Royal Netherlands Meteorological Institute
Ministry of Transport, Public Works and Water Management

OMI to Safe Mode September 27 2008 Anomaly Report

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Change status:

Issue	**Date**	**Comments**	**Affected pages**
draft	6 August 2010	Draft issue	All
1	24 August 2010	Issue 1	All

1 Anomaly Description

1.1 Summary

On September 27th 2008 at 02:07:30 GMT OMI stopped generating science data. A TM check of the motor phase of the FMM failed at the start of the LED SIS. As a result the LED SIS stopped executing with non non-nominal exit code 55. This caused the TMON 35 to trip, which started the execution of the FM SCS IN3 ("Safe SCS") resulting in a transition to Idle mode which effectively stopped the generation of science data. As part of the FM procedure, the FMM is supposed to move to nadir position. As another FMM anomaly was suspected it was decided to start taking science data on September 30th 2008, but without taking calibration and irradiance measurements for which the FMM has to move.
Just before the LED SIS the monthly_2 branch of the Solar calibration SIS was executed apparently successful. But analysis showed that at the end of the monthly_2 branch of the Solar calibration SIS some instructions to move the FMM were ignored by the ELU because one of the mechanisms was still moving. This problem, that only occurred in the monthly_2 branch of the Solar calibration SIS, explained the failure at the start of the LED SIS that was executed directly after the Solar calibration SIS. It was decided to update and upload the Solar calibration SIS before the next scheduled execution of the monthly_2 branch of the Solar calibration SIS on October 29th 2008.
On October 2nd OMI resumed full nominal operations generating earth science data as well as calibration data.

1.2 Background

In the spring of 2006 the FMM anomaly occurred. Although the cause of the anomaly was never found, it was decided to change the way of operating the FMM. Main purpose is to avoid bouncing of the mechanism against the calibration end-stop. In the new way of operating the FMM, it is always assumed that the FMM is at a well defined initial position before the FMM starts to move to the calibration position. This initial position is defined by the FMM motor phase value which should always have the same initial value. It is this initial FMM motor phase value which is checked for in every SIS that uses the FMM.

A Stored SIS consists of 255 cells with instructions. The Solar calibration SIS contains the ELU instructions to perform the Solar calibration measurements. There are different branches with different measurement settings. The different branches share however the instructions that they have in common (like mechanism movement instructions).
Just before the LED SIS the montly_2 branch of the Solar calibration SIS was apparently run successfully.
An updated version of the Solar calibration SIS was uploaded successfully on September 4th 2008. Several branches (daily and weekly branches) of that Solar calibration SIS were executed successfully since then. However, the monthly branch of the Solar calibration SIS was executed for the first time on September 27th 2008 just before TMON 35 tripped.

1.3 Investigation

Analysis showed that at the beginning of the LED SIS the FMM motor phase had a value "STATE_4" whereas the value should have been "STATE_3".
It turns out that at the end of the Solar calibration SIS, the FMM motor phase had already this wrong value "STATE_4" instead of "STATE_3". The fact that, despite a wrong value for the FMM motor phase, the Solar calibration SIS ran successfully is because there is no check of the FMM motor phase value at the end of the Solar calibration SIS. Only the status of the opto-coupler is checked at the end of a SIS which, in this case, had the correct value "LIT" after moving the FMM from its calibration position back to nominal position. A check of the FMM motor phase is only performed at the start of a SIS.

Although the monthly_2 branch of the Solar calibration SIS was run for the first time in flight, the SIS cells that are used for moving the mechanisms are the same for all branches. And these other branches of the Solar calibration SIS have been running successfully so far.

Further analysis showed that during the execution of the Solar calibration SIS, at the end of the Solar calibration measurement, an instruction is send by the IAM to the ELU.
This instruction should have put a value 79 in the ELU FMM step count register. It is assumed this instruction has been send indeed because the instruction shows up in the APID 1892 echo data. Also the ELU instruction counter increased.
In the engineering telemetry the value 79 does not show up in the FMM step count register as it should have. This FMM step count register still had its old value 1. This was the first direct indication something went wrong with the ELU handling of an instruction.
Then the IAM sends an instruction to move the FMM from its calibration position to the nominal position. However, since the FMM step count register contained the value 1 instead of 79, the FMM did not reach its nominal position.
Even if it is assumed that the FMM was moving by only one step from the calibration position into the direction of the nominal position then a change of the FMM motor phase value should have been observed. But the value did not change. This was a second indication something went wrong with the ELU handling of an instruction.
As a result the FMM motor phase had a value "STATE_4" instead of the required "STATE_3" at the end of the Solar calibration SIS.
At the beginning of the next SIS, which is the LED SIS, it is checked if the FMM motor phase has a value "STATE_3". Since the value was different ("STATE_4") the LED SIS stopped running and generated a non-nominal exit code 55.
This non-nominal SIS exit code 55 caused the TMON 35 to trip resulting in FM actions to start via SCS IN3 (“Safe SCS”).
As part of the FM action the FMM was moved. This FMM movement seemed to be successful. The FMM motor phase value at the end had the expected value "STATE_3". This indicated that at the end of the FM actions the FMM was in nominal position.
Also from the engineering data there was a strong indication that the FMM was in nominal position. Pixel data overflows during certain parts of the day side of the orbit were observed. No overflows are possible with the FMM in calibration position.
There is no indication that the FMM itself caused the anomaly.
Something went wrong on the ELU when handling at least two instructions.
On September 30th 2008 OMI started taking science data again, but without running calibrations that need to move the FMM. The radiance data confirmed that the FMM was in nominal position.

2 Causes and Contributing Factors

2.1 Preliminary root cause

As a TM check of the motor phase of the FMM failed at the start of the LED SIS, another FMM anomaly was suspected.

2.2 Root cause conclusion

The cause of the anomaly was found to be a timing issue in the Solar calibration SIS for the monthly_2 branch only.
The corrective action to avoid the anomaly in the future is to update the Solar calibration SIS.

At the end of the Solar calibration SIS, when the Solar calibration measurement is finished, the DifM and the FMM must be moved back to their nominal position. This is the same for all branches (daily, weekly or monthly) of the Solar calibration SIS.
The ELU is designed such that any mechanism related instruction will be received by the ELU but ignored for further processing as long as one of the mechanisms is moving.

When running the monthly_2 branch of the Solar calibration SIS version 7.2, an instruction was send to the ELU to move the DifM 249 steps back to its nominal position. This movement takes about 2.5 seconds (all three OMI

mechanisms have a 100 Hz stepper motor). Note that the number of steps the DifM must be moved back depends on the branch of the Solar calibration SIS. Only for the monthly_2 branch this value is 249.
Then only 2 seconds later, while the DifM was still moving, an instruction was send to put the value 79 in the FMM step count register of the ELU. This instruction was ignored for further processing. This explains why the value 79 did not show up in the engineering telemetry.
Immediately after the FMM step count instruction, again while the DifM was still moving, an instruction was send to move the FMM back to its nominal position. Also this instruction was ignored for further processing. This explains why we did not see a change of the FMM motor phase value and why this value was "STATE_4" at the end of the Solar calibration SIS instead of the usual value "STATE_3".
It is now also understood why the anomaly did not show up for the other branches of the Solar calibration SIS. The number of steps the DifM must be moved back at the end of the Solar calibration SIS is the following:

branches	steps
Daily	100
Weekly_1	100
Weekly_2	73
Monthly_1	100
Monthly_2	249

Only for the monthly_2 branch the DifM will still be moving when the FMM related instructions are send and hence these instructions will be ignored for further processing.
For all other branches the DifM movement will be finished by the time the FMM related instructions are send. These instructions will be processed properly.

In the previous version 6.1 of the Solar calibration SIS, the time in between the DifM instruction and the FMM instructions was larger due to a different implementation. Therefore the anomaly did not show up in the 6.1 version of the Solar calibration SIS.
This anomaly could not show up when testing the Solar calibration SIS version 7.2. A SIS is tested by running the SIS on the IAM simulator. Timing details like the duration of a mechanism movement are not simulated.

3 Impact

From September 27 02:07:30 until September 30 00:00:00 OMI was in idle mode and no science data was taken. OMI resumed taking science data on September 30, but no calibrations for which the FMM has to be moved were performed. On October 2nd OMI resumed full nominal operations generating earth science data as well as calibration data. The lack of calibrations with FMM had no significant impact on the science data.

4 Proposed anomaly solutions

The corrective action to avoid the anomaly in the future is to update the Solar calibration SIS to extend the wait period when the DifM is moving.

5 Resolution

On October 23rd 2008 the updated version of the Solar calibration SIS (7.3) was uploaded to the spacecraft.
On October 29th 2008 the monthly_2 branch of the updated Solar calibration SIS version 7.3 ran without any problems.

6 Abbreviations

- FM Fault Management
- TMON Telemetry Monitor
- FMM Folding Mirror Mechanism
- DifM Diffuser Mechanism
- LED Light Emitting Diode
- SIS Stored Instruction Sequence