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REPORT ON SPACECRAFT ANOMALIES FROM SOLAR EVENTS

In response to CGMS action PA 2

This paper reports about all anomalies attributed to solar events that have been detected on the EUMETSAT in-orbit satellites (i.e. Metosat-6, 7, 8 and 9 and Metop-A) from October 07 till September 08.

These events include a Met-9 Safe Mode on 13-5-08, a Metop PLSOL on 19-3-08 and several outages on IASI and MHS on board Metop A.

The anomalies on EUMETSAT spacecraft due to solar events before October 07 were reported in CGMS-35 EUM-WP-05.

REPORT ON SPACECRAFT ANOMALIES FROM SOLAR EVENTS

1 INTRODUCTION

This paper reports about all anomalies attributed to solar events that have been detected on the EUMETSAT in-orbit satellites (i.e. Metosat-6, 7, 8 and 9 and Metop-A) from October 07 till September 08.

All similar events till October 07 can be found in CGMS-35 EUM-WP-05.

2 SOLAR EVENTS

This working paper is the EUMETSAT response to the Permanent Action No. 02: "CGMS Members to report on spacecraft anomalies from solar events at CGMS meetings".

Solar events are here defined as any in-orbit event that has a sudden impact on the satellite status or performances (e.g. unexpected outages, re-configurations, triggering of on-board protections, loss of performances) and are due to in-orbit radiation effects, meteorites or debris impacts and other similar sudden events (as opposed to ageing) that can be attributed to the space environment.

The paper is divided in two main sections, the first one is dedicated to the geostationary satellites (Meteosat) and the second one to the polar satellite (Metop-A)

2.1 Meteosat satellites

There are currently 4 Meteosat satellites in operations, two of the first generation (i.e. Meteosat-6 at 67.5 deg East, and Meteosat-7 at 57.5 deg East) and two of the second generation (i.e. Meteosat-8 at 9.5deg East, and Meteosat-9 at 0.0 deg).

The sections below list and describe all solar events on board the Meteosat satellites from October 07 till September 08.

2.1.1 Meteosat-8 Unexpected Orbit Change

On 22 May 07 Meteosat-8 experienced an unexpected orbit change that was not the result of a ground commanded manoeuvre. This orbit change event included a decrease in spin rate, a change in attitude, some nutation, a temperature change on the R1/R2 thrusters and fuel lines, and a small drop in solar array power.

This event was classified as an Incident and an Incident Review Board (IRB) was established by EUMETSAT with the support of the European Space Agency (ESA) and Thales Alenia Space (TAS), the Meteosat-8 manufacturer. Investigations and tests revealed that the Unified Propulsion sub-system, the Thermal Control sub-system and to a lesser extent the Electrical Power sub-system were affected by this incident. In particular, one of the nominal thrusters used for East-West station keeping manoeuvres resulted affected and possibly damaged.

Regarding the root cause of the incident, the investigation indicated that the most likely cause was a collision, with either a micro-meteorite or some space debris (as described in CGMS-35 EUM-WP-05)

However, on 1 February 08, Meteosat-8 experienced another orbit change event. This second event had very similar characteristics to the one of 22 May 07 described above with the main differences being that the second event was slightly larger in amplitude, a different thrusters pair was involved (R3/R4), no drop in Solar Array power occurred and a different thermal behaviour was observed. Additionally, after this second event a spin-axis wobble developed.

The occurrence of a second, very similar, event indicated that the two events were connected and put in doubt the initial conclusion that the most likely cause was a collision. Accordingly, the investigation team discarded the theory of the collision with an external object and they are now reviewing in detail the satellite design. Among several possibilities, the investigation includes a spontaneous mass release as potential root cause of the two events.

2.1.2 Meteosat-9 Safe Mode on 13-5-08

On 13 May 08 at 21:06UTC Met-9 experienced its first safe mode transition since launch. The main onboard computer switched to its redundant unit. In the same reconfiguration all other subsystems controlling the satellite vital functions switched to their redundant units and the payload switched off. During the same night all operational services at 0° (with the exception of LRIT due to a limitation of Met-8) were swapped to Meteosat-8 and the total service outage was less than 4 hours. As a consequence the Meteosat-8 Rapid Scanning Service was interrupted.

After anomaly investigation the conclusion was reached with the support of Thales Alenia Space that the event was most likely caused by a transitory event (e.g. bit flipping in the memory that is used to control the health of the main on board computer). The main facts leading to this conclusion were that no other signs of abnormal behaviour were detected before the reconfiguration and that the sign of such a transitory event contained in the Buffer of Anomalies stored on board and retrievable from ground. In addition, neither EUMETSAT nor Thales Alenia Space identified any risk that would prevent the recovery to start.

Based on the above considerations, the recovery procedures for Meteosat-9 started in the morning of 15 May 2008 and SEVIRI resumed imaging in the morning of 16 May 2008 and dissemination of Meteosat-9 High Rate SEVIRI image data resumed on Friday 16 May 2008.

The mission swap from Meteosat-8 back to Meteosat-9 took place at 10.00 UTC on Monday 19 May 2008 and the Rapid Scanning Service with Met-8 resumed at around 14:00 UTC on Monday 19 May 2008.

The investigation on the root cause is now concluded and it has confirmed the initial conclusion that the root cause is most likely a Single Event on one of the electronic components in the interface between the main on board computer and the module that monitors the health of the main computer itself.

An Incident Review Board (Incident #32) has been established to manage the investigation and define corrective actions. Focus is given to identify any operational change that may reduce the probability of re-occurrence and also to optimise the recovery procedure to be faster without compromising the safety of the recovery.

2.2 Metop satellites

There is currently a Metop satellite in operations (Metop-A).

The sections below list and describe briefly all solar events on board the Metop-A satellite from October 07 till September 08.

Metop-A Events linked to radiation effect	
Date	**Event**
01 Nov 07	IASI – Transition to Heater Refuse and subsequent recovery (SEU in DPS subsystem). Mission outage of 09h:31m:46s
08 Nov 07	IASI – Transition to Heater Refuse and subsequent recovery (SEU in DPS subsystem). Mission outage of 11h:17m:51s
18 Nov 07	IASI – Transition to Standby Refuse and subsequent recovery (SEU in DPS subsystem). Mission outage of 105h:18m:50s
04 Feb	IASI Heater Refuse because of an SEU in CCM – successfully recovered (outage< 7h)
3 Jan	MHS in fault mode after spin state anomaly successfully recovered (outage< 6.5h).
09 Feb	IASI Heater Refuse because of an SEU in DPS – successfully recovered (outage< 4h)
19 Mar	SVM reconfiguration caused by a SEU in the PMC Bus Coupler. As consequence, a PLSOL was triggered.
06 June	MHS in fault mode after spin state anomaly due to an SEU – successfully recovered (outage< 7.5h)
21 July	IASI in heater refuse mode (data outage 3 hours)

2.2.1 IASI Heater Refuse Events

Susceptibility to SEU observed on IASI is greater than the prediction. It is mandatory to better characterise this effect with respect to the solar activity cycle and ageing factor in order to define appropriate mitigation actions to minimise the mission outage for Metop A and also the follow-on satellites. A working group led by CNES has released the final report in June 2008, indicating that a modification to the on-board data processing software is the best trade-off between obtaining a sensible reduction of the outage times due to SEU and the complexity and cost of the solution to be implemented. The way forward proposed is to have the modification applied as a patch to the unit flying on Metop-A (FM2) and implemented in the baseline SW for the next units (PFM and FM3).

Upon the last occurrence of this problem on 21 July 08 at 23:44 UTC, early identification of the cause of the anomaly resulted in a quick recovery of the instrument at 02:47 UTC on 22 July 2008. This has been achievable thanks to recent procedure updates and agreement with CNES to identify the signatures of previously experienced SEUs and to avoid the necessity for the involvement of CNES experts in anomaly

analysis and recovery. The level 1 product generation and dissemination have been immediately resumed, with products being of degraded quality until about 03:15 UTC.

2.2.2 SVM Reconfiguration on 19 March 08

On 19th March 2008 the Service Module (SVM) software detected a problem to communicate with the Payload Module Computer "PMC-1".

During the subsequent autonomous reconfiguration, the internal CCU bus was switched to the redundant one and due to the breakdown of the communication protocol with the Payload Module Computer, the entire Payload Module (including all instruments) was switched down.

The SVM data-bus and all bus couplers were swapped to B-side and functional assembly put in “backup” mode. Following the satellite anomaly procedure, the Controller re-acted rapidly switching back to “Working” the functional assembly in order to avoid a satellite safe mode should another anomaly occurred.

On 20th March with the support of the industry, Eumetsat switched ON again the PMC 1 on bus-coupler A, using data-bus B. All equipments indicated a nominal status, so it was decided to switch the data-bus on the A side. This successful operation allowed the investigation team to conclude that Metop-A had suffered a transient anomaly caused by a Single Event Upset. The SVM was then put back to its nominal configuration allowing the start of the PLSOL recovery procedure.

2.2.3 MHS in Fault Mode

A SEU event changed the value contained in the reflector controller position register.
This was seen by the instrument as a RDM Zero Position Sensor, resulting in an apparent large scan position error.
The scan controller started reacting to this error by driving relatively high currents to bring the apparent error to zero. In the process of doing this the on board limits on the allowed RDM currents (1.25 Amps) was violated and therefore an autonomous transition to the Fault mode was triggered to bring the instrument in a safe state.
This typical signature which occurred 3rd of January and 6th of June is therefore referred to as: “Fault mode induced by an Incipient Motor Spin state triggered by SEU”.

3 CONCLUSIONS

As a EUMETSAT response to Permanent Action No. 02, this paper reports about all anomalies attributed to solar events that have been detected on the EUMETSAT in-orbit satellites (i.e. Metosat-6, 7, 8 and 9 and Metop-A) from October 07 till September 08.

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