FEEDBACK FROM IN ORBIT PERFORMANCES

Grégory Personne, Airbus DS

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Feedback From In Orbit Performances – Airbus DS ENS fleet

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Airbus DS in-orbit fleet for Earth Observation, Navigation & Science - Key facts

- ✓ **66 satellites launched since 1983**
- ✓ **Over 521 years accumulated in orbit**
- ✓ **42 operating satellites currently**
- ✓ **More than 7 years lifetime in average**
- ✓ **Record lifetime for Soho >20 years in operations… still running!**

⇒ **Available telemetry provides substantial data for performance analyses**

… and in-orbit unexpected events to investigate and resolve across the fleet

Airbus DS is organised to maximize the benefits from in-orbit experience

Global vision:

- In-flight experience is a key asset and shall **influence future designs**
- "test as you fly, fly as you test"… I**n orbit conditions are unique** vs fidelity of ground testing: space environment, mission duration vs ageing, actual mission profiles, etc.
- In-orbit support cover both anomalies investigation/resolution and in-orbit experience return
  => **Deserves dedicated effort / organisation to 'mine this gold'**

Transnational network in place Airbus DS

- To improve and structure the in-orbit experience sharing and capitalisation
- To organize access to /sharing of this information (dedicated portal)
- Information sorted out per technical domains (MSC)
- Addressing anomalies / unforeseen events and actual in-orbit performances
- Transnational coordinated network with one focal point per ENS satellite
- Synergies with Telecom Satellites In Flight Support

Dedicated powerful & efficient tool

- Telemetry management tool TELMA for regular mass-data archiving & processing

Strong willingness to improve Spacecraft design using in-orbit feedback

Objective

To use the In-orbit performances to influence and optimize future designs at Airbus DS:
- master the right level of margins (while securing missions)
- simplify process or design
- master achievable performances on key topics

Methodology

Selection of key topics each year with strong expectations on concrete results and achievements and in coordination with ENS programs.

Collect in-orbit data to analyse and challenge the current sizing hypothesis.

Analysis carried out with lean methods: ease the sharing and dissemination of this information.

Status

A few analyses already completed covering various domains (solar array sizing, image post-processing, orbit prediction/propagation, sloshing dynamics, GPS performances,….)

More studies planned for 2016 and beyond: thermo-elastics, radiations, battery ageing, etc.

Results: some concrete applications and results in the area of
- satellite design enhancement
- margin management consolidation
- designers mindset evolution

Feedback From In Orbit Performances – how?

Collect & archive data from satellites in orbit

- ✓ **Raw telemetry**
- ✓ **Ground Control data (FDS, TC)**
- ✓ **Flight Events e.g. anomalies, manoeuvers**

Collect the needs for data analysis from

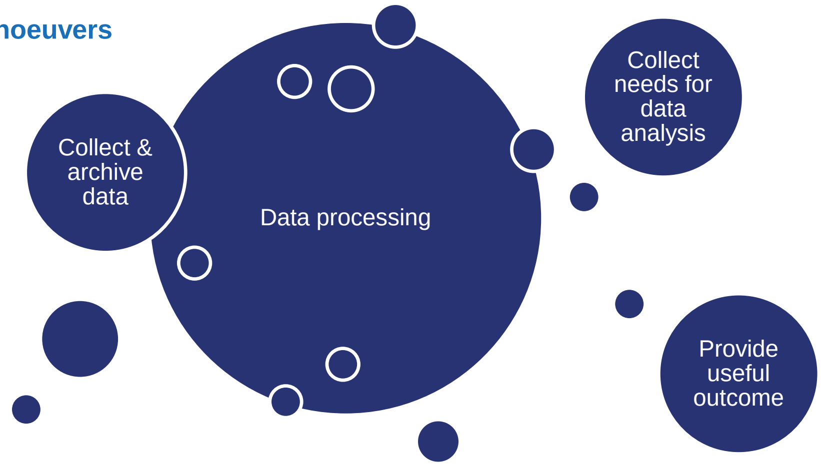
- ✓ **Spaceraft Designers**
- ✓ **Customers/Operators**

Process the data

- ✓ **Mass-data analysis**
- ✓ **Focused investigations**

Provide readily useful outcome

- ✓ **Knowledge briefs**
- ✓ **Performance files**
- ✓ **Event statistics**
- ✓ **Requirements for design enhancement for**
  - ➢ **improved in-orbit support**
  - ➢ **Performances & availability optimization**



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Example of in-orbit feedback: Optimization of power sizing

Facts:

- recent LEO missions often exhibit large in-orbit energy margin.
- Battery ageing usually better than anticipated after a few years in orbit
- After a thorough analysis, 2 main causes of SA over-design put forward
  - Power sizing assumptions too conservative (at S/C PDR level) : margin+ summation rules, failure cases, mission scenario, thermal analyses.
  - Solar array performance better than predicted.

Results:

- issue of recommendations for the different stakeholders implied in the SA sizing (System Engineer, Power & Thermal MSC, SA supplier).
- Application to program e.g. co-engineering with SA subcontractor
  - Consolidation of the design drivers and maturity of requirement at system level.
  - Assessment of the technology maturity with supplier.
  - Agreement with the supplier of the sizing rules and margin policy.
- Additional benefit: optimisation of Thermal Control sizing method to avoid overdesign.
- Consolidated assumptions on Platform Product Line to avoid over-sized battery.

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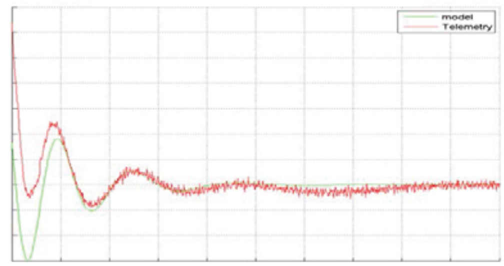
Example of in-orbit feedback: Dynamic Impact of Fuel Sloshing

Fuel sloshing dynamic impact on agile satellite

- In orbit performance: analysis of the dynamic impact of fuel sloshing on agile satellite during manoeuvres, in term of frequency&damping and impact on satellite pointing.
- Achievement: characterization of damping (higher than prediction) and frequency ; comparison with actual on-ground modelling and update of parametrization to get a best fit ; sensitivity to remaining fuel mass
- Applications: consolidated hypothesis for S/C with high-demanding pointing requirements and/or large on-board sloshing mass.



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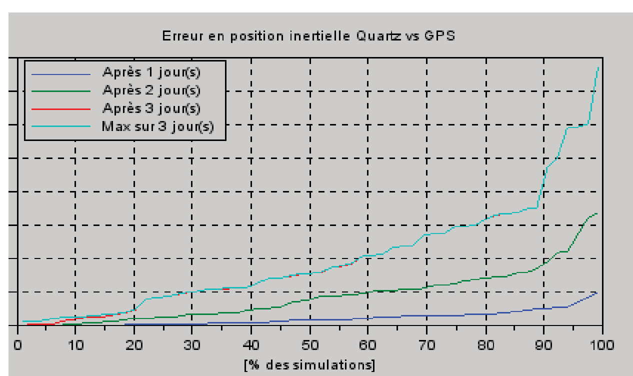
Example of in-orbit feedback: Orbit Propagation on-ground

- In-orbit performance: analysis of orbit propagation performances with current Airbus DS in-house tool (Quartz) and process.
- Achievement:
  * assessment of actual performances for orbit predictions over 3 days
  * identification and test of improvements: upgraded model, management of solar activity prediction
  * assessment of mission analysis performances (orbit maintenance).
- Applications:
  enhanced processing for orbit propagation



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Example of in-orbit feedback: Propellant Gauging

Thermal propellant gauging technics (TPGT)

- This technic can be used in complement to usual gauging technics like PVT and dead reckoning .
- It is an independent and absolute method that **allows improving overall gauging accuracy especially when remaining mass is low**.
- It consists in heating the tank in orbit , analysing the tank thermal evolution and measuring the thermal tank inertia then deriving the propellant mass in the tank.
- Extensive in-orbit experience has been gained in Telecom on Eurostar tanks including propellant passivation with experience return on near EOL gauging measurements.

- Achievements:

* application to Alphasat with specific tank thermal H/W and ground thermal calibration of tank ,
* adaptation to MEX and VEX with Eurostar tank design but no calibration on ground and no specific thermal H/W

=> Operational difficulties on MEX as the heaters were not powerful enough, several consecutive tests were proposed to achieve accuracy with a statistic approach.

- Applications:

* Embedded case-by-case on upcoming satellites from product line

-limitations:

-not well suited for cases with large propellant mass e.g. controlled reentry

What's next?

Standardised TM data collection & archiving, with support from our customers

Continuation of focused data analysis
- Achieved performances
- Events statistics

Closing the loop with satellite designers
- Collecting the needs
- Supporting on-demand requests
- Fostering the benefits of in-orbit Return of Experience

Airbus DS are exploring new avenues in the field of data mining for
- Early detection of anomalies
- Machine learning & behaviour forecast

Thanks for your attention