Contribution of the On Board Software Management tool to the Galileo Operations

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The Galileo In Orbit Validation Satellites enable via the Packet Utilization Services (PUS), the possibility to perform software updates for all patchable SW and memory devices on board the spacecraft. This type of operation takes a great amount of time in terms of preparation and validation. The On Board Software Management (OBSM) Tool main functionalities were validated at the Galileo Control Center before the launch of the two first IOV satellites, using reference images provided by the manufacturer. During the first weeks of the mission the tool was used to verify that the on board software images and memories were intact. This was done via checksums calculation and real time image dump processes. The application has also shown to be very useful for large command stack generation and for the images storage and distribution. The feature allowing the generation of commands submitted to specific device constraints is still under testing. The tool main functionalities being now validated, the OBSM use could be expanded to further memory devices on board the IOV spacecrafts. A detailed memory mapping via the use of the models could also speed up the analysis process. This paper presents the status of the deployed OBSM for In Orbit Validation phase and outlines the potential features that could be implemented for future improvements based on the experiences from the on-going mission.

I. Introduction

Galileo is Europe's programme for a Global Navigation Satellite System (GNSS) providing a highly accurate, guaranteed global positioning and timing service. The complete Galileo constellation will consist of 30 satellites in three orbital planes at an angle of 56 degrees to the equator. With the satellites taking about 14 hours to orbit Earth at altitudes of 23 222 km, there will always be at least four satellites visible anywhere in the world.

DLR Gesellschaft für Raumfahrtanwendungen (GfR) mbH is a company of the German Aerospace Center DLR having its seat at the Galileo Control Center Oberpfaffenhofen. On 21.10.211 the successful launch of the first two Galileo Satellites took place, initiating the operational phase of Galileo with the so called In Orbit Validation (IOV) phase.

For the Galileo Control Center in Oberpfaffenhofen the time allocated for operations such as software memory patching will be extremely limited. Therefore it is essential that the Galileo flight operations team is using a reliable and time efficient software operations tool. For this reason the On Board Software Management (OBSM) application from the Satellite Control and Operation System SCOS-2000 is being used and tested during the first part of the IOV phase. The basic functionalities, environment, performance and possible improvements of SCOS-2000 OBSM are discussed in the following sections.

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II.   On Board Software Management tool for Galileo IOV

A.   Tool functionalities

The On Board Software Management (OBSM) tool is an extension from the Satellite Control and Operation System SCOS-2000, the Mission Control System (MCS) used for the Galileo mission. To function properly the OBSM needs as inputs the software or memory device image, a model describing the image sections and the memory device file (MDF) containing the information (e.g. PUS service 6 commands) relevant for each device. For IOV, the input files were delivered by the satellite manufacturer and present the following layout:
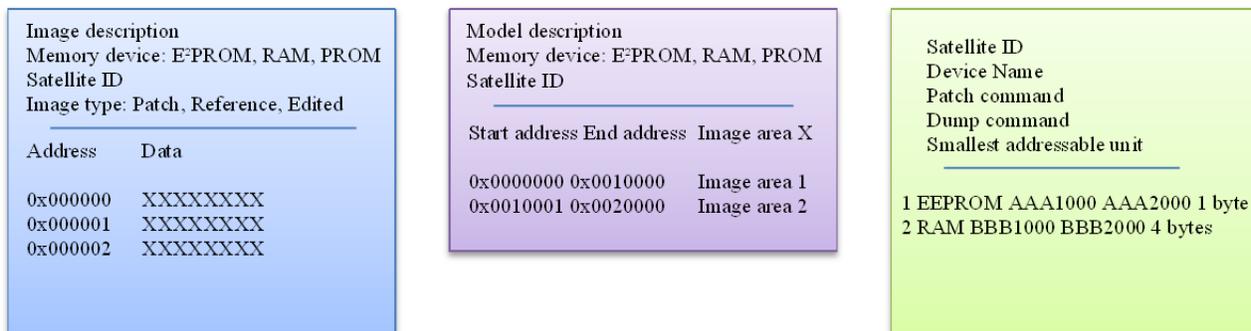

Figure 1. Memory image, model and device file layouts.

The model brings additional information to be used for data analysis. The device software images and the memory device file are necessary to handle the tool basic functionalities.

The deployed OBSM Tool for IOV implements most of the basic functionalities of OBSM SCOS Release 5 such as image and model view, automatic telecommand generation, image comparison, image editing, image verification via checksum, live and retrieved downlink monitoring, and report generation. This version supports properly the multi satellites/domains and multi devices management compare to the previous version deployed for GIOVE-B mission which uses SCOS 3.1 in its Mission Control System.

Following the evaluation and the operations preparation phase for the first IOV launch some improvements have been implemented to cope with the mission's need. It was related to the PUS Service 6 group repeater implementation. The application allows the user now to select the size of the data to be uploaded in one command. The selection is very useful when a device has specific write/read constraints (Software/Hardware smallest addressable unit for example). The tool also inquires the user to enter a time delay to be inserted before each command release. This is to avoid sending out too many commands too quickly and to control the bandwidth of the data downlink.

The basic functionalities are tested and validated in several scenarios as presented below. The MMI fits the operational need and is very user friendly. In terms of performance the OBSM is designed well to manage huge size of images (6 Mbytes). However in future parallel dump operations with multi satellites are foreseen since this capability has not yet been exercised.

B. Configuration Control

During the IOV phase, the Galileo Control Center works in cooperation with several external interfaces. These ones include the satellite manufacturer, the Launch and Early Orbit Phase (LEOP) control centers in Toulouse (France) and Darmstadt (Germany). To manage the transfer of data between the GCC and its many interfaces a Ground Control Segment Facility (GCS) called the Operation Preparation Facility (OPF) is used.
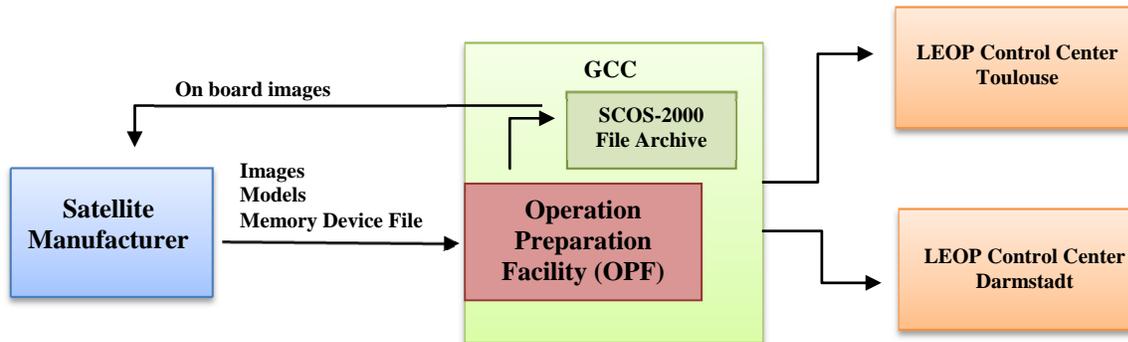

Figure 2. Images, models and memory device files transfer to Galileo entities via OPF

From the OPF repository the files can be directly forwarded to the other control centers and distributed to the file archive from SCOS. This transfer is done instantaneously upon user request.

It shall be noted that after downlink, the data are saved directly in the archive from the Mission Control System and not in the OPF. From the file archive, images can be transferred directly to the satellite manufacturer if required for data analysis. From this process the OBSM files are kept under two configuration control systems. The files delivered from the satellite manufacturer are stored in the OPF and are available for transfer to other control centers while the real time images are stored in the Mission Control System File Archive (FARC).

C. Image validation process

Images delivered from the manufacturer need to be validated before being used for real time operations. The GCC is equipped with different control rooms, one of them being reserved exclusively for testing and validation. Instances of the spacecraft simulator, the Operations Preparation Facility and the OBSM are available within this room.

For reference images delivered without checksums, the complete image is dumped from the simulator and all bytes are compared using the OBSM. For reference images delivered with checksums then the checksum list can be dumped and verified instead of the complete image. The sequence of commands used for the checksum calculation is available as part of the operational database. Differences detected between the simulator and the reference image will be analyzed before the file transfer to the operational chain. This last step is done via the OPF located in the main control room. The validation path is shown as red in the figure 3. To trace the validation status it is considered useful to implement additional links marked as dashed yellow below.
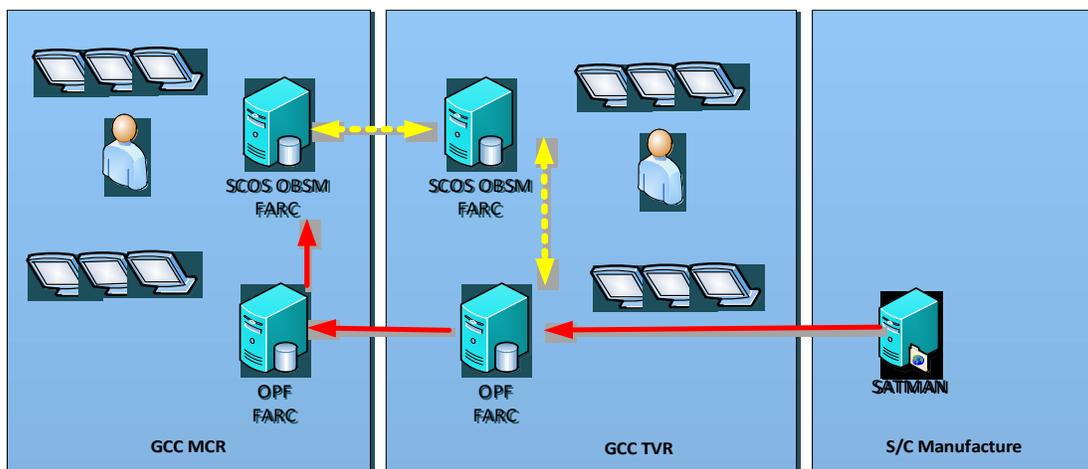
Figure 3. Image validation flow

III. Usage scenarios

A. On board Software updates

The OBSM is designed to support all types of operations related to software maintenance. In the case of a software patch, the new SW image needs to be available in the OBSM image catalogue for comparison. For IOV the SW updated images are delivered by the manufacturer and transferred to the OBSM via the process described above. Using the comparing function from the OBSM, an image is formed out of the differences between the record of the current SW image on board (considered up-to-date) and the patch image. The load and dump commands are generated from the difference image. In this way, only the required SW area is addressed.
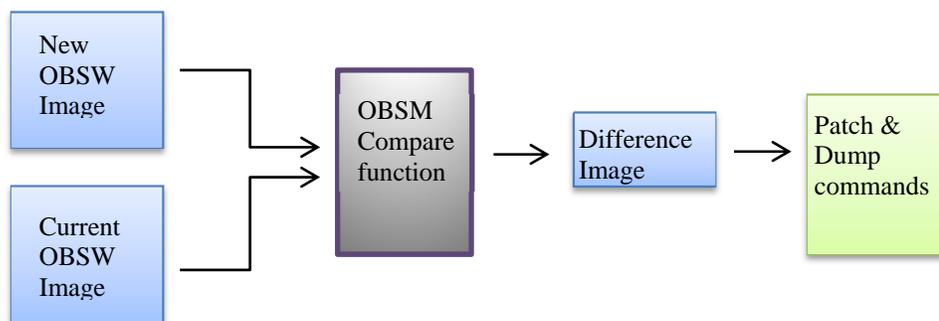

Figure 4. Software patches generation process using OBSM

The command stacks are saved directly in the archive server, and therefore kept under configuration control. This process avoids the upload of a complete new software image, which would take a great amount of time. Indeed each IOV on board software image size is approximately 1, 3 Mbyte. Considering that the commands can load up to 1 kbyte in 4 seconds, the operation would take around 90 minutes for one of four banks.

Without such a tool like the OBSM, it would be practically impossible for the user to generate large SW patches without making errors. Alternatively the command stack could be created and delivered by the manufacturer, but then again for the image verification the check would need to be performed manually. This process would take up to several hours if not entire days. Thanks to the OBSM monitoring function, the user can quickly detect if a failure occurred during the upload and a new patch can be prepared within few minutes.

This scenario was run and validated for small SW patches (20 to 25 bytes) during the IOV satellite test campaign. Tests were executed successfully and the upload and verification process took a few minutes only.

B. Signal configuration upload

For every Galileo service a defined navigation channel is allocated. These channels are formed using combinations of three navigation bands using different pseudorandom noise ranging codes. Each of these codes is stored in the Navigation Signal Generation unit memories.

For testing and maintenance purposes, it will be required to change the code filter coefficients and waveform tables. These tables count around 400 codes parameters for each channel and need to be uplinked to the RAM and EEPROM memories of the Navigation Signal Generation unit. Such operations are very critical as they can affect the navigation signal quality of service.

With the current process the new codes are delivered by the satellite manufacturer and patches are generated as presented above.

At the stage of writing the Galileo Control Centre is preparing the necessary steps to exercise this operation.

C. Routine Memory checks

The first memory verification checks of the IOV platform were executed during the satellites commissioning phase. The tool was used to generate command sequences and for data verification. The table below presents the number of differences found between the memory configurations before launch and at the start of the platform commissioning phase:

Table 1: Differences found between on board memory image and base image

Device	Differences detected by OBSM
ASW	0
vital context configuration file	13
SGM EEPROM	>100
SGM RAM	>800

Most of the modifications brought to the memory images were performed during the LEOP phase. For maintenance purposes all memory devices should be dumped and checked on a regular basis.

IV. OBSM future developments

Although the OBSM tool is validated and usable as it is, many improvements could be made so that its usage could be extended.

A. Data Analysis for Safeguard Memories

The models are meant to give more information on the data within the image. When a model is loaded with an image, the image sections are highlighted and the data description defined in the model appears on the image side. For example in IOV, the model is used only to distinguish the image header from the segment data.

To help the data analysis process it would be ideal to have a detailed description of the configuration parameters and their values. How it currently works, the operator needs to locate the HW address into the configuration table manually. This is very time consuming and error-prone. The figure 5 shows a possible specification of a safe guard memory model.
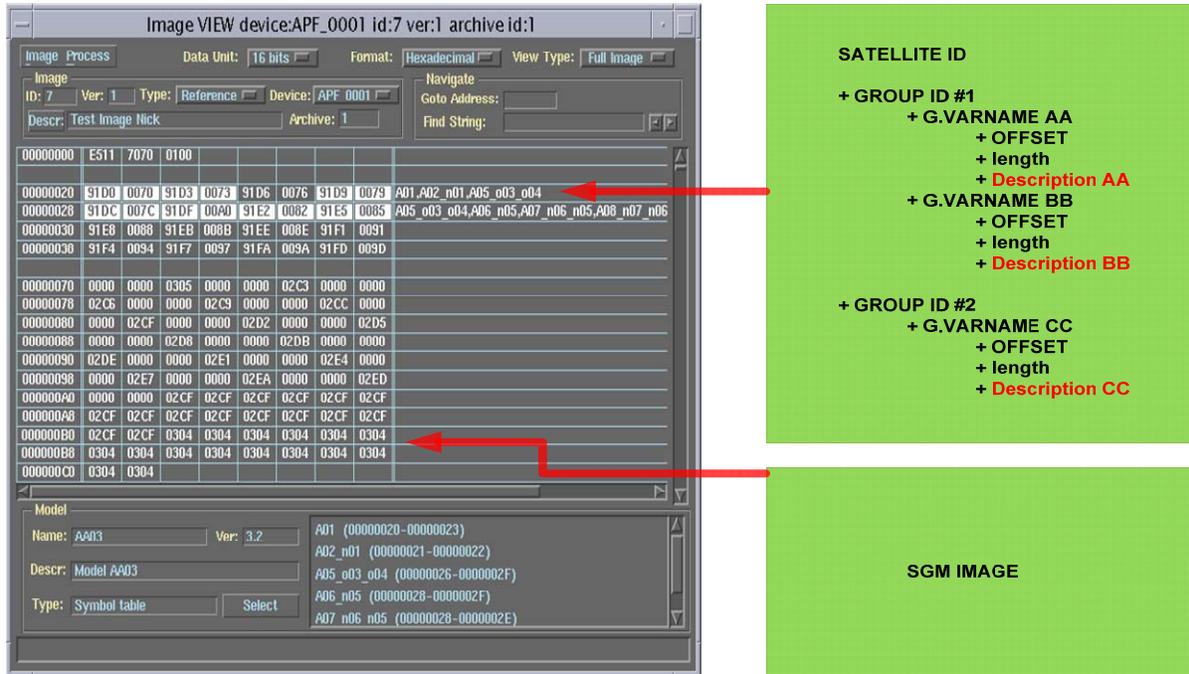
Figure 5. An example of safeguard memory model

To stress the importance of this topic for IOV and in the future consider that the look up table of satellite configuration is delivered as set of excel files comprising 84 spread sheets in total. Each contains couple hundreds of configuration parameters which might change during the satellite mission life time. Currently both the SGM Images and the excel files have to be maintained. This approach is not sustainable for a constellation of 30 satellites.
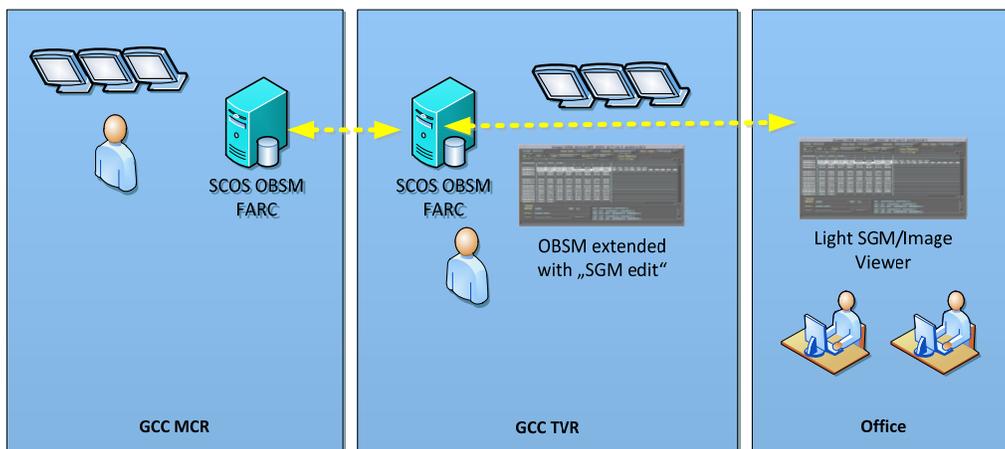

Figure 6. possible future scenario

Figure 6 shows a possible future scenario. At present for routine memory maintenance the patch operation is performed using PUS service 8. The OBSM Tool is used only for dump data verification and the decoding itself is done using the excel look up table. This functionality could be extended so that SGM patch operations can also be performed using OBSM by having appropriate model supplied by the spacecraft manufacture. The SCOS OBSM FARC will then serve as central repository for the satellite configuration memories. To support off-line data analysis a light version of OBSM (for SGM/image viewer) shall be deployed for viewing the satellite configuration which will supersede the excel files maintenance. It is known today that there is no such a tool available.

B. Model Edit Function and Data Conversion

Currently all models are delivered by the satellite manufacturer. Once transferred and saved into the file archive they can be loaded into the OBSM model catalogue but never modified. It would be a great improvement if new models could be created by the operator directly within the OBSM. As an example, the Processor Module RAM is the largest memory on board the spacecraft with a size of 6 Mbytes. During operations we often need to perform dumps from specific regions of the RAM. Since the current model covers the complete image, the commands for these dumps always have to be generated manually. The new function could be implemented easily by adding an edit function just as currently for the images. Model could be saved with a new version or a new identifier so that it does not overwrite the base file. The simulator requires as an input images in SREC format whereas the OBSM supports only SCOS format. The functionality of OBSM can be extended to support SREC/SCOS data conversion.

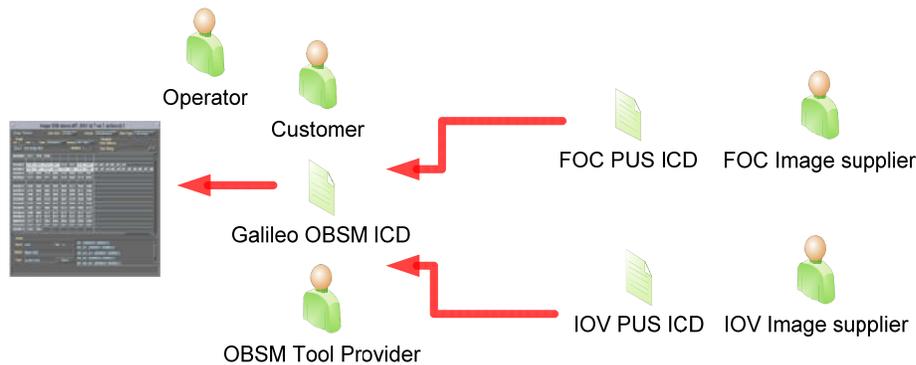**C. Architecture plan for Galileo Full Operational Constellation Phase**

Figure 6. OBSM Interface Control Document

Due to the fact that the PUS implementation might be different between satellite manufactures it is necessary to maintain a single OBSM ICD to guide the evolution of the tool. This will ensure as well that the OBSM tool is compatible between sites and can be used to ease the direct transfer and data analysis.

V.   Conclusion

Although the tool has already shown to be very efficient during the first part of the IOV, it is still subject to improvements. At the moment the files input are adapted to a format which is used by one satellite manufacturer. Some adjustments will have to be made when images will be received from different manufacturers. For this reason the tool should become more flexible and generic.

Further benefit can be achieved if the OBSM Tool can be used by LEOP service provider to generate a modified satellite configuration image and provide this to Galileo Control Centre following the S/C hand-over for comparison purpose. This will ease the verification and ensure a consistency.

The OSBM performance will become more and more important during the Galileo full constellation deployment. For this reason the Galileo Control Center will continue testing and upgrading the tool along the project IOV phase. It is a good choice to have it as part of the Galileo ground control system.

Appendix A
Acronym List

EEPROM	Electrically Erasable Programmable Read Only Memory
GCC	Galileo Control Center
HW	Hardware
IOV	In Orbit Validation
LEOP	Launch and Early Orbit Phase
MCS	Mission Control System
MDF	Memory device file
OBSM	On Board Software Management tool
OBSW	On Board Software
RAM	Random Access Memory
SCOS-2000	Satellite Control and Operation System 2000
ASW	Avionics Software
GCS	Ground Control Segment
PUS	Packet Utilization Services
OPF	Operations Preparation Facility
PRN	Pseudo Random Noise
SGM	Safeguard Memory

Acknowledgments