DETAILED FDI ANALYSIS OF AOCS MODE

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ABSTRACT

A R&T study has been performed in 2014-2015 by Thales Alenia Space for ESA (contract n° 1-7565/13/NL/MH) for the detailed FDI analysis of a new AOCS de-orbit mode.

Currently a heritage AOCS/FDIR is often reused from missions to missions with only some add-ons or tailoring for some specific requirements.

The FDIR development and definition process comes late in the projects and is not properly addressed in the early architectural design and trades. This limits thus the AOCS FDIR capabilities in terms of observability, response time and availability.

In addition the new space debris mitigation regulations impose additional constraints on the AOCS requiring a robust de-orbit function with demanding reliability at end-of-life.

Because of all these reasons, there is an emerging need to develop improved safe and de-orbit modes and to reassess the AOCS/FDIR architectures which are currently not always fully satisfactory.

There is finally also a need to develop a generic FDIR development approach for the AOCS to take into account FDIR inputs/outputs since the early design phases of the project (A/B1) and allow for an optimal trade-off between various system architectures.

OBJECTIVE OF THE STUDY

The main objective of this study was to

- to develop an improved and as far as possible generic AOCS SAFE and de-orbit modes valid for different classes of LEO missions and considering also the new de-orbit requirements,
- an improved and as far as possible generic FDIR architecture for SAFE and de-orbit modes allowing the execution of post-mission disposal operation in a safer and reliable manner,
- to develop an improved and as far as possible generic AOCS FDIR development process for all phases of a project, especially the early design phases allowing for trade-off between various system architectures.

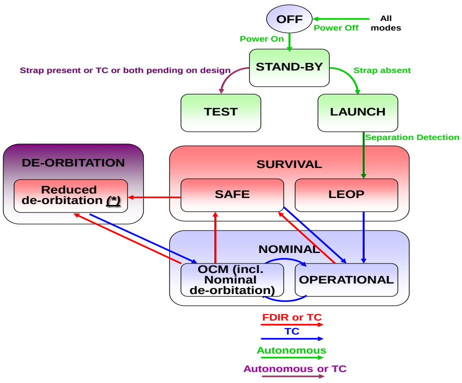
STUDY ORGANIZATION & ACTIVITIES

In order to achieve these objectives the whole study has been organized in three main phases:

1. Requirement definition & development process whose main activities have been to :
    - Identify the relevant classes of LEO missions with their typical needs, constraints and influence on the current FDIR strategies;
    - Analyse and derive a detailed set of AOCS/FDIR and deorbit requirements;
    - Draft a generic FDIR development process and design framework for AOCS.
2. Architecture trade-off and conceptual design whose main activities have been to :
    - Trade-off and assess the feasibility of an optimal (minimal complexity and design robustness to changes) AOCS/FDIR architecture;
    - Perform a preliminary design of a generic AOCS and FDIR for the de-orbit mode, considering commonalities with other modes of common LEO missions;
    - Conduct FMEA and RAMS analyses in order to justify the AOCS/FDIR conceptual design and to evaluate the probability of success of the post-mission disposal operations.
3. Detailed design & performance demonstration whose main activities have been to :
    - Detail the design of the AOCS/FDIR architecture for the de-orbit mode;
    - Develop a proof of concept simulator and a validation plan;
    - Demonstrate the AOCS/FDIR performance through simulation.

STUDY RESULTS

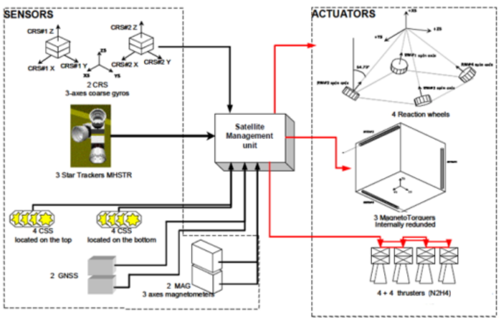
A new AOCS de-orbit mode valid for different classes of LEO missions have been derived in the frame of this study : the Reduced De-Orbitation Mode (RDOM). It has been defined in order to be able to realize the EOL disposal operations even if the Orbit Control Mode (OCM) could not be reached anymore because of failures.



The AOCS units selected for this new mode are less performing with respect to those used in the OCM but according to RAMS analyses they are very reliable. Therefore they are expected to be still available for the post-mission disposal.

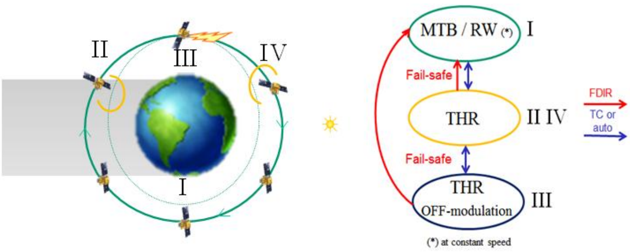
		Mode	SAM		TRM		NOM		OCM		RDOM	
Hardware	Number	Redundancy	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF
MHSTR	2 EU + 3 OH	Cold for EU Both EUs address the 3 OHs		X (1)	X		X		X			X (1)
GPS	2 antennas 2 receivers	Cold 1 out of 2		X (1)	X		X		X			X (1)
CSS	8 solar cells	Hot	X			X (1)		X (1)		X (1)	X	
MAG	2	Cold / 1 out of 2	X			X		X		X	X	
CRS	2	Cold / 1 out of 2		X (1)	X			X (3)	X			X (1)
RWS	4	Hot / 3 out of 4	X (2)		X		X		X		X (2)	
MTB	3	Cold / 1 out of 2	X		X		X			X	X	
THR	4	Cold / Set of 4		X		X		X	X		X	

The proposed AOCS design is based on TAS LEO heritage in order to benefit from flight proven functions and retour over experience even if some modifications have been realized because of the constraints imposed by the post-mission disposal.



At least more powerful thrusters are required in order to limit the number of manoeuvres needed to reach the disposal orbits.

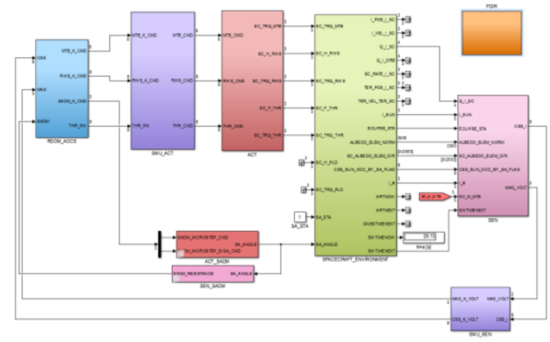
Specific disposal strategies and AOCS actuation logics have been developed in order to execute end-of-life manoeuvres from the RDOM.



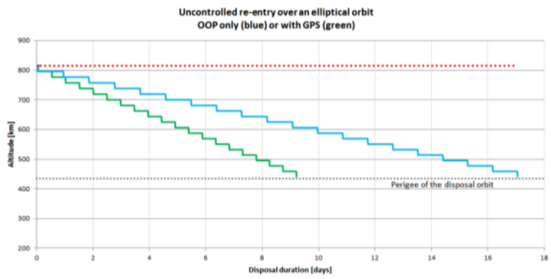
I. SAFE attitude maintaining
II. Orbit change attitude acquisition
III. Orbit change manoeuvre execution
IV. SAFE attitude acquisition

Finally the AOCS/FDIR architecture has been validated through several simulations conducted in the last phase of this study.

AOCS/FDIR simulations have been run by means of the Aocs Design Escape Simulator of Sentinel-3 (ADESS) where failure detection, isolation and recovery mechanisms have been added.



These simulations have allowed firstly to derive the ideal and preferable performance at satellite level then to verify the feasibility from the AOCS point of view.



Finally the performance and the correct behaviour of the AOCS/FDIR in presence of failures have been assessed. All these simulations have shown that the architecture presented in the frame of this study is compatible with the execution of the EOL disposal operations even in failure conditions.

An addition outcome of these simulations has been that it is very useful to introduce the FDIR mechanisms in the AOCS simulator as this allows to validate the choice of FDIR concepts and threshold monitoring since the first phases of the satellite development process and avoid costly modification in later phases.

CONCLUSION AND PERSPECTIVE

All the activities of this study been achieved with success and the main objectives have been fulfilled.

The results and recommendations provided in the frame of this study will allow to make future satellite fully compliant to space debris mitigation requirements and to limit the proliferation of space assets in already crowded low Earth orbits as satellites will be able to execute end-of-life operations even in presence of several failures.

In addition the generic FDIR development process for AOCS derived in the frame of this study will allow to avoid, or at least limit, major modification in the AOCS/FDIR architecture in advanced phases of the project by taking into account payloads and de-orbit requirements since the early phases (A/B) of the design process.

REFERENCE

[1] ECSS-U-AS-10C : Space Sustainability – Adoption Notice of ISO 24113: Space Systems – Space Debris Mitigation Requirements

[2] ISO24113 : Space Systems–Space Debris Mitigation

[3] Loi N° 2008-518 du 3 juin 2008 relative aux opérations spatiales

[4] Décret N° 2009-643 du 9 juin 2009 relatif aux autorisations délivrées en application de la loi N° 2008-518

[5] Arrêté relatif à la réglementation technique en application de la loi relative aux opérations spatiales du 3 juin 2008