Reusable toolset for an Easy-to Build Payload Ground Segment

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For years, scientific laboratories have proposed to the French Space Agency (CNES) various scientific space experiments in many different fields such as astrophysics, astronomy, microgravity, environment and earth sciences.
Three main entities are involved in a space mission: the space segment, with satellite and scientific payload, the ground stations and control centre, and the payload ground segment with end users.
To reduce the cost of the access to space and thus to favour the emergence of new missions, CNES endeavours to develop generic systems in order to make available to the space community an access to space with reduced delay and cost.
That is why CNES decided in 1996 to develop the Proteus mini-satellite series to meet the needs for 500/700 kg satellites on low orbits. Two years later, the development of MYRIADE was decided, aimed at satellite having a typical mass between 100 and 150 kg.
A new stations network in currently under development with X/S band stations around the world to improve performances while the Control Centre has also been renewed. MIGS (Microsatellite Ground Segment) is a multi missions centre able to host up to 7 satellites at the same time. Automatic services allow limited human resources to supervise operations.
In this context, to benefit from a full generic solution, the need for a reusable payload ground system becomes obvious.
Therefore, to reduce scientific laboratories workload, CNES has been developing generic tools in order to fulfil the main functions of a scientific payload ground segment. As a result, the tools being already qualified by previous missions, the validation part is reduced, reliability is improved and operations are facilitated.
This paper aims at showing the payload ground system as a fully part of the whole system, and the way to facilitate the whole process of development.
In a first part, the architecture of a payload ground system is analysed focussing on the invariants in the main functions and operational concepts.
In a second part, a description of the main tools is given, emphasizing improvements in flexibility, operations as well as efficiency in validation process.
Eventually, two very different instances are presented in a third part, with:

- ***TARANIS*, a micro satellite of the CNES MYRIADE series designed to detect and study different phenomena associated to atmospheric storms,**
- ***SVOM,* a mini satellite, in cooperation with China, which main objective is the observation of gamma-ray bursts in the deep universe**

I. The context: Proteus and Myriade series

The main aim of these two programs was to have generic parts that can be directly re-used or re-used via limited adaptations to realize a new mission. These generic parts are:

- a recurrent platform
- a generic ground segment with some elements shared between Proteus and Myriade series

as well as ground facilities used for validation tests at satellite or system level.

The PGGS (Proteus Generic Ground Segment) command control ground segment firstly developed for the Proteus series has been transformed in a multi-mission product for the Myriade micro-satellites and Proteus mini-satellites.
The Myriade control ground segment is named MIGS (MIcroSatellite Ground Segment) and has a capacity to operate up to 7 satellites implementing five different scientific missions. It is operated since DEMETER mission in 2004.
The MIGS reference architecture includes the following elements:

- a S/X band network
- a Command Control Center (CCC)

This centre is composed of reusable software, infrastructure and methods dedicated to the operations of CNES small satellites (MYRIADE and PROTEUS series). Software set is specifically configured for each mission. It is divided into several units:

- G1 in charge of satellite/ground interfaces management
- G2 in charge of orbits determination and attitude control,
- G3 in charge of TM data storage and offline processing.
- G4 in charge of interfacing the payload ground segment.
- A Data Remote Processing PC allowing to visualize or to monitor the telemetry,
- A WWW server allowing to retrieve data from the Satellite Control Centre,
- A task scheduler in charge of the Satellite Control Centre automation,
- SYGALE in charge of the alarms management.

This multi-satellite control centre used for DEMETER, PARASOL, PICARD has also been used for small missions like JASON series or SMOS and will be used for TARANIS.

To avoid obsolescence and take advantage of new technologies, a new Myriade generation is currently under development, with new satellite bus version (MYRIADE EVOLUTION), new version of earth stations network (CORMORAN) and new version of multi-satellite Control Centre (ISIS CCC).
The experience of a program with generic parts offers the advantage of improving the system after each mission thanks to lessons learned and of course reducing the cost with the re-use of most of the elements. Every new space mission will benefit from these generic parts and modularity of the system.

However, the development duration remains driven by the payload planning, as technical challenges have to be solved with every new payload; that is why every solution allowing to reduce the development of the payload ground system part will allow to focus on the payload itself.
For that purpose, CNES decided to propose generic tools in order to fulfil the mains functions of a scientific payload ground system. In order to develop appropriate tools, we had first to analyse previous missions.
DEMETER and PARASOL, two scientific missions on board micro-satellites have been analysed.

II. Lessons learned from previous missions

A. Functional analysis

Few years ago, payload ground segments were supposed to be very specific as adapting an existing software was considered to be more expensive than developing a new one.
The payload ground system is the centre in charge of managing the on ground operations of the payload and data analyses. So, just have a look at payload operations under responsibility of the ground segment: [ESCC-E-ST-70]:

- Payload operations analysis, preparation, planning and scheduling;
- Payload data processing, archiving, delivery,
- User services,
- Performance analysis and reporting,
- Algorithm tuning, development, validation;
- System maintenance

Then, looking at different scientific missions functional architecture, it appears that a large part of the system is identical for each system.

1) From this analyse, a functional architecture common to most of the ground systems can be proposed which can be split in three layers: a payload management layer, a data management layer and a ground monitoring layer described below in details. Each function must be seen as the addition of a recurrent part and a mission specific part (see fig.1).

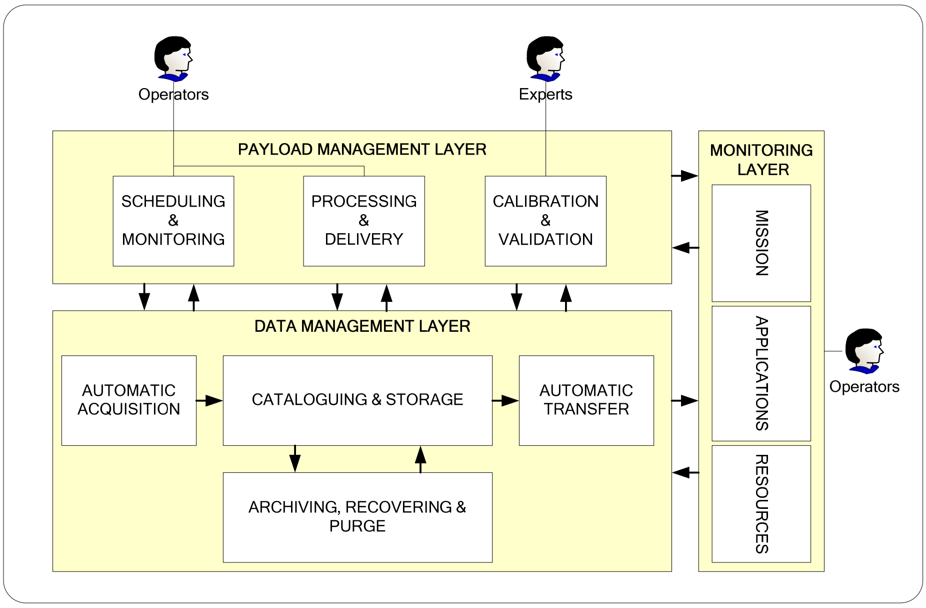

Figure 1. Functional architecture of a payload ground system

Each function is composed of recurring parts compliant with any mission and specific parts to be adapted or added depending on the mission specificities

1. **The payload management layer with top level functions**:

   - ***The payload scheduling function*** deals with the commands plan to be uploaded to the payload. Two methods are often used. The command plan is established and tested on a test bench during the pre-launched qualification phase. The operator has in this case only to change dates. Another method is to use a software to automatically produce the plan. In this case operator has to configure the algorithm parameters (ex: measurement mode, programming duration) and execute the program. The software is validated before the launch. In operation, the programming activity is usually done automatically, but a telecommand plan can also be produced manually if necessary.

   - ***The payload monitoring function*** deals with the verification of data downloaded from the payload with two different goals: daily monitoring and offline analysis. The daily monitoring automatically checks the good health of the payload. Simple laws are applied to housekeeping data, like comparison to a threshold, difference with previous value or plot of a daily curve. Only wrong parameters are logged into a file or visualized on a synoptic. Offline analysis is performed by payload experts. They use specific software to verify performance of the payload or assess drift of parameters.

   - ***Payload data processing*** is related to scientific production. Raw data downloaded from the payload are processed to various levels. Every single mission has his own definition of data levels. However, level 0 data are usually raw data sort by type and without communication layer. Level 1 data are calibrated data (i.e.: data with a physical unit) calculated from raw data. Level 2 are the physical parameters extracted from level 1 data with the best resolution of the instrument. They are most of the time the parameters to be measured by the space mission. Level 3 and 4 data are added value products like maps or data correlated to other mission products. Levels 1 to 4 processors are specific to the instruments and experiments and often developed by PI laboratories.

- ***Payload product delivery*** is a web-oriented system giving to public or authorised users an access to the mission data base. External users can either retrieve files or display data.

- ***Payload calibration and validation*** are functions managed by experts. A first group analyses low level data to establish *calibration laws* for every instrument. This group may require a specific payload programming in order to calibrate the payload. A second group is in charge of the scientific validation of the products. This groups can provide to the operator updated scientific algorithms to be uploaded.

2. The data management layer with low level functions:

- ***Acquisition and transfer***: a FTP type process is used to exchange data between operational centres. Files exchanges are triggered periodically or on event arrival. Protocol, volume, name and data format can be managed through configuration files.

- ***Catalog and storage*****:** all acquired or produced data are referenced in a data base and stored on disks. The data model is specific to the mission but experience shows that there is a similar part for each mission. This part concerns all data delivered by the satellite control centre (such as Orbit Event File) and data related to the system configuration.

- ***Archiving, back-up, recovering and purge***: the data base and storage system are periodically backed up and archived. These actions allow to purge the data base in order to maintain the system performance. In case of a major failure, it allows also to recover the system to the last restore point.

3. The ground monitoring layer with functions related to operator control.

Three levels of time scale are to be considered: short, middle and long term. Short term means immediate monitoring, medium term means analyzing data over a period of one day to one week, long term corresponds to a period from one month to one year.

- ***Resources monitoring***: all the necessary resources for the system to be fully operational are involved: disk and memory space, computer processor availability, network connection status, data base access or synchronisation. Short term monitoring is necessary before executing a new task or inform operator about a failure. Medium term monitoring informs about the resources increase and helps anticipating failures. Long term monitoring allows to know the availability of the system and what is useful to assess the system performance or to elaborate requirements of future systems.

- ***Application monitoring***: corresponds to a status view of every applications running on the system. Operators want to know at every moment the status of past activities (failed, warning, normal), status of current activities (duration of the process, computer memory in use) and status of scheduled activities (date of execution, list of tasks). All these information are essential to manage the centre. Short and medium term information allow operators to know quickly the status of all applications. Medium term information eases investigation of failure (which process, when, what message in the log) and helps scheduling a free time interval to relaunch a task or interrupt the system for maintenance. Long term monitoring allows making a synthesis about the performance of the system (mean duration of each process, number of failure).

- ***Mission monitoring*** deals with user requirements. Example of monitored parameters: quality of the scientific products, number of elaborated products per day, time to generate the products, missing raw data, list of acquired/sent files from/to exogenous centres. The mission monitoring allows operators to inform users about the mission progress. A short and medium term monitoring helps operators to manage the centre and make its synthesis for the weekly operational meeting.

Long term information allows estimating the operability of the mission and preparing the annual review.

This functional decomposition is compliant with any mission. It can be used as a basis to establish the architecture of new projects. In addition, this decomposition shows the various layers of a payload ground system and then emphasizes the complexity of this kind of operational centre.

B. Operational analysis

From an operational point of view, looking at different previous missions shows that ground system are operated using a similar concept.

Mission Operation Center are often operated by laboratories themselves with only few human resources. Human activities are focused on system monitoring, on exceptional tasks (ex: management of the configuration, the scheduling sequence or scientific processors) and maintenance (hardware, software, team training). Exploitation teams of a small scientific satellite are on duty only during working hours and working days. That means that the system must be automated as far as possible.

C. Resources

Despite the micro-satellite context, the volume of data managed can be quite important (4 GB/day for Taranis) and must be processed as they are produced.

The payload scheduling function may also be a complex process with automatic and manual operations. So, it is a fully operational mission and scientific centre which has to be developed, as Micro satellite doesn't mean small amount of data nor mini ground segment.

As for human resources, most of the time, the amount of resources required to develop a whole system has to be re-assessed and are much higher than first identified.

The main error is to consider only the top level functions (scheduling, monitoring, processing) and forget the workload related to the data management layer and ground monitoring layer as well as the resources necessary for the validation phase.

D. Time schedule

If we look backwards, we can notice that the development duration of missions such as DEMETER (a mission quite similar to TARANIS) as well as PICARD, is about 5 years with the main part dedicated to definition, coding and validation.

The engineering process at CNES is a classical one (V cycle)

- Phases A and B: ground system requirements are defined then specified, involving both CNES and laboratories
- Phases C/D: the system is design and produced by an external contractor
- Phases E1: validation of the system

Each process requires a full set of documentation to specify and supervise development, validate, operate and maintain the system.

However, scientific data processing definition is usually not completely defined when developments begin, as scientific teams focus on payload definition and development. But waiting too long for precise scientific needs may lead to delay in the system delivery.

To avoid modifications and to improve the development process, phase C (sub contractor phase) should start as late as possible.

The solution in order to be on time could be to increase team size, reduce the functional perimeter, **or benefit from an existing system.** So, new missions specificities could be managed mainly by software configuration.

E. Improvement solutions

Considering experience from previous missions, a solution to improve the engineering process of payload ground segment development has been studied.

First of all, the need of an appropriate and accurate documentation is highlighted. For example, DEMETER ground system has been used for 10 years and the ground system has to last some years after satellite end of life. It is thus necessary to produce and maintain technical documentation to operate and sometimes upgrade the system during its lifetime.

The main documents have been identified and must be carefully produced thanks to relevant templates.

Then, recurring needs of the system can be satisfied by reusing the software developed for previous missions.

To be able to fit to any mission, we decided to provide a toolset rather than a generic ground segment centre to be able to meet the requirement or only part of the requirements of any new mission and remain adaptable and evolutive.

The main advantage is to reduce the development duration to a minimum and enables to quickly have a qualified system.

III. CNES solution for an easy-to-build payload ground system

From the analysis described in the previous paragraph, many invariants in the functional architecture of a payload ground system have been identified. Hence, two types of toolsets have been elaborated.

- A set of documents and tools for phases A/B
- A set of software and platform for phases C/D

These sets constitute the CNES framework for the development of a reusable and easy-to-build payload ground system.

This solution allows laboratories to benefit by these improvements so that they can devote more resources to the development of the payload.

CNES solution has already been tested on some mission currently under way, and will be applied on Taranis and SVOM missions. These two missions will be described in this paper in the last part

A. Phase A: feasibility studies

Thanks to the suggested CNES approach, payload management strategy, ground segment architecture and project organization are quickly established during the first meetings with laboratories allowing them to focus on payload concept, performances and schedule.

B. Phase B: preliminary design

Phase B is the most important phase as it is related to the definition and specification of the system requirements. This phase also aims at precisely assessing project time schedule and risks as well as setting up the project organisation. Writing specification needs a good definition of the system to be developed as well as the method to write requirements. Thereby, the development process would be significantly facilitated if this step is reduced to the mission specific functions. To achieve this goal a set of template documents has been elaborated taking into account requirements from previous ground systems. This set is composed of several documents to be adapted and completed for each project:

- *A template document* of the ground system requirements. It is written with the Unified Modelling Language (UML) method and can be easily adapted. This document addresses the following system requirements: top and low level functions, monitoring, hardware, operational, safety, performance, availability, development. For each topic, the common requirements are included and mission related requirements are to be completed.
- *A template document* to describe scientific algorithms interfaces.
- *A template document* to describe the main product assurance requirements.
- *A template documents* to describe project schedule, plan and organisation.

Thanks to these template documents, phase B can benefit from a frame validated by previous project and focused on the mission specific needs. Moreover, this approach allows a direct transfer of the lessons learned. The template documents can be updated after each project (see figure 2)

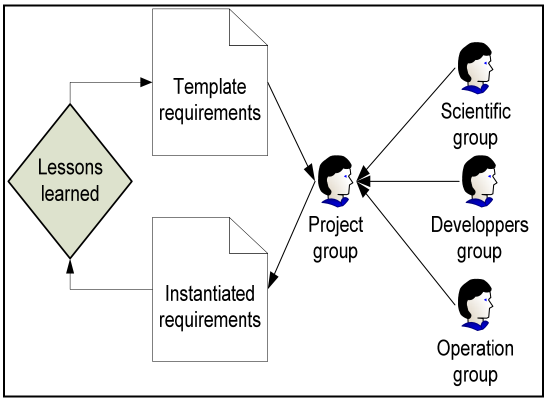

Figure 2. Set of template documents

C. Phase C/D: Design and development

Reuse of software needs a technology which enables to add new functions easily (plug-in, web services) and must also comply with a configuration management by files or data base in order to avoid a modification of the software core.

A list of tools or components have been developed, validated and improved, and are now available to cover almost all the functions of a payload ground segment. Only the resource monitoring function is not managed by a CNES tool. The following table shows the list of available components.

Function	Tool name
Data management layer	SAG / PHOEBUS
Payload Scheduling	GenTC
Payload Monitoring	IMIS/PRESTOPLOT
Data Processing	SAG / PHOEBUS
Product Delivery	SITOOLS II
Mission monitoring	IMIS
Application monitoring	SAG / PHOEBUS
Data Processing	PRESTODECOM
Resources monitoring	*Nagios*

Table 1. Tool set composing the CNES reusable payload ground system

- The **SAG** tool is used for the data management layer. It manages external and internal interfaces and two databases. The spacecraft database includes the payload telecommand and telemetry definition as well as the payload monitoring laws. This base is provided by the satellite control centre. The second data base is a mission dedicated base where all other payload data are defined.
  SAG is also used for its capacity to manage processors triggering and also for its capacity to monitor scheduled activities (i.e.: application monitoring)

- **PrestoDecom and PrestoPlot** are related to the application management pole and provide processing functions for MIGS telemetry decommutation, and curves and data plot.

- **Gen-TC, IMIS, SITOOLS II** and **NAGIOS** (not a CNES tool) provide functionalities to the scheduling and monitoring pole and to the data processing and delivery pole.

The next figure (Fig. 3) shows a superposition of this software architecture with the functional architecture (figure 1) and the operational architecture.

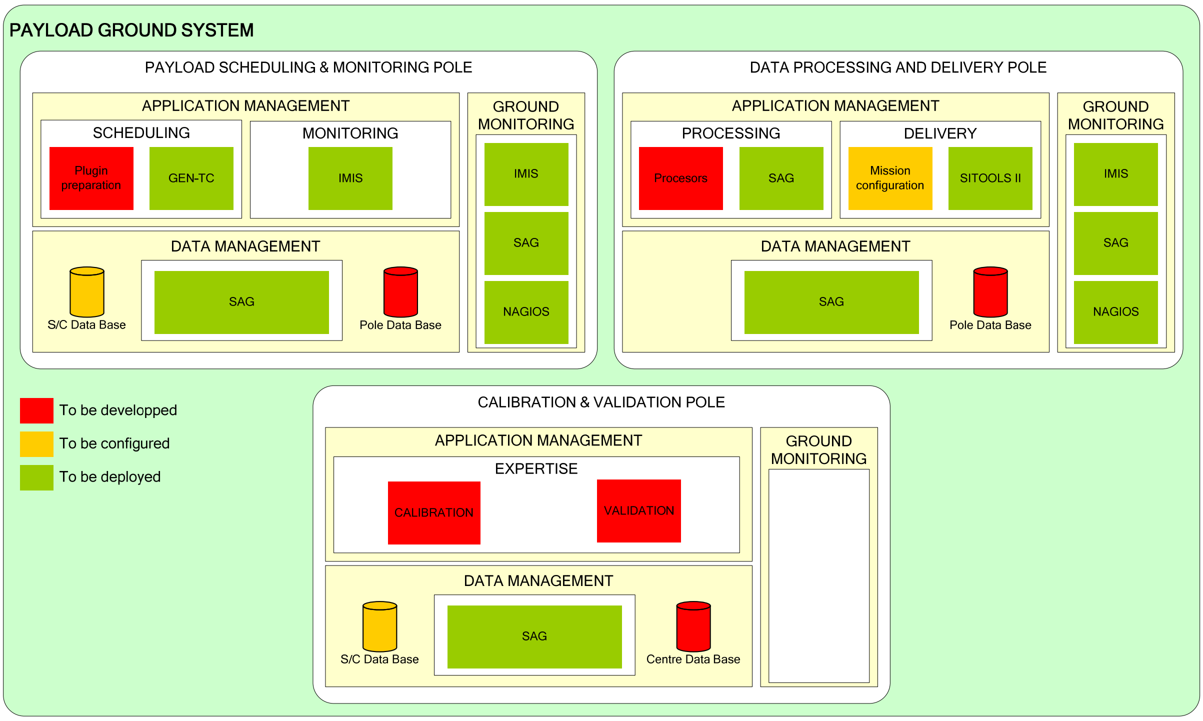

Figure 3. Software and functional architecture of a reusable payload ground segment.

A colour code allows identifying elements to be developed (red), configured (orange) or deployed (green). The ground monitoring layer of the Calibration & Validation pole is left empty

D. Description of CNES tools

1. SAG: "Structure d'accueil générique"

a. SAG main features

It has been designed at first for PLEIADES Earth Observation Program to be used by a group of experts or scientists who want flexibility to manage processing and interfaces.

The SAG is the core of the system with a framework which provides:

- Software to access catalog data
- Integration of processing components (dedicated to user or shared)
- Interfaces between data and processing modules

Elements to be configured by the administrator for each new project:

- External interfaces management and processes to be launched on new data acquisition
- Data base definition
- Number of users, data volume

Its flexible and scalable architecture complies with the following requirements:

- Defining a user data model with no impact on the software (generic access to data)

  Data base manages only meta data and the catalog is used for searching purposes as data is stored in regular file system directories
- Integration user components with a GUI builder and built-in APIs.

  This allows scientists or experts to be very responsive especially during commissioning phase when necessary to implement new or updated components within the framework.
- Offering a scalable architecture to fit any performance requirement and comply with growing projects.

b) SAG architecture

In order to fulfil the concepts described above, the framework has been designed using a **Service Oriented Architecture.**

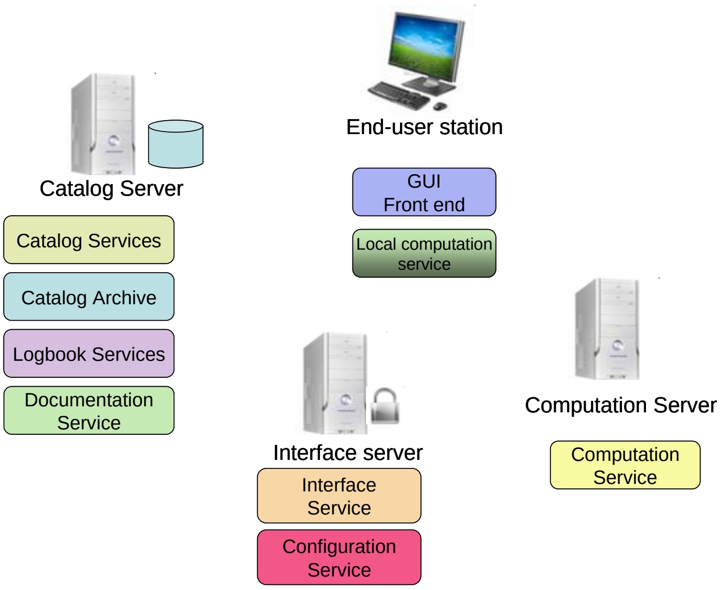

Figure 4. SAG Service Oriented Architecture

Depending on the number of users, or CPU needs, the services may be dispatched over a configurable amount of hosts from a single computer to a CPU farm and can easily evolve by an update of configuration files.

c) COTS used

The following COTS selected are open-source to ensure both durability and low costs and are portable on the major Operating Systems:

- Apache HTTD Tomcat Axis for web services
- Eclipse RCP, the multi-language software development environment comprising an integrated development environment (IDE) and an extensible plug-in system
- PostgreSQL the Open source data base with PostGIS for geo-referencing needs
- Hibernate, an object-relational mapping (ORM) library for the Java language

Besides Pleaides, scientific missions such as MegaTropiques, VENµS ans Mars Science Laboratory (MSL) have already benefit from this framework..

2. The Instrument Monitoring Interactive Software (IMIS)

***a)* IMIS main features**

IMIS main goal is to allow the operator of a scientific payload control centre to monitor the payload instrument health on a daily or weekly basis.
The instrument(s) health is monitored through the telemetry parameters downlinked from the spacecraft.
In some cases, it is also relevant to correlate the monitoring of telemetry parameters with the commands that have been executed on-board the spacecraft: for example, when monitoring a parameter indicating the instrument functioning mode, it may be interesting to know when commands modifying this mode have been sent.
IMIS provides also highlighting on the instrument(s) health thanks to the correlation of the monitored data with spatial information.
IMIS software is intended to provide all functionalities to achieve these objectives.
For this purpose, IMIS software handles three main categories of data:

· **Telemetry parameters** comprising parameters measured on-board the spacecraft and ground-computed parameters,
· **Executed commands**: this is the list of commands uplinked to the spacecraft and executed on-board,
· **Ancillary data** such as ephemeris data enabling to correlate the temporal telemetry parameters with the spacecraft location.

b) IMIS Architecture

IMIS is based on a client-server architecture with data storage on server side.

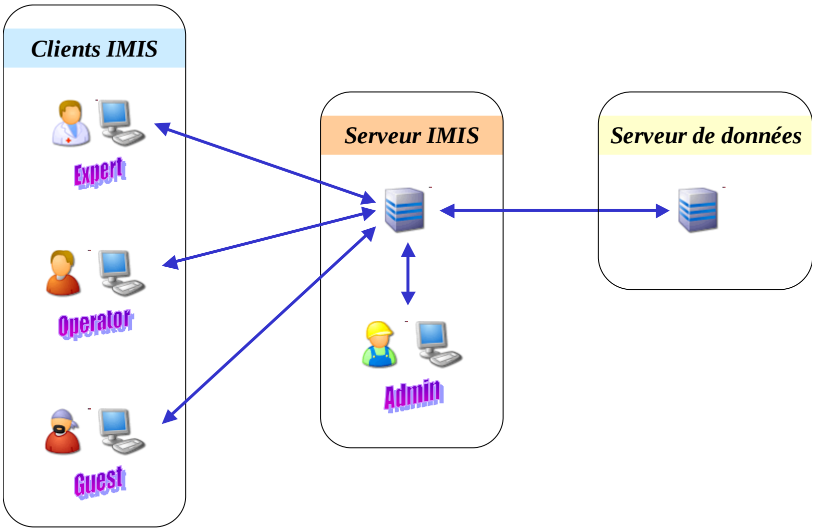

Figure 5. IMIS architecture

c) COTS used

Again, the selected COTS are open-source to ensure durability and low cost and are portable on the major Operating Systems. In addition to TOMCAT, Eclipse RCP and PostgreSQL, we also have:

- JSE, Java Standard Eition
- LOG4J, a Java-based logging utility

This tool has already been used for Mars Science Laboratory (MSL) and Saral missions.

3. GenTC

GenTC is a graphical tool for the telecommand plan elaboration. Firstly developed for the PICARD integration and validation phases it has quickly been used in an operational context. The first mission was JASON 2, then other altimetry CNES missions. In order to be fully compliant with other tools, recent evolutions have been implemented. The telecommand plan is elaborated by various ways with the new version of GenTC:

- Users build a plan by successive introduction of telecommands. Each is configured and timestamped.
- Users build a plan by activating a preparation plug-in that computes automatically the telecommand sequence. This plug-in is developed specifically for the mission.

Users update a plan previously elaborated.

GENTC is a client-server application which also uses COTS such as JSE and Eclipse RCP.

4. SITOOLS II

a) Sitools II main features

SITools II is an open source web application, built in a generic way. Its purpose is to offer a data access layer as a new element of an existing archival system. It is a convenient tool for scientific communities which are expected to provide data access to their experiments.
SITools II, a web application under GPLv3 license, has been designed in a community mind. It offers common services through an "easy-to-use" open source web platform. Furthermore, SITools II is highly tunable. It allows to connect different data sources and to expose their contents in various ways.

With its opened architecture, SITools II is also a framework that permits developers to extend the server API, simply integrating their own applications as plug-ins. Thus developers can act at each step of the data research, request and retrieval, but also create highly specific services. The SITools II client is also extensible by adding modules and advanced graphical components.

b) Architecture

SITools II is based on client/server architecture.
This object-oriented framework at server side is composed of a SITools II core and a set of extensions. The SITools II core is distributed as a standalone JAR and contains the SITools II API. Users typically write extensions against this SITools II API.

The framework at the client side, written in JavaScript, is composed of a core part and extensions as application modules. Each module can be removed or added thanks to the module manager.

5. Additional tools

A scientific ground segment deals with many data types. All kind of data have to be described in a unique and non ambiguous way. In order to help users and to improve reliability in data, the BEST workbench is proposed which offers a tool suite allowing, through a performing graphical user interface, to:
- **describe** project data (OASIS modeller),
- **simulate** data compliant with their description (Data Product Editor),
- **read or write** data (through an API available for C, Ada, Java, FORTRAN),
- **check** the data compliance with respect to their description,
- **validate** data thanks to several utilities (ASCII dump, curves drawer).

Plugins, added to Oasis, offer additional editors :
- Monitoring & Control plugin to describe the content of a Satellite Data Base
- XSD plugin to describe XML data using XML Schema (without any knowledge of the required syntax).

BEST is a generic tool based on XML internal format covering the entire data life cycle.
It is available on: Windows, Linux and Unix platforms and is developed using free technologies and as far as possible open source. Best is available at the following address:

http://logiciels.cnes.fr/BEST/FR/best.htm

6. Tools integration

A study has been conducted at CNES in order to integrate the tools presented before.

A bench has been developed and is currently installed into CNES facilities to make demonstration, analyze performance, and test compatibility with other tools.

IV. Instances of generic payload ground segment

A. TARANIS

1. Mission description

The general objective of the scientific TARANIS mission is to study magnetosphere-ionosphere-atmosphere coupling via transient processes. Taranis is dedicated to the observations of red sprites, blue jets, elves, sprite halos, gigantic jets, etc, named Transient Luminous Events (TLEs) and the observations of Terrestrial Gamma ray Flashes (TGFs). All these phenomena have pointed out the existence of impulsive transfers of energy between the Earth atmosphere and the space environment.
Taranis is a micro satellite to be placed in a quasi-polar orbit. **The system will make maximum use of the elements and resources from CNES MYRIADE micro satellite program**.

The payload ground segment TMSC (Taranis Scientific Mission Centre) is part of the global management and processing system of the TARANIS mission. It must make it possible for the scientific community to best exploit the onboard instruments by providing the necessary resources to manage and control the experiments.

The responsibility of the payload ground segment is shared between CNES and LPC2E, a prime laboratory which coordinates all scientific laboratories involved.

Thanks to the toolset availability, it appeared quickly that the most efficient and low cost organization to develop the TMSC was to have CNES responsible for the architecture and the generic framework whereas LPC2E, as a scientific laboratory, is responsible for the development of scientific components.

2. Architecture

The main functions of the payload ground segment are as follows:

- automatic data acquisition
- payload scheduling
- payload monitoring;
- data processing & product generation (raw data, low resolution data, high resolution calibrated data, mission products)
- data and product selection, visualization and delivery
- data archiving.

The various laboratories responsible for instruments of the Taranis payload are invited to develop their own instrument data processing in any language (Perl, Python, C, java…) without GUI.

In this context, the architecture proposed by CNES is widely based on SAG since it offers the main generic required functionalities: catalog management, data processing management, APIs for more complex integration. Operational requirement are also met thanks to the SAG: users rights management, logbook service, processing monitoring with alarm management, system supervision. SAG also offers a GUI builder to quickly define a GUI to launch any command line processing.

In addition, operations will be facilitated with IMIS which allows payload monitoring whereas it is still under discussion whether Sitools 2 will be used to perform data access .

Taranis architecture is today widely covered by CNES generic tools:

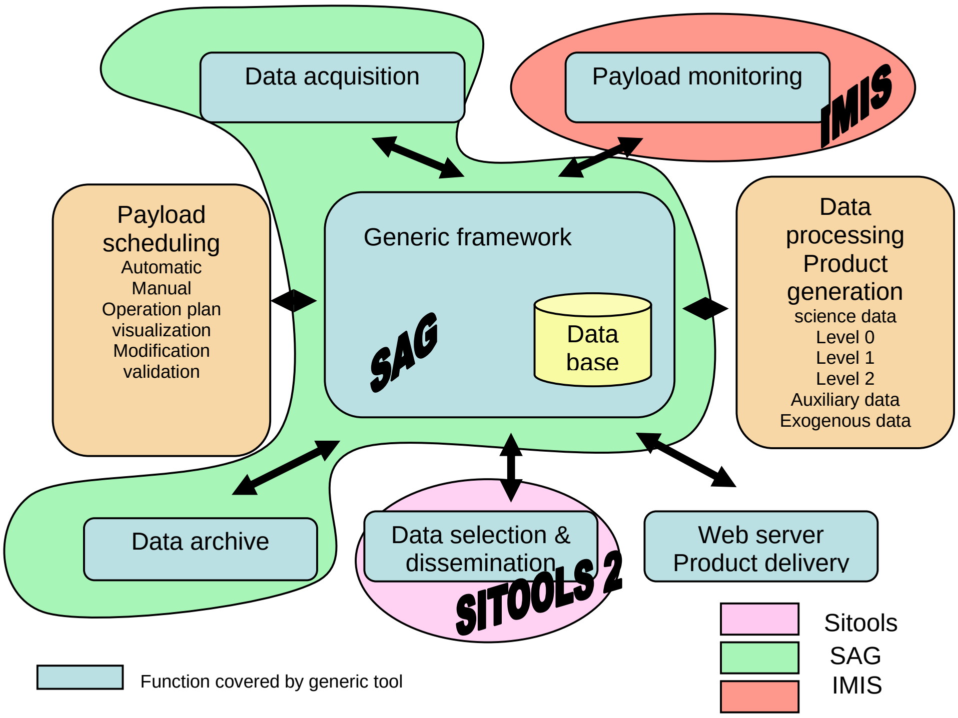

Figure 6. Taranis architecture versus generic tools

For Taranis, this generic framework will be used in a local area network, although it is possible to be dispatched over distant sites.

The data model is currently being defined: list of data types to store, search criteria, link between data types, contextual menu options to get the display of each data type.

Definition of the data model is done via XML configuration files, with XML schema in order to control data files.

Hardware configuration is also being defined taking into account

- the total amount of data (25 Gbytes- 4 years mission) for the set of disks
- the CPU needs to possibly configure shared computation servers
- the numbers of local users at the same time
- the interfaces volumetry and processes to run automatically on interfaces reception
- the level of security to achieve (authentification service access)

Integration process is done very easily as soon as components developed by laboratories are available and provided that they meet the interfaces requirements with SAG.

Components can be any kind of executable files scripts or binaries and are integrated using command line file parameters of any text format without specific skill.

Thanks to this framework, a first version of the payload ground segment (TSMC) will be developed in a quite short time allowing scientists to concentrate on payload development and on scientific validation.

The whole system will be integrated thanks to an incremental method limited to three versions (see Figure 7).

The first version deals with the Scheduling & Monitoring pole and will be developed for the beginning of the mission compatibility tests.

The second version could be an update of the first pole and completed with the Data Processing & Delivery pole. This version 2 will be developed for the mission operational tests.

Version 3 (last version) will be composed of an update of version 2 and completed with the third pole. This version must be validated for the end of the mission phase E1. The main advantage is to allow to follow scientific components development schedule. This solution also offers the users flexibility for the development of mission related functions.

Moreover, the validation process will be reduced, focussing on mission specificities, as generic functions have already been validated.

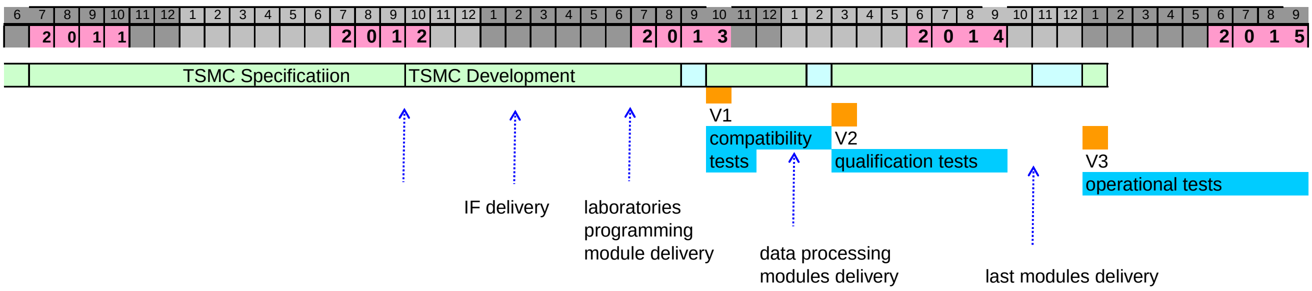

Figure 7. Taranis development planning

This planning for Taranis development shows that versions are very close, due to an easy integration process and a reduced validation phase already tested on previous missions which allows to be confident with the whole process.

B. SVOM

1. Mission description

SVOM Project (Space Variable Objects Monitor), in cooperation with China, consists in developing an X and gamma-ray astronomy mission which main objective is the observation and characterisation of the Gamma-Ray

Bursts from the deep Universe. SVOM was the aim of a Memorandum of Understanding between CNSA (China National Space Administration) and CNES defining the responsibilities shared between the agencies.
SVOM satellite will be put in orbit at 600 km altitude with a slight inclination (30°) to avoid the disturbances existing in the polar areas. It will carry four main instruments:

- a X and gamma rays camera (ECLAIRs, France),
- a low energy X-rays telescope (MXT, France),
- a gamma-ray burst spectrometer (GRM, China)
- a visible telescope (VT, China).

This scientific mission is a very ambitious one, since a high level of performances is required, leading to a quite complex architecture on board as well as for the ground segment.

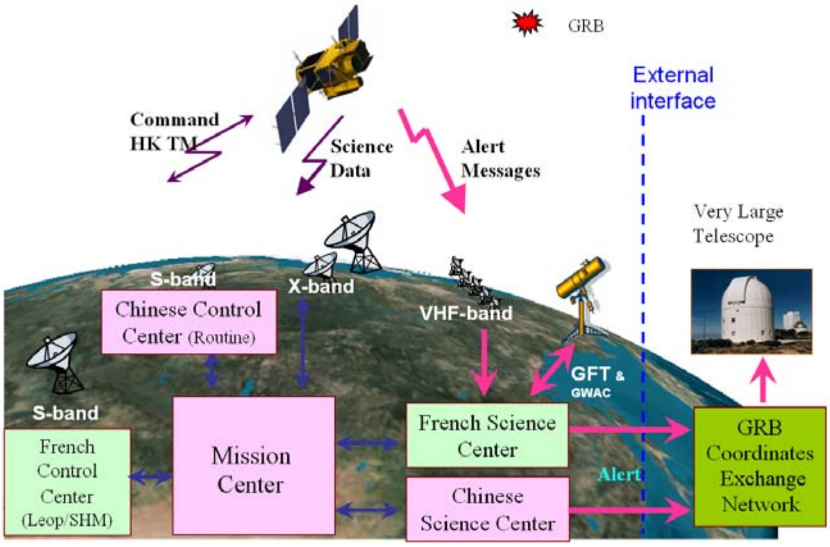

Figure 8. SVOM mission

To fulfil the mission objectives, SVOM mission will use ground means including, in addition to the means dedicated to the space platform control and command tasks, the following elements:

- GFT (Ground Follow-up Telescope)
  Robotic telescope in charge of measuring the burst celestial coordinates with high accuracy in less than four minutes after receiving an alert
- GWAC (Ground Wide Angle Camera - Chinese supply)
  Set of ground telescopes pointing towards the same region of the sky than ECLAIRs instrument,
- Alert network (French supply)
  Entity enabling a permanent contact from the satellite to the ground; it is dedicated to receive at any time the alert signal delivered by the satellite and to transmit it in less than a minute to the French Science Center (FSC). This network is also used to transmit in quasi real-time a part of the scientific data.
- **FSC (French Science Center)**
  Science center where alert data are automatically analyzed in quasi real-time by automates in charge of distributing the alert to the large telescopes. The alert data are also analyzed by several French and Chinese scientists which take turns in order to ensure an operational scientific vigil 24/24 hours.

SVOM is not a micro satellite of the MYRIADE program, but a mini satellite supplied by CNSA.
However, the ground payload segment can benefit from any generic tool used for any other program satellite.

2. *SVOM architecture*

Due to the high level of requirements the payload ground segment has been separated in 4 different entities with a dedicated task for each:

- **FSC-PM** (French Science Centre - Payload Management) in charge of French payload TC generation , payload monitoring, TM/TC data base management and payload configuration management, processing of raw science data then generation, distribution and archiving of level 0 data files
- **FSC-ASM** (Alert and Science Management), in charge of alert data processing and distribution, and science products generation
- **Eclairs and MXT Instrument Centers** dedicated to instrument management and long term monitoring.

The following figure shows the SVOM payload ground segment architecture.

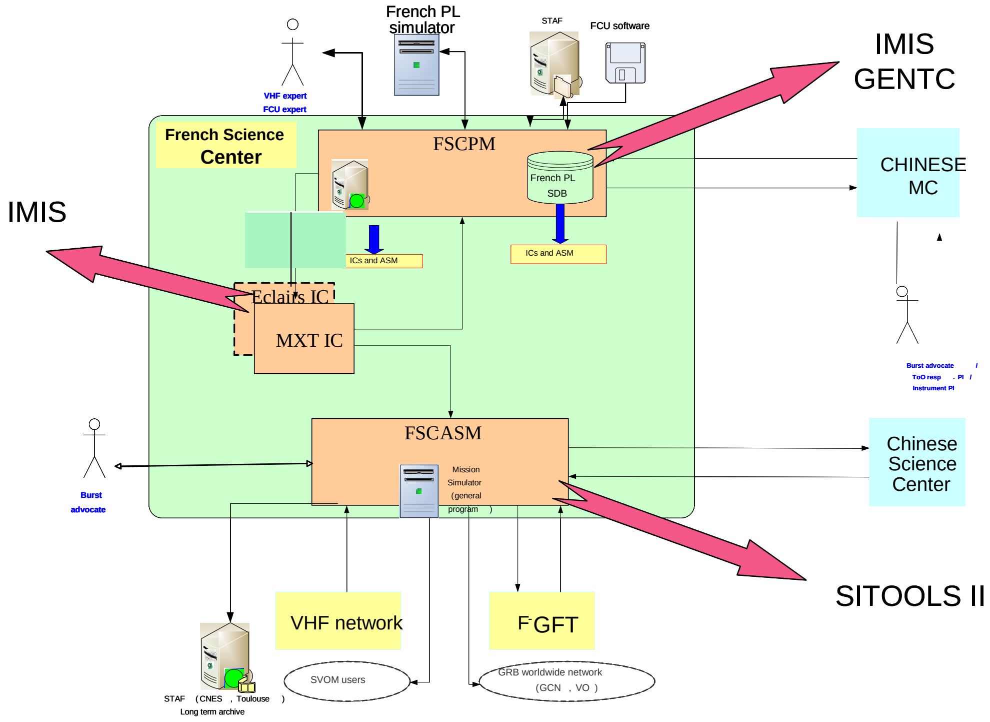

Figure 9. SVOM payload ground segment architecture

FSC responsibility is shared between IRFU which is a CEA (Commissariat à l'Energie Atomique) scientific laboratory and CNES.
IRFU is responsible for FSC-ASM which deals with the near-real time processing of alerts whereas CNES is will be responsible for FSC-PM.
As this payload ground segment is split into 2 different entities, the SAG is not convenient especially for FSC-ASM which has a strong requirement of real time processing, nor fot FSC-PM which main responsibility is payload programming.

Every center will however benefit from some CNES generic tools:

- FSC-ASM for data and products access, visualization and dissemination with the use of **SITOOLS II**, which has been tested with success by the laboratory.

- FSC-PM as well as Instrument Centres (IC) will use **IMIS** tool for they are responsible for payload monitoring (medium and long term monitoring)
  GenTC is also to be used to prepare operation plans.

Moreover, data description is fully done at each level with **Best** tools.

V. CONCLUSION

For a few years now, experience from several missions has shown that generic tools as well as documentation frame is of significant help for scientist and engineers as they allow to reduce the resource necessary to develop the system. Moreover, this solution improves with lessons learned and new options introduced by every project. Reuse of generic functions allows to benefit from a good level of qualification.
The examples of Taranis and SVOM, though very different in their concept, organization and responsibilities sharing, show that the available toolset provided by CNES is suitable and modular so as to be an efficient and low cost solution for any payload ground segment center.

CNES solution enables to easily build the architecture of a payload ground system and quickly have a qualified system thanks to the reuse of software components.

VI. ACKNOWLEDGMENT

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