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Emergency end of life operations for CNES remote sensing satellites—Management and operational process ☆

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ABSTRACT

The French Space Agency (CNES) is currently operating thirteen satellites among which five remote sensing satellites. This fleet is composed of two civilian (SPOT) and three military (HELIOS) satellites and it has been recently completed by the first PLEIADES satellite which is devoted to both civil and military purposes. The CNES operation board decided to appoint a Working Group (WG) in order to anticipate and tackle issues related to the emergency End Of Life (EOL) operations due to unexpected on-board events affecting the satellite. This is of particular interest in the context of the French Law on Space Operations (LSO), entered in force on Dec. 2010, which states that any satellite operator must demonstrate its capability to control the space vehicle whatever the mission phase from the launch up to the EOL. Indeed, after several years in orbit the satellites may be affected by on-board anomalies which could damage the implementation of EOL operations, i.e. orbital manoeuvres or platform disposal. Even if automatic recovery actions ensure autonomous reconfigurations on redundant equipment, i.e. setting for instance the satellite into a safe mode, it is crucial to anticipate the consequences of failures of every equipment and functions necessary for the EOL operations. For this purpose, the WG has focused on each potential anomaly by analysing: its emergency level, as well as the EOL operations potentially inhibited by the failure and the needs of on-board software workarounds… The main contribution of the WG consisted in identifying a particular satellite configuration called "minimal Withdrawal From Service (WFS) configuration". This configuration corresponds to an operational status which involves a redundancy necessary for the EOL operations. Therefore as soon as a satellite reaches this state, a dedicated steering committee is activated and decides of the future of the satellite with respect to three options: a/. the satellite is considered safe and can continue its mission using the redundancy, b/. the EOL operations must be planned within a mid-term period, or c/. the EOL operations must be implemented as soon as possible by the operational teams. The paper describes this management and operational process illustrated with study cases of failures on SPOT and PLEIADES satellites corresponding to various emergency situations.

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1. Introduction

The number of operational satellites operated on Low Earth Orbits (LEO) has been continuously increasing for the last decades. In the same time the amount of man-made debris in space is growing inexorably. That causes a lot of issues for the operational satellites which may regularly react towards collision alerts. The international community has been alerted about this situation by the IADC (Inter-Agency Space Debris Coordination Committee). This committee is trying to limit the debris proliferation by emitting guidelines [1] to the Space Agencies and satellites operators. Recently the French government published a law called Law on Space Operations (LSO) which clearly indicates that French satellite operators must limit the impacts of their missions on the space environment. This law is applicable to all the phases in the satellite life from the launch up to the End Of Life (EOL) phase. In this context the EOL disposal operations are of particular interest because they aim at limiting the creation of new space debris within a long-term period.

During their lifetime the satellites may be affected by unexpected equipment failures which may cause on-board reconfiguration to isolate the faulty equipment. That is why it is important to analyse the consequences of on-board anomalies on the spacecraft capabilities for implementing EOL disposal operations. In that sense a specific Working Group (WG) has been created within the French Space Agency (CNES) in order to tackle these issues. This document is dedicated to the work done by this WG.

This paper first presents the CNES remote sensing missions from the precursor SPOT 1 up to the last one PLEIADES. Then the different objectives of the WG are detailed in order to underline the complexity of the proposed challenge. After that the LSO is briefly presented and the various EOL disposal operation concepts are explained. Then this paper focuses on the main contributions of the WG illustrated by some practical examples. Finally, all the recommendations formulated by the group, which have been accepted by a steering board, are reminded in order to highlight the guidelines for future projects.

2. CNES remote sensing missions

2.1. Overview

CNES operational teams are currently operating five remote sensing satellites. This fleet is composed of two civilian (SPOT) and three military (HELIOS) satellites and it has been recently completed by the first PLEIADES satellite (PHR for *Pleiades Haute Resolution* in French) which is devoted to both civil and military purposes. The CNES ensures the station keeping of all these satellites on its usual customers' behalf which are the DGA (*Direction Générale de l'Armement* in French) depending on the Ministry of Defence for the military satellites and the private company Spot Image for the SPOT family. Thereby in this contractual organisation important and critical decisions could not be taken without the preliminary agreement of the customers.

2.2. Operational organisation

All these satellites are devoted to Earth observation purpose. They are placed on low Earth orbits characterised by an altitude between 700 and 830 km. The orbit inclination with respect to the equatorial plan is close to 90 degrees. The main property of these polar orbits is that the satellite is ensured to visit the same place on the Earth surface within a determined period of time. To maintain these particular orbital elements, which are subject to various orbital perturbations, flight dynamics teams perform periodic station keeping manoeuvres. Concerning the vehicle behaviour, spacecraft operation teams are in charge of the platform and payload monitoring based on the analysis of the housekeeping telemetry. They may also conduct specific operations such as updating parameters of the on-board software or switch-on of redundant equipment for health check for instance. Finally, the customers' needs are taken into account through the payload programming which is done by mission operation engineers. All these tasks are supported by CNES teams in accordance with the exploitation agreements between the CNES and its customers.

2.3. Brief background history

The first remote sensing satellite launched for the CNES was SPOT 1 (*Satellite Pour l'Observation de la Terre* in French). It was launched in 1986 by an Ariane 1 launcher from the Europe's Spaceport in Kourou French Guiana. After more than 17.5 yr in orbit the decision was taken to stop its commercial use and to start the disposal operations. Last 2 satellites launched for Earth observation purpose were HELIOS 2B in 2009 by means of an Ariane V launcher and first PEIADES satellite (PHR1A) late 2011 by a Soyuz STA launcher. Table 1 gives for each CNES remote sensing satellite the key dates (launch and disposal) and the reached lifetime.

This table clearly shows that these satellites are quite robust because the majority of them exceeds the specified lifetime by two or three times. This robustness characteristic comes obviously from the hardware architecture chosen by the design teams but it is also due to the on-board

Table 1
Key dates (launch and disposal) and reached lifetime of CNES remote sensing satellites.

Satellite	Launch date	Disposal date	Reached lifetime (yr)
SPOT 1	02/22/1986	11/28/2003	17.7
SPOT 2	01/22/1990	07/29/2009	19.5
SPOT 3	09/26/1993	11/14/1996	3.1
SPOT 4	03/24/1998	TBD[a]	13.3
SPOT 5	05/04/2002	TBD	9.2
HELIOS 1A	07/07/1995	TBD	16
HELIOS 1B	12/09/1999	10/21/2004	4.8
HELIOS 2A	12/18/2004	TBD	6.6
HELIOS 2B	12/18/2009	TBD	1.6
PLEIADES 1A	12/17/2011	TBD	–
PLEIADES 1B	Late 2012	TBD	–

[a] To be determined.