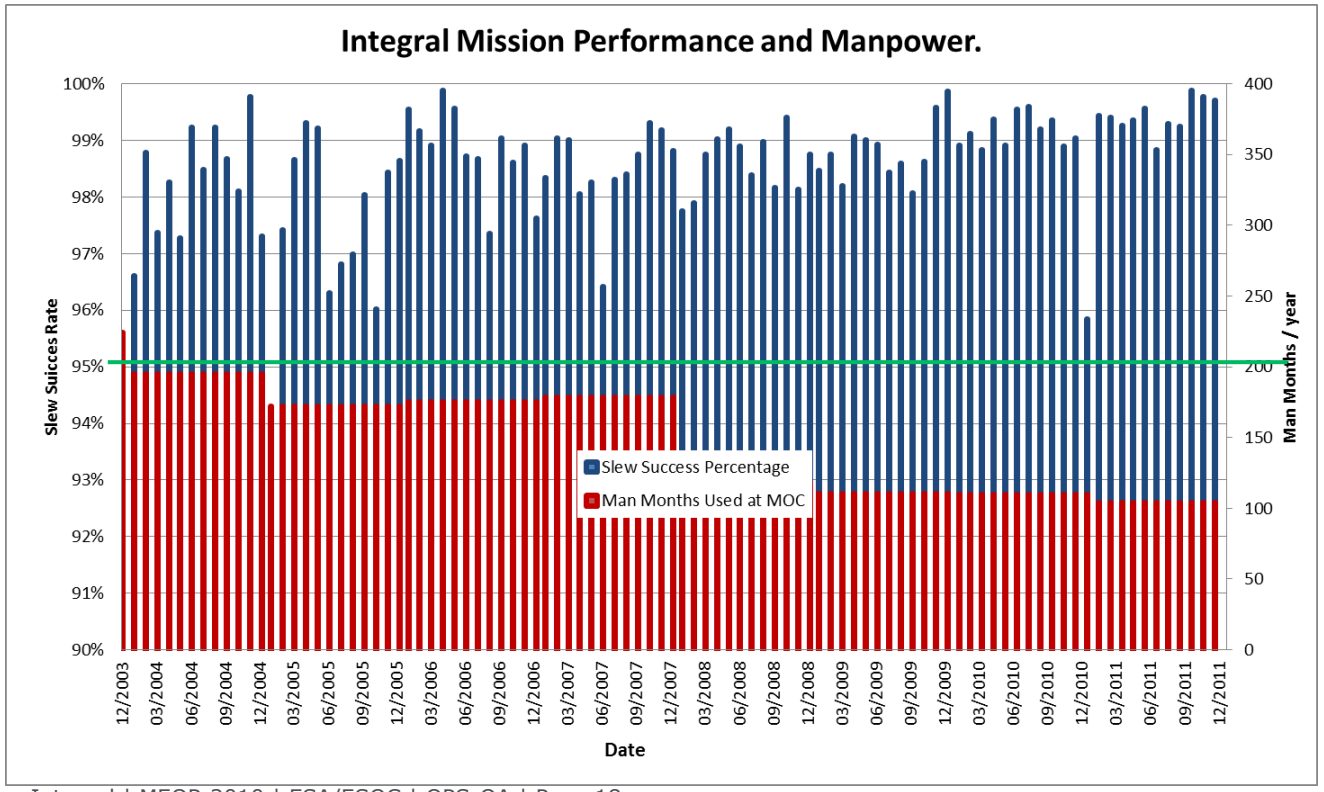
	INT	XMM (pre MEOR 2007)
SOM	1 (1)	1 (1)
SOE	3 (5)	4 (5)
Analyst	1 (2)	1 (2)
SPACON	3 (6)	3 (6)

- SOMs assigned individually but act as back-up for one another – no change
- SOEs assigned individually, but with **back-up functions** for the 2nd mission
  - 1 new shared SOE for MCS porting validation (1.5 years tbc)
  - Some sharing of SOEs with other missions - Gaia
  - **On-call shared** between the missions
- **SPACONs fully shared**, 1 controller controls both missions simultaneously – no change

Integral MOC - FCT

No degradation in mission performance following merger / reduction – no change.

- Performance measure is number of completed slews (about 1000 slews per month planned)
- Slew execution requires reliable functionality of entire ground segment
- Yearly manpower figures also plotted.



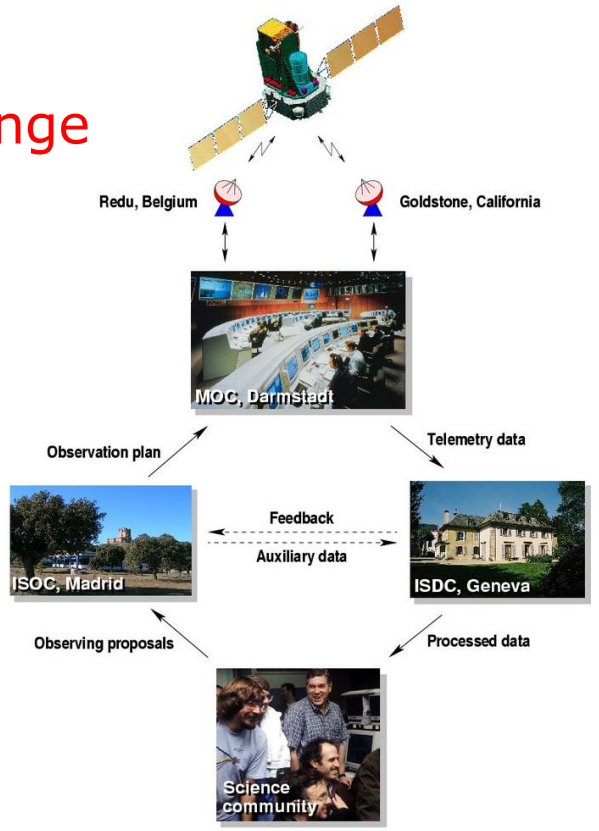
Integral MOC – Networks and Communications

ESA Internal

- ESOC Networks infrastructure – No change
- ESA inter site connectivity – No change
- Shared resources which will remain available to integral – No change

ESA external

- Communications to DSN and Weilheim
  - Shared resources which will remain available to integral – DSN no longer used
- Communications to ISDC
  - To be upgraded in 2010 – done new Hardware, reduced monthly costs



Integral MOC – ESA Ground Stations

ESA Ground Stations configured to support Integral:

- REDU: prime station – 95% of support
- VIL2: main back-up in case of unavailability of REDU / DSN
- MSP: back-up in case of unavailability of REDU, VIL2 and DSN, hardly used
- Perth: can provide visibility close to perigee, hardly used

- REDU completely available to Integral

until after 2014

- A few short periods of maintenance
- Gap in visibility opens up in late 2014
  - TBD by ESOC FD if this gap can be delayed or even removed.
  - This gap cannot be covered by another European station
  - Use of Kiruna being investigated

Integral MOC - Ground Station Visibility

- Station Visibility Evolution (REDU, DSN)