CGMS-35 EUM-WP-05
v1A, 17 October 2007

Prepared by EUMETSAT
Agenda Item: B.4
Discussed in Plenary

REPORT ON ANOMALIES FROM SOLAR EVENTS

In response to CGMS action PA 03

Summary of the Working Paper

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)

Report on 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).

2 Solar events

This working paper is the EUMETSAT response to the Permanent Action No. 03: “CGMS Members to report on 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

After Meteosat-5 re-orbiting in April 07, 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 3.4 deg West, and Meteosat-9 at 0.0 deg).

The sections below list and describe briefly all solar events on board the Meteosat satellites.

2.1.1. Meteosat-8 Loss of Solar Array Current

The Meteosat-8 Solar Array current experienced a relatively rapid decrease (i.e. about 3% total loss in a few hours) on 28 October 2003 (MSG AR9693). The loss is permanent; however it does not cause any operational issue as design margins were built in the solar array current generators to cope with similar events.

A similar effect, although with lower amplitude (i.e. about 1%), was noticed on Meteosat-5, 6 and 7 around the same time. It was later on confirmed (see http://umbra.nascom.nasa.gov/SEP/seps.html) that these losses were likely to be due to the radiation emitted by the sun during an exceptionally large solar flare whose arrival to the earth was estimated to be around 28-29 October 2003.

2.1.2. Meteosat-8 DNEL

The Meteosat-8 satellite switched itself unexpectedly to safe mode on 4 October 2004 (AR11202). The safe mode was caused by a ”Disconnect Non-Essential Loads (DNEL)” command sent by an autonomous protection on board. This protection is to protect the satellite against an under-voltage either in the Main Bus or in the Batteries. The event caused an interruption of all Meteosat-8 missions for about 3 days due to the investigation time and also the recovery time. The satellite was eventually commanded back into operations and all missions on board resumed nominally showing that it was not a permanent failure.

The investigation led to the conclusion that this anomaly was again due to a SEU in one LM139 comparator that is used in the under-voltage detection circuit within the satellite Power Distribution Unit (PDU).

A ground recovery procedure was put in place to react to similar DNEL events.

2.1.3. Battery charge ended early

The re-charge (after eclipse) of Battery No. 2 of the Meteosat-8 satellite stopped unexpectedly on 27 October 2005 (MSG AR13160). This was about 50 minutes before the nominal end of charge. The event did not cause any operational impact and no dedicated recovery action was necessary as the state of charge of the battery was adequate for the following eclipse. The eclipses were successfully crossed in the following day(s) showing that it was not a permanent failure.

The investigation led to the conclusion that this anomaly was due to a SEU in one LM139 comparator that is used in the Battery Charge Regulator (BCR).

A ground recovery procedure was put in place to react to similar events during the battery recharge.

2.1.4. Meteosat-9 SEVIRI SEU

The Meteosat-9 Spinning Enhanced Visible and Infrared Imager (SEVIRI) unexpectedly stopped scanning on 3 April 2006 (MSG AR14132). The event caused a 3-day interruption of the in-orbit Commissioning of Meteosat-9 SEVIRI. Imaging was resumed by commanding SEVIRI back to Normal and. after commanding, the SEVIRI resumed nominally showing that it was not a permanent failure.

The investigation led to the conclusion that this mode transition was caused by an SEU on a RAM memory of the Functional Control Unit (FCU) of SEVIRI.

A ground recovery procedure was put in place to react to similar events on SEVIRI.

2.1.5. Meteosat-9 MCP IFP changed mode

The Meteosat-9 Intermediate Frequency Processor (IFP) of the Mission Communication Payload (MCP) unexpectedly changed configuration on 17 August 2006 (MSG AR15039) and switched from Automatic Level Control (ALC) to Fixed Gain Mode (FGM).

In addition Channel 3 of the IFP was found to be switched on while before the anomaly it was off. The IFP is an electronic box used to control and condition the frequency signal from the acquisition electronics (images and others) before it goes into the Solid State Power Amplifiers (SSPA) to be downlinked via the antennas.

The event caused a drop in the RF signals (including images) to ground. However, the level remained sufficiently high to allow proper reception of the imaging data. The nominal the transmission of imaging data to ground was re-established by commanding the IFP back to ALC mode. After commanding the spacecraft reacted nominally confirming that it was not a permanent failure.

The investigation led to the conclusion that this anomaly has the same root cause of the one in the above section “2.1.2 - Meteosat-8 CACE to Fixed Beam mode” as the CACE and the IFP have the same DC/DC converter and the DC/DC converter is SEU sensitive.

A ground recovery procedure was put in place to react to similar events on the IFP.

2.1.6. Meteosat-8 to Safe Mode

The Meteosat-8 satellite switched itself unexpectedly to safe mode on 23 September 2006 (MSG AR15234). The safe mode was caused by a Configuration and Data Management Unit (CDMU) internal protection.

The CDMU contains the main on board computer and it manages most of the satellites operations including on board protection, commands execution and telemetry monitoring. The protection that was triggered on 23 September 06 monitors the internal voltage of the CDMU.

The event caused an interruption of all Meteosat-8 missions for several days to allow a proper investigation of the event. However, as Meteosat-9 was available as in-orbit backup satellite, it was possible to swap all the Meteosat-8 services to Meteosat-9 in less than 3 hours with some acceptable disturbances to the operational services.

The satellite was eventually commanded back into nominal operations and all missions on board resumed nominally confirming that it was not a permanent failure.

The investigation led to the conclusion that this anomaly was again due to a SEU in one LM139 comparator that is used to detect the internal voltage within the CDMU.

A ground recovery procedure was put in place to react to similar CDMU events.

2.1.7. Meteosat-8 Unexpected Orbit Change

Meteosat-8 experienced an unexpected orbit change on 22 May 07 (MSG AR16385). This change concerned spin rate, attitude and orbit semi-axis. Investigations have revealed that the Unified Propulsion Sub-system, the Thermal Control Sub-system and to a lesser extent the Electrical Power Sub-system have been affected by this incident.

In particular, the nominal radial thruster R1 used till now for the East-West station keeping manoeuvres seems damaged, while the redundant thruster R2 providing the same function is still functional and has been used to conduct an operational manoeuvre.

On the Thermal Control side, the external surface of the satellite has been damaged and some internal parts of the satellite are now exposed both to cold space and sun illumination as the satellite spins. This has caused a new thermal equilibrium to be reached inside the satellite, an equilibrium that will change with the season. Initial eclipse operations have been performed smoothly which leads to a level of confidence that thermal control will be maintained as required during eclipses.

The hypothesis that Meteosat-8 has suffered a collision with an object crossing the geostationary orbit, possibly a micro-meteorite, remains the most likely. Less likely, and now discounted by the investigation, is loss of mass from the spacecraft, as no further spacecraft anomalies have been revealed by testing so far.

As the redundant branch of thrusters is functioning and as it appears that a stable thermal configuration for the eclipse season has been found, there should be no impact on Meteosat-8's ability to serve as the in-orbit backup satellite, and to provide the Rapid Scanning service.

However, a level of redundancy has been lost which could have a longer-term impact on Meteosat-8's availability. This is under investigation as part of the process of closing the analysis of this incident.

2.2 Metop satellite

2.2.1. GOME Ghost EQ SOL

The Metop GOME entered Standby Refuse on reception of an EQ SOL signal on 26 October 06 (EPS AR6210). The EQ SOL is a signal sent by the Metop platform to the payload to warn that a power switch off is following. In reality investigations showed that this EQ SOL signal was not sent by the platform or requested by GOME and in all probability this was due to a SEU in GOME as Metop was in the SAA area at the time of the occurrence. Similar events have been observed at least 8 times until a software patch has been implemented to remove this effect.

2.2.2. GOME Scan Unit switched On un-commanded

The Metop Global Ozone Monitoring Experiment (GOME) instrument produced, on 22 November 06, an initialisation error when trying to switch on the scan unit as this was already on (EPS AR6537). The source of the anomaly has been traced to 3 days before when, on 19 November 2006 the GOME scan unit (SU) went ON, without any command being sent. The cause of the anomaly is believed to be a SEU, hitting an opto-coupler HCPL523K (same type as in paragraph below) controlling the SU power switch. Metop was over the South Atlantic Anomaly (SAA) at the time of the SU spurious switch-on

2.2.3. MHS Fault mode entry

The Metop Microwave Humidity Sounder (MHS) instrument switched itself into Fault Mode on 20 December 2006 (EPS AR6823). The Investigation shows that the anomaly was caused by a radiation SEU in the “Zero Position Sensor” of the motor causing a large error in the motor position data and resulting in loss of control. This is a known anomaly called which has happened twice before on NOAA-18. Further evidence for a radiation SEU is that the anomaly occurred in the South Atlantic Anomaly, as did the two NOAA-18 anomalies.

2.2.4. IASI Laser SEU anomaly

The Metop Infrared Atmospheric Sounder Interferometer (IASI) switched itself into Heater Refuse Mode on 15 May 2007 (EPS AR7897). In this mode IASI does not acquire data, but its internal temperatures are controlled to allow a prompt restart of acquisition. The anomaly investigation by EUMETSAT with support of CNES and Thales Alenia Space led to the conclusion that this anomaly was due to a SEU that corrupted the target temperature used by the IASI laser frequency control loop.

2.2.5. IASI 1-bit error

The Metop IASI switched itself into Heater Refuse Mode on 13 June 2007 (EPS AR8035). The anomaly investigation led to the conclusion that this anomaly was due to a memory bit corruption by a SEU that caused the IASI Data Processing System (DPS) to go in WAIT mode followed by a Heater Refuse mode.

2.2.6. Metop SSR anomaly

The Metop Solid State Recorder (SSR) became corrupted on 3 July 07. (EPS AR8148). As a reaction to this corruption, the SSR reduced its recording capability of about 10% to remove the corrupted area from the usable area. Investigations showed that this corruption was due to a SEU in the SSR when Metop was above the South Pole. After investigation it has been decided not to reset the SSR as the available memory is still compatible with the Metop operations.

2.2.7. IASI DPS SEU Pixel-3 suspend

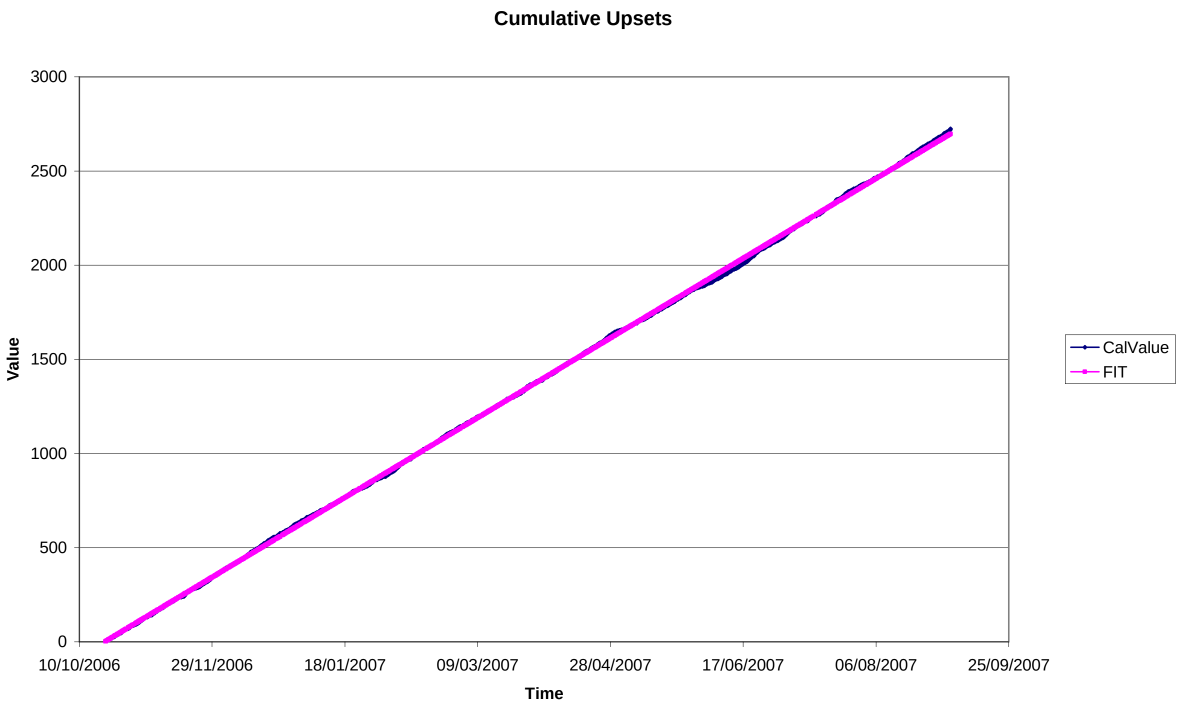
The Metop IASI switched itself into Heater Refuse Mode on 20 July 2007 (EPS AR8241). The investigation concluded that a SEU hit the volatile memory of one of the processing chains in the IASI DPS

2.2.8. ADCS TLM corruption/unprocessed messages

The Metop ADCS mission telemetry (as opposed to the housekeeping telemetry) was corrupted on 22 August 07. (EPS AR8480). In this condition 90% of the ADCS messages were unusable. Investigations showed that this corruption was due to a SEU in one of the RAM (Metop was around the SAA area at the time of the occurrence) and the problem was cured by resetting the memory by the CNES Master beacon

2.2.9. Metop No of SEUs and Geo location

The following charts gives the cumulative number of SEUs over time, the hourly frequency of the SEUs, the geo-located probability of SEUs and the rate of correction of the EDAC of the Solid State Recorder on board, respectively. No outages have been caused by these detected SEUs (all corrected by the EDAC).


Cumulative Upsets
3000
2500
2000
1500
1000
500
0
Value
10/10/2006
29/11/2006
18/01/2007
09/03/2007
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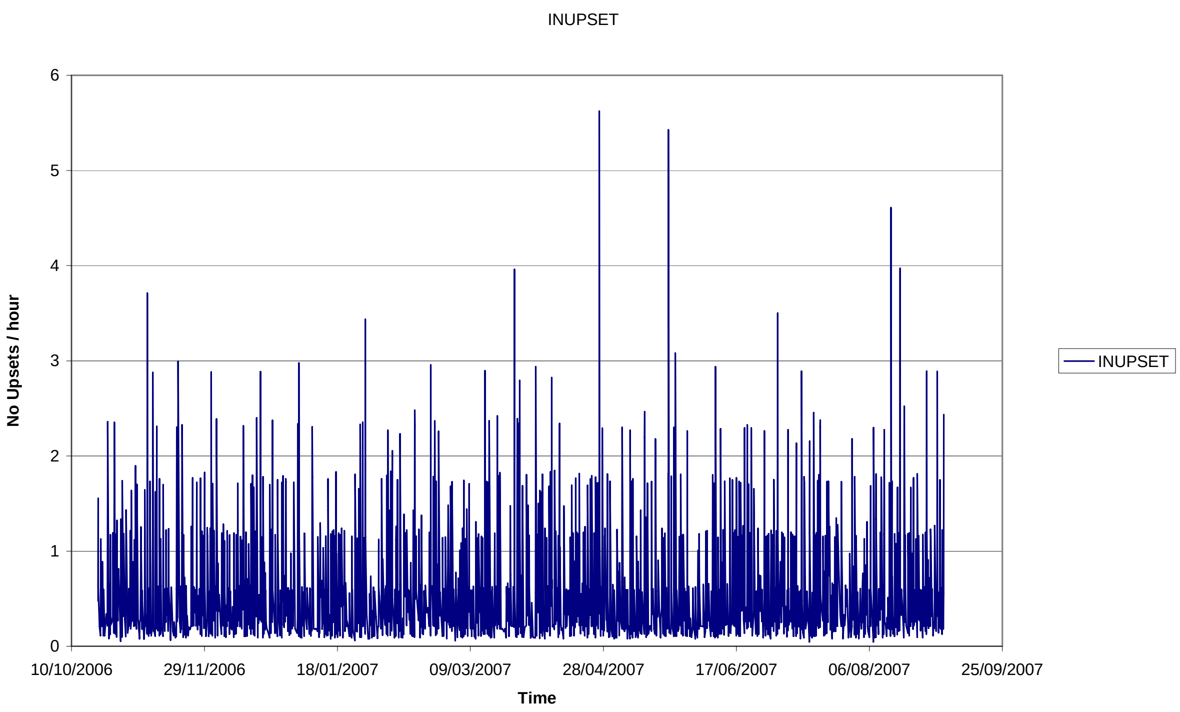
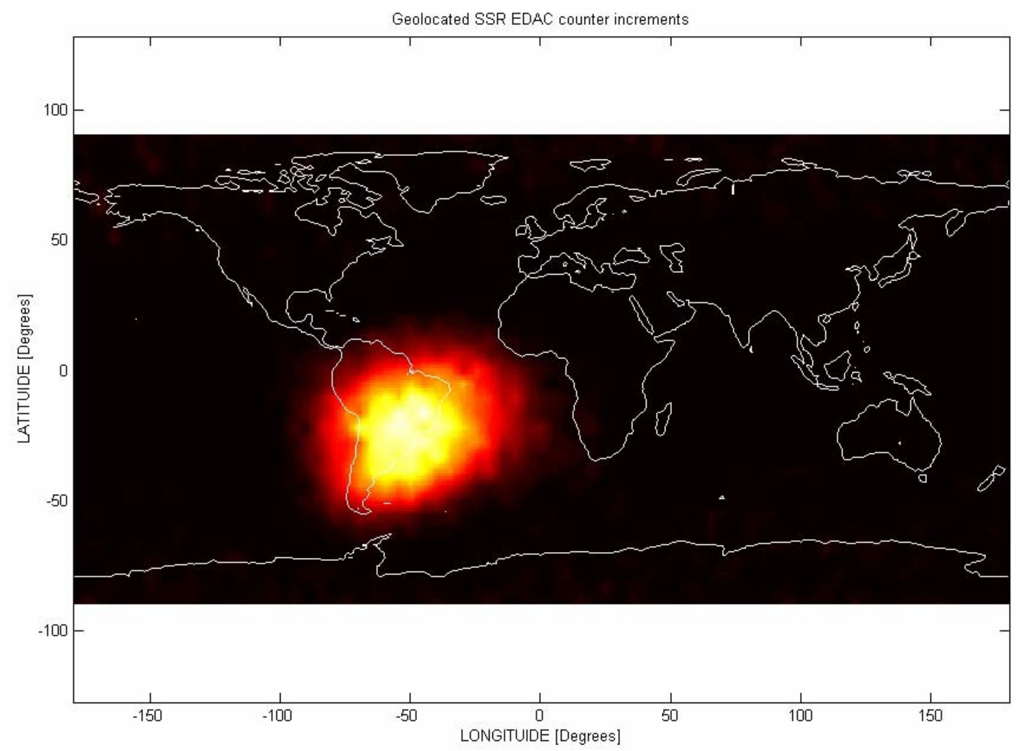
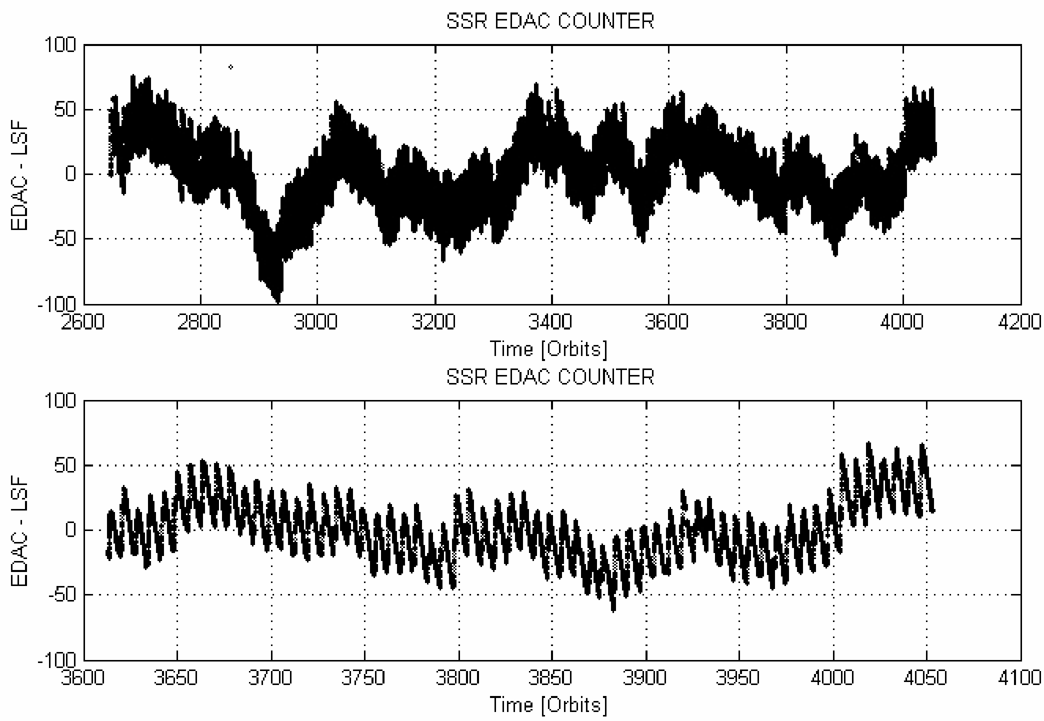
17/06/2007
06/08/2007
25/09/2007
Time
CalValue
FIT


INUPSET
6
5
4
3
2
1
0
No Upsets / hour
10/10/2006
29/11/2006
18/01/2007
09/03/2007
28/04/2007
17/06/2007
06/08/2007
25/09/2007
Time
INUPSET


Geolocated SSR EDAC counter increments
LATITUIDE [Degrees]
LONGITUIDE [Degrees]
100
50
0
-50
-100
-150
-100
-50
0
50
100
150


SSR EDAC COUNTER
EDAC - LSF
Time [Orbits]
SSR EDAC COUNTER
EDAC - LSF
Time [Orbits]

3 CONCLUSIONS

As a EUMETSAT response to Permanent Action No. 03, 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).