INTEGRAL Users Group, SOM

Richard Southworth

01/12/2021

ESA UNCLASSIFIED – For ESA Official Use Only

Contents

- Flight Control Team + MOC
- Orbit
- Z-flip
- Gyro slew (GSL)
- Safe Mode
- Array Degradation
- Instrument Operations
- AOB

Flight Control Team

- Richard Southworth (Ops Manager, System, @80%)
- Jutta Huebner (Ops Engineer, P/L @50%)
- Ian Benson (Ops Analyst 100%)
- Marius Baab (Systems Analyst @50%)
- Dave Salt (Ops Engineer, AOCS, also 50% XMM) – retired in November, not replaced
- Liviu Toma (Ops Engineer, AOCS, also 50% XMM)
- Stefano De Padova (Ops Engineer, MCS + OBDH , also 50% XMM)
- Timothy Finn (Ops Engineer, RFS, P/L, also 50% XMM)
- Norbert Pfeil (Ops Engineer, EPS + TCS + MCS, also 50% XMM)
- Thomas Godard (Ops Engineer, AOCS + automation, also 50% XMM)
- Arnfried Magunia (Ops Engineer, Ops support systems, also 50% XMM)
- Greta De Marco (Ops Engineer, PLM, Planning + automation, 100%) – new (replaces B Gandolfo)

Temporary support:

- Jim Martin (On-board software modifications, GSL, Safe Mode)

MOC

No major activities currently ongoing

Ground Stations

- VIL1, VIL2 and MSP (INTA) tested and available, good performance
- Goonhilly tested and available, good performance
- KIR availability, reliability and coverage are still very good
- Orbital evolution means these 4 station will each have almost full science visibility from end 2022
- Perigee coverage by DSN, KRU – safety mitigation

Mission Control System Evolution in 2023

- Hardware Upgrade with only minor software modifications

On Board Software Maintenance System (OBSMS) from Industry pre launch has failed

- Ported to VM without extra HW component (loss of some test capability)
- AOCS patch developed, tested and compiled in 2021

All other systems + support stable

Orbital Evolution

Perigee altitude fell below 6000km in 2018

- Mid 2021 ~1500km (lowest ever, now increasing)
- End 2025 ~4500km

2010 - 2013 perigee below 6000km, impact:

- Increased rate of SA degradation (SAS, AAD)
- Thermal effects due to Earth Albedo – SPI

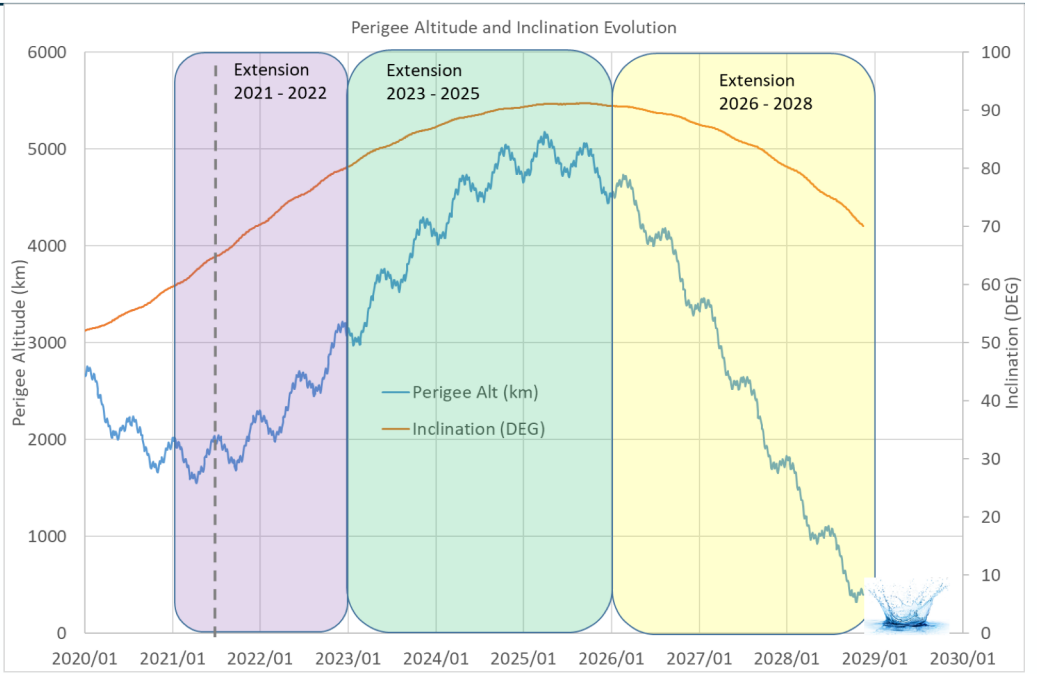
Same symptoms expected from early 2018…

- SA degradation less than expected
- No thermal impact on SPI
- Possible increase in SEU type events below 2000km

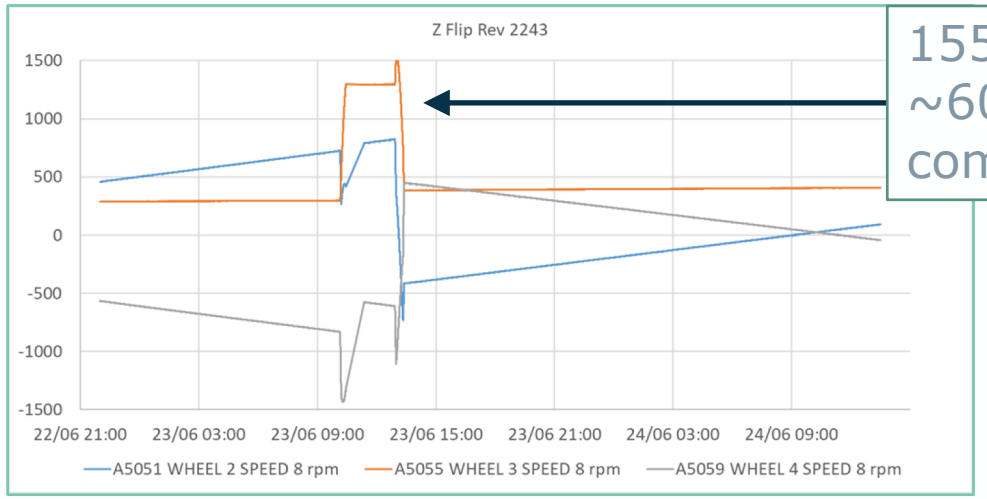
Inclination also increasing => improves European station coverage

In line with earlier predictions

Evolution very stable / predictable since thruster use inhibited

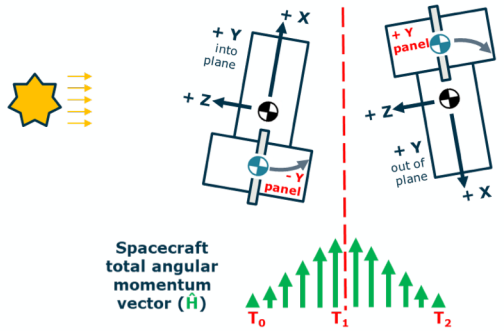


Z-flip



155° Z-flip
~60 hours drift compensated

Z-flip theory (D Salt)



By rotating the satellite around the sun line (Z-axis) over a planning period the angular momentum stored in the reaction wheels can be controlled

This can be done using multiple manoeuvres of various sizes

- The full range of pitch and roll angles remain available

FD Tools deployed to SOC to assist them in planning and assessing angular momentum control (as well as science!)

Full range of unconstrained attitudes is still available to SOC

- The sequence of attitudes is now important

We can still do everything we could do before the propellant anomaly.

The pointing direction is not constrained

Gyro Slew

Z-flip requires large slews about the sun line (Z) to redistribute angular momentum between the wheels

- Such slews constrained by starting angular momentum, can become unstable leading to attitude control loss

  => Z-flip slews to reduce angular momentum must be initiated with low angular momentum!!
- May force Science Operations Planners to move away from targets earlier than they wish to
- Potentially impacts target of opportunity response
  - Before initiating a large slew we may need to manage angular momentum (dummy attitude?)

AOCS Software patch **developed and deployed** to use gyroscope output as (Z) attitude reference

- Z-flip slew constraint no longer applicable - increase wheel speed range
- De-constrains planning and fully restore performance (maybe even improve!)
- Some safety aspects also included in patch
- Ultra Fast ToO (<2 hours) – new capability for INTEGRAL **(faster than before RCS failure!!)**
  - No need to plan / control momentum with bias or Z-flip beforehand

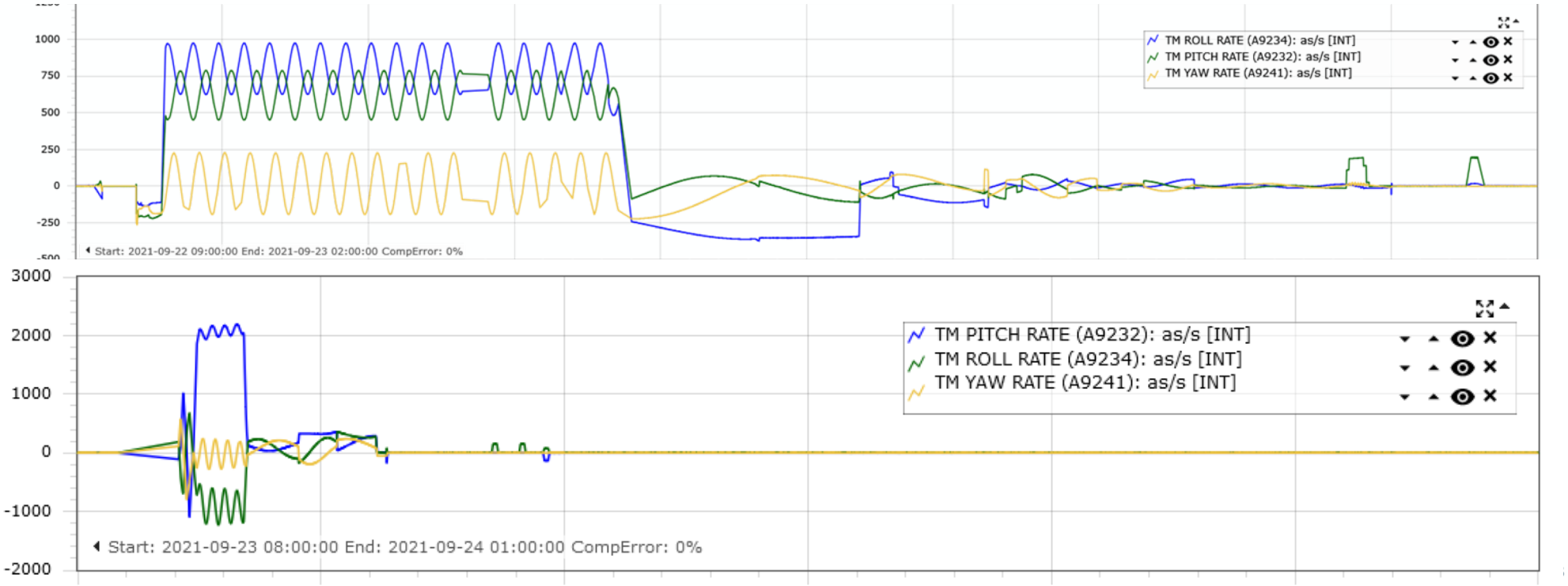
AOCS / RCS - Attitude Loss Recovery

Recovered by direct commanding of wheel speeds using ‘on the fly’ tools developed by FD (industry confirmation)

- Tools now part of FD INTEGRAL toolset
- Equivalent tools and procedures developed by FCT
- New on-board Safe mode should prevent this

Automated ground procedure under test to intervene fast and prevent such an attitude loss event again

2nd event recovered much faster using tools and experience from 1st event



AOCS / RCS - Safe Mode!

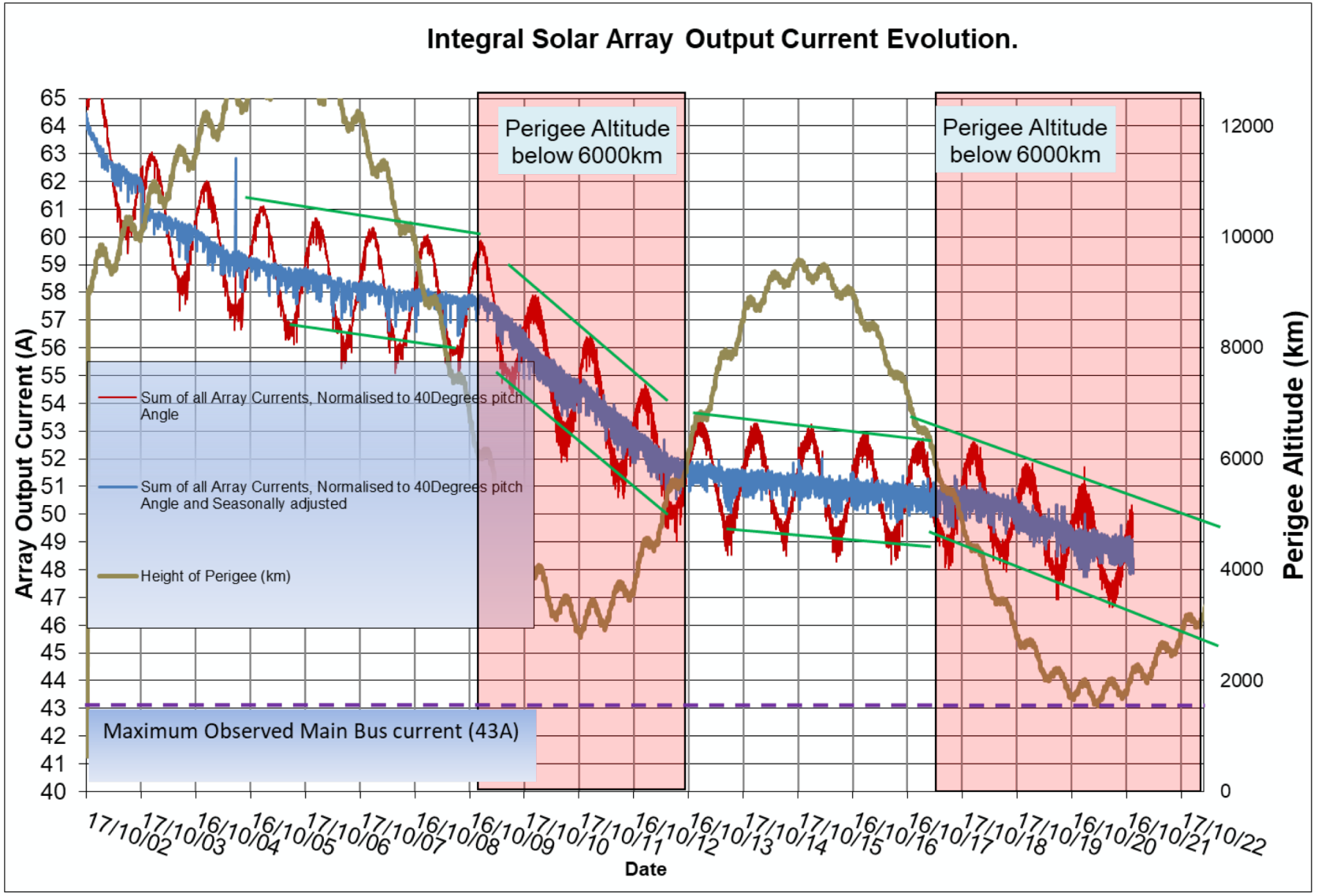
Science capability restored, what about safety?

- Thruster based safe mode is no longer reliable (now disabled)
- Remaining actuators are the reaction wheels – **known to be healthy (we even have a working spare)**

Clear concept based on use of existing control modes on board the satellite

- Sun Sensor Acquisition (SSA) Mode is thruster controlled mode
    - Thrusters are now isolated!
    - From ground we can command reaction wheel momentum demands in SSA
    - Allows open loop control of satellite attitude from ground
- Can cope with high body rates using reaction wheels only
- Simulations demonstrate that this allows recovery from failures at least as extreme as those in September
    - Many cases already simulated using equivalent ground procedures
- General safe mode to recover from multiple failures, same entry conditions as existing safe mode
- Design and development ongoing
- Target Completion by end 2022

Solar Arrays



Degradation 2018-2021 less than feared

No Power budget restrictions before end 2025

- In line with TEC study (2020)

Battery health complements array capacity

ECL Signal false trigger

- Low risk before end 2023
- Strategy in place
- Constrain science attitudes (7%) for about 90 days / year

Instrument Operations

IBIS delayed activation at the start of the rev:

- Activation by the proton belts at perigee results in excess flux for IBIS/VETO and IBIS/ISGRI post perigee. PIs requested to delay activation by 40 minutes. Test mission planning products will be circulated soon for verification and validation of the new approach.

Superfast TOOs with initial staring observation at ToO attitude already 1-2 hours after ToO approval

- It has been agreed between FCT, FD and ISOC how to best implement superfast ToOs. Test mission planning products will be circulated soon for verification and validation as well as review of the current RPOS process.

OMC EU A Power Supply Failure

- After the loss of attitude on 22nd September OMC power supply could not be restarted
- Routine operations since then using power supply B.

Estimate of the next annealing & effect due to the cryo-cooler switch-off for recovery of the attitude anomaly:

- Irradiation of detectors not impacted by attitude anomaly => next annealing about 04/03/2022, with outgassing of the cold box to get rid of additional pollution due to the heating up during recovery of the attitude anomaly
- Current MOC tentative planning, pending possible further input from PI.