SVOM Mission Operations: Commissioning and Early routine phase operations

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Abstract

Launched on June 22nd 2024 by the Chinese Long March 2C rocket from the Xichang launch base, the Space Variable Object Monitor (SVOM) is the result of collaboration between two national space agencies; the Centre National d'Etudes Spatiales (CNES) and the China National Space Administration (CNSA), with the main laboratories contributions involved in the mission such as CEA (Commissariat à l'Energie Atomique et aux énergies alternatives) and IRAP (Institut de Recherche en Astrophysique and Planétologie) for France and NAOC (National Astronomical Observatory of China) and IHEP (China's Institute of High Energy Physics). SVOM has been designed to detect all known types of gamma-ray bursts (GRBs), to provide fast and reliable GRB positions, to measure the broadband spectral characteristics and temporal properties of the GRB prompt emission.

In this paper, after illustrating an overview of the SVOM mission and the scientific goals, we briefly show a description of the as-built spacecraft that is currently being operated and the on-board instruments that the mission carries to achieve these goals. It provides a summary of the key system characteristics and driving requirements.

We pay special attention to the ground system architecture that is composed of the French and Chinese ground segments. We describe the SVOM mission operations concept, focusing on many the novel aspects. These include the scientific observations, data flows between different components, mission planning and operational tools that support automated operations. This is followed by explaining how SVOM joint operations fulfils mission requirement in the distributed and complex system through Chinese-French contribution. We then provide a summary of the commissioning and early routine phase operations, challenges encountered and findings. This paper concludes with the experience gained, some lessons learnt and perspectives.

Keywords: SVOM, operations, operations concept, commissioning, ground segment, ground system.

Acronyms/Abbreviations

CNES : Centre National d'Etudes Spatiales
CNSA : China National Space Administration
CEA : Commissariat à l'Energie Atomique
IRAP : Institut de Recherche en Astrophysique and Planétologie
NAOC : National Astronomical Observatory of China
IHEP : Institute of High Energy Physics.
NSSC : National Space Science Center
SECM : Shanghai Engineering Center for Microsatellites
CAS : Chinese Academy of Sciences

1. Introduction

SVOM (Space-based multi-band astronomical Variable Objects Monitor) is a French-Chinese mission dedicated to the detection and follow-up of short flashes of hard X-ray and gamma-ray photons called gamma-ray bursts (GRBs) and of other high-energy transients. SVOM is space mission developed in collaboration between the China National Space Administration (CNSA), the Chinese Academy of Science (CAS) and the Centre National d'Etudes Spatiales (CNES). It involves several research institutes from these two countries with the main contributions from the Institute of Research into the Fundamental Laws of the Universe (IRFU) and the Research Institute of Astrophysics and Planetology (IRAP) for France and the National Astronomical Observatory (NAOC) and the Beijing High Energy Institute (IHEP) for China.

After a brief presentation of SVOM mission and the scientific goals, SVOM instruments, we pay special attention to the ground system architecture that is composed of the French and Chinese ground segments. These include the scientific observations, data flows between different components, mission planning and operational tools. We describe the SVOM mission operations concept, the SVOM joint organization and management in operational phase. We then provide a summary of the commissioning and early routine phase operations, challenges encountered and findings by highlighting the operations and ground segment aspects, in particular the French Operational Center.

2. The SVOM mission

2.1 The SVOM mission objective

The mission has been designed to survey the high energy sky and to follow-up cosmic transients at optical and X-ray wavelengths.

Launched on June 22nd 2024 by the Chinese Long March 2C rocket from the Xichang launch base, the SVOM satellite is put into an orbit with a 30-degree inclination, an altitude of 625 km. It involves both space-based and ground-based instruments. The SVOM space platform which includes four space instruments: the ECLAIRs telescope, the Gamma Ray-burst Monitor (GRM), the Microchannel X-ray Telescope (MXT), and the Visible Telescope (VT). The SVOM mission also includes a set of Ground Wide-Angle Cameras (GWACs) and two dedicated Ground Follow-up Telescopes (GFTs).

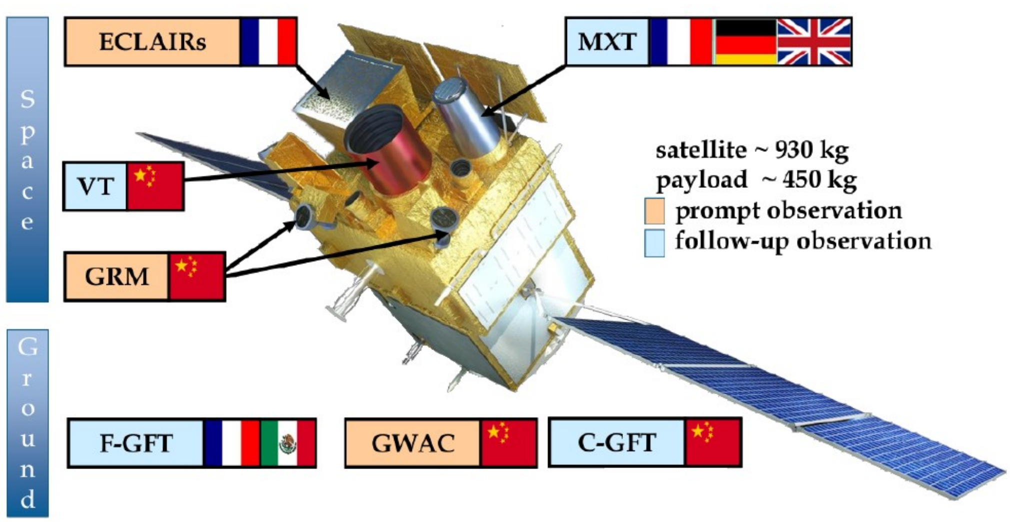

Fig. 1. Overview of SVOM satellite with space-based and ground-based instruments

The SVOM spacecraft can re-point itself without ground intervention, based on the alerts distributed by the on-board instrument ECLAIRs. The wide-field instruments ECLAIRs and GRM monitor the sky, looking for GRB prompt emission in the hard X-ray and the γ-ray for GRM. When they detect a new transient source, ECLAIRs gives an estimated sky position of the GRB, and transmits it to the satellite. If the detection is made with a sufficient Signal-to-Noise Ratio (SNR), the SVOM satellite slews towards the target, pointing its narrow field instruments MXT and VT. These instruments detect the first epochs of the afterglow and narrow the localization error box to a few arc seconds. Moreover, the dedicated SVOM ground observatories also observe the ECLAIRs error box within a few tens of seconds after the detection. The refined localization obtained along with some of the burst characteristics are transmitted to the science community so that other observatories can perform dedicated follow-ups.

Beidou Navigation Satellite System short message is used for SVOM, as an addition to the SVOM satellite system to enhance the potential scientific outcomes of the mission. Beidou short message system are used to upload Target of Opportunity observations and to download GRB alert message and data to the ground.

2.2 French and Chinese cooperation

The global organization of the SVOM program in operational phase is defined as follows:
- the mission is globally under CNSA/CAS responsibility with CNES participating in all French components.
- the system responsibility is shared between CNSA/CAS and CNES.
- the satellite is under CNSA/CAS responsibility.
- the operations are under CNSA/CAS responsibility. Each party is in charge its own ground segment canters

3. The SVOM Instruments

3.1 The SVOM Space-based Instruments

The mission consists of 4 main instruments, two French instruments (ECLAIRs and MXT) and two Chinese instruments (GRM and VT):
- The telescope ECLAIRs is a coded-mask instrument with a field of view (FoV) of 2 sr. This instrument is capable of triggering and locating GRBs with a precision of less than 12′ in the 4–120 keV energy band.
- The Gamma-Ray burst Monitor (GRM) is composed by three units that together cover a larger field of view than ECLAIRs (~5.6 sr) and extend its energy band up to 5 MeV.
- The Microchannel X-ray Telescope (MXT) can detect GRBs in the 0.2–10 keV energy band. This instrument is capable of locating them with a precision < 13′.
- The Visible Telescope (VT) can observe GRBs in the visible band (400–1000 nm) and can localize them with a precision ~1″.

3.2 The SVOM Ground-based Instruments

The SVOM scientific objectives require in addition to satellite measurements, ground based measurements connected to space instruments through the VHF network. The SVOM Ground-based instruments are supported by three ground-based facilities dedicated to the prompt emission observation and the afterglow follow-up of SVOM GRBs.

The Ground-based Wide Angle Camera system (GWAC) of SVOM is designed to observe in the visible domain the prompt phase of SVOM GRBs. The GWAC is a set of several units, each made of 4 wide-angle optical cameras (Joint Field of View (JFoV)) and a small photographic camera (Full Field of View (FFoV)) on a single fast-moving mount. This system is also equipped by three robotic telescopes (two 60 cm diameter and one 30 cm diameter) that can quickly follow interesting events detected by GWACs.


Fig. 2. GWAC installation at Xinglong Observatory (Beijing, China)

Two Ground Follow-up Telescopes (GFT) are dedicated to observe quickly the high energy transients detected by SVOM and to measure their light curves and their positions. In order to maximise the probability of immediate observations in response to SVOM alerts, these telescopes are located about 120 apart in longitude.

The Chinese Ground Follow-up Telescope (C-GFT) is located at Jilin Observatory (Beijing, China). This telescope has a 1.2-meter diameter primary mirror. The telescope will be exceptionally responsive to SVOM real-time data, and communication systems.


Fig. 3. The Jilin Observatory (left) and the C-GFT telescope (right)

The French Ground Follow-up Telescope (F-GFT) or COLIBRI is located in San Pedro Mártir (Baja California, Mexico). This telescope is able to point to any source in the sky in less than 30 seconds, allowing to study the first minutes of GRB afterglows. COLIBRI is equipped by two cameras, DDRAGO and CAGIRE (CApturing Grb InfraRed Emission).


Fig. 4. The French Ground Follow-up Telescope (F-GFT) or COLIBRI

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4. The SVOM Ground Segment

For ensuring its own responsibility during operational phase, each partner is in charge a specific ground segment according to the overall scheme shown in the following figure.

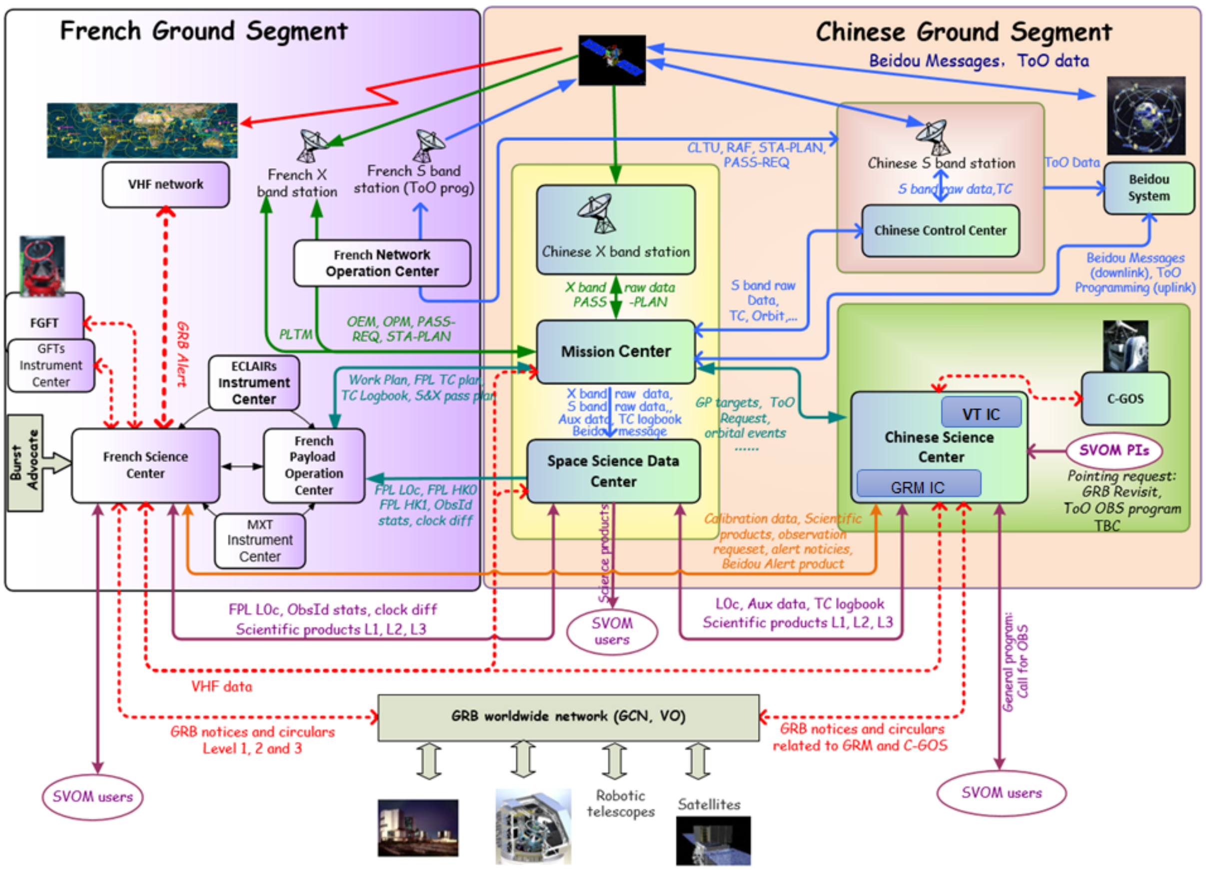

Fig. 5. SVOM ground segment overview

As described in the figure, the SVOM ground segment is divided between French and Chinese responsibilities.

4.1 The Chinese Ground Segment

The SVOM Chinese Ground Segment consists of the following components:

- a Chinese Control Center (CCC)
- a Mission Center (MC)
- a Space Science Data Center (SSDC)
- a Chinese Science Center (CSC)
- a C-GOS (Chinese Ground Observation System), including the Chinese Ground Follow-up Telescope (C-GFT) and the Ground Wide Angle Cameras (GWACs)
- a GRM Instrument Center (GRM-IC)
- a VT Instrument Center (VT-IC)
- a set of ground stations (S and X bands)

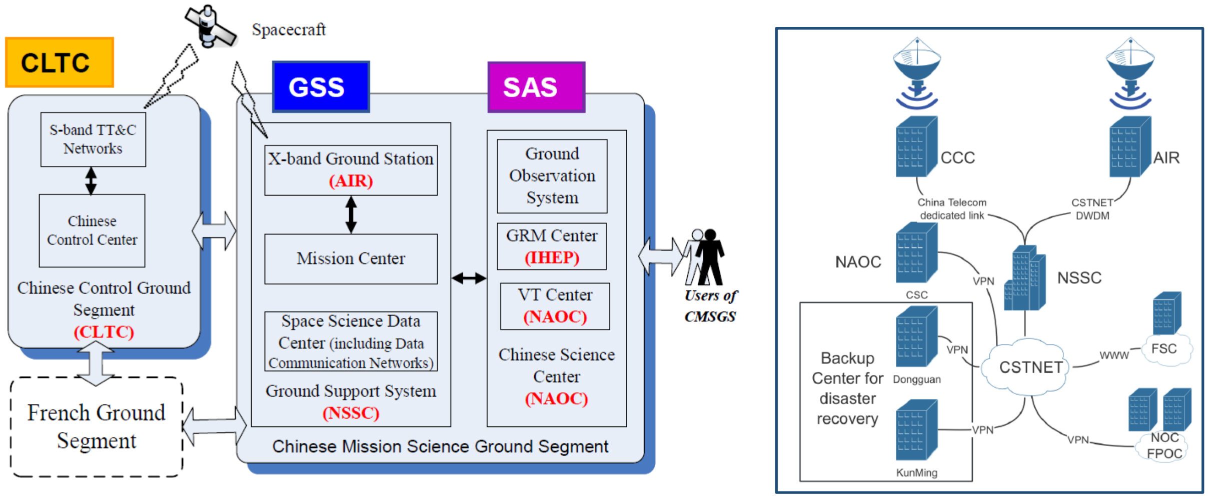

Fig. 6. SVOM Chinese ground segment (left) and data communication network (right)

The **Chinese Control Center (CCC)** is located in Xi'an (China) and managed by **CLTC** (China Satellite Launch and Tracking Control). The CCC is main ground component which manages satellite in each phase. The CCC receives payload and pointing commands from the Mission Center (MC) and generates the platform telecommands. The CCC is responsible for sending the commands to the satellite through the **S-band stations**. The CCC is in charge of acquisition, decommutation and monitoring of HK (housekeeping) telemetry including the platform, critical CPL (Chinese Payload) and FPL (French Payload) HK parameters.

The **Ground Support System (GSS)**, located in Beijing is under the **NSSC** (National Space Science Center) of the **CAS** (Chinese Academy of Sciences) responsibilities. The GSS is a key component in the whole French and Chinese Ground Segment. There are three parts of SVOM Ground Support System (GSS): Chinese X-band station, Mission Center (MC) and Space Science Data Center (SSDC). It interfaces with satellite through Chinese X-band station, Beidou, CCC, CSC and SVOM users. It also interfaces with FPOC, NOC and FSC.

The **Mission Center (MC)** is responsible for the following main activities: mission planning and scheduling, payload command management, pointing request plan generation, data processing and management and the payload health status monitoring. The MC is responsible for overall mission coordination and payload operations.

The **Space Science Data Center (SSDC)** is responsible for the following main activities: science data pre-processing, data management, archiving, permanent preservation and distribution. The SSDC manages the Chinese Data Communication Network (DCN), and provides E-services environment to allow public access to the SVOM results. The DCN connects all elements of Mission Science Ground Segments.

The **Chinese X-band station** is managed by the **AIR** (Aerospace Information Research Institute) of the CAS. It ensures the following main functions: scientific satellite tracking, data receiving, data recording and output formatting, and data transmission.

The **Chinese Science Center (CSC)** is managed by NAOC and located in Beijing. The CSC is responsible for the following main activities:

- Providing software tools dedicated to Call for Observations (Obs), General Program Proposal management process, target selection process and ToO management process
- Managing VT and GRM instruments and monitoring health of instruments
- Generating CPL (Chinese Payload) standard science products
- Providing tools to support BA (Burst Advocate) working and to support the science community to analyze and exploit SVOM data,
- Managing Chinese follow-up telescope (C-GFT) and GWAC and Chinese Science products computation,

The Chinese Ground Observation System (CGOS) includes the Chinese Ground Follow-up Telescope (C-GFT) and the Ground Wide Angle Cameras (GWACs). The C-GFT telescope is dedicated to GRB follow-up observation. It is automatically driven by the GRB alert message coming from the CSC and sends images to the CSC.

4.2 The French Ground Segment

The CNES is responsible of the coordination of all the French Ground Segment and operations activities. The following centers are managed by CNES in Toulouse (France):

- FPOC (French Payload Operation Center)
- NOC (Network Operation Center) and a set of ground stations (S and X bands)
- VHF ground network

The **FSGS (French Scientific Ground Segment)** includes the following scientific centers:

- FSC (French Science Center)
- MIC (MXT Instrument Center)
- EIC (ECLAIRs Instrument Center)
- GIC (GFT Instrument Center)
- F-GFT (French Ground Follow-up Telescope)

The **French Payload Operation Center (FPOC)** is located at CNES in Toulouse. The FPOC ensures on-board and ground operations. The FPOC is in charge of the following activities:

- Managing and operating the French Payload (ECLAIRs and MXT instruments)
- French Payload Command and Control management
- French Payload health and status monitoring
- Software and tools management (validation, maintenance and exploitation)
- Infrastructure monitoring
- Anomaly and changes management

The **NOC (Network Operation Center)** is managed by CNES and located in Toulouse. This canter is in charge of all French ground stations (S and X band) scheduling, station monitoring and control. It interfaces to the Mission Center for the station support request processing and the pass reservation confirmation. It will also be used for ToO uplinking by using French S-band stations if Chinese S-band station couldn't meet the required delay of 12h for Gravitation Waves observations.

The **Very High Frequency (VHF)** stations network are managed by CNES in Toulouse. The VHF stations network are composed of 47 stations and deployed homogeneously as possible around the Earth's surface.

The **French Science Center (FSC)** is managed by CEA and located in Paris Saclay. The FSC is in charge of the following activities:

- VHF data management (reception from antennas, decoding, storage and notifications)
- MXT and ECLAIRs X-band data and auxiliary data management (reception from SSDC, decoding, storage, notifications)
- Chinese Science Center and French follow-up telescope (F-GFT) communication
- Computation of French science products and distribution for all programs

The **MXT Instrument Centers (MIC)** is managed by CEA and located in Paris Saclay. The MIC is in charge of the following activities:

- MXT instrument configuration commands generation
- MXT instrument performance validation and long term monitoring
- MXT instrument on-board software management

The **ECLAIRs Instrument Centers (EIC)** is managed by IRAP and located in Toulouse. The EIC is in charge of the following activities:

- ECLAIRs instrument configuration commands generation

- ECLAIRs instrument performance validation and long term monitoring
- ECLAIRs instrument on-board software management

The **F-GFT Instrument Center (GIC)** is managed by CPPM and located in Marseille. The GIC is in charge of the following activities:

- Monitoring of F-GFT (COLIBRI) status (observation conditions, system, current programs, long term performances, etc)
- Definition of the observation strategy
- Data processing and science product upload to FSC database

4.3 The SVOM ground stations network

4.3.1 *VHF stations network*

The Very High Frequency (VHF) stations network, a network of VHF receivers are composed of 47 stations which are deployed homogeneously as possible around the Earth's surface in order to collect in real time the alerts produced by the satellite. They ensure a near real-time space-ground link availability for 80% of the time. The VHF stations network are managed by CNES in Toulouse.

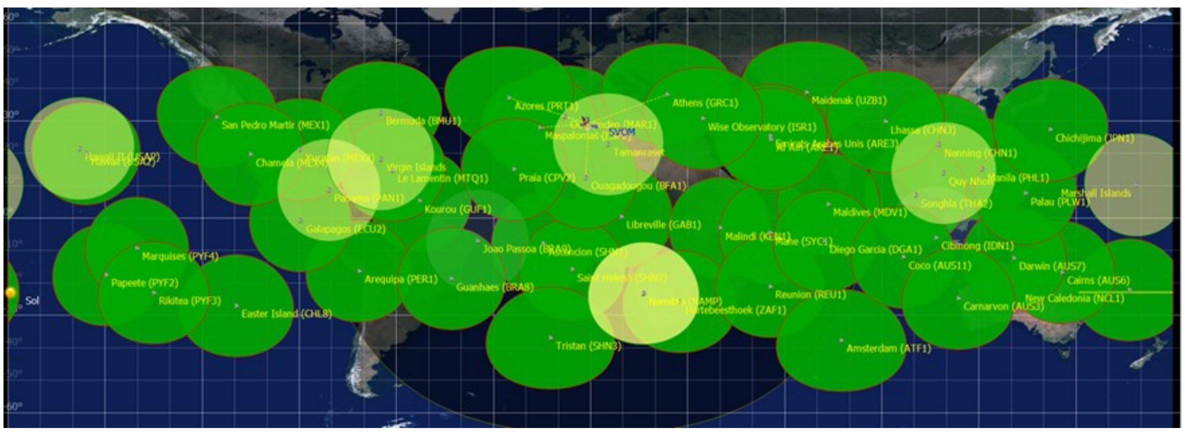

Fig. 7. VHF stations network

These VHF ground stations are connected to the French Science Centre (FSC). When a VHF station detects a signal from SVOM, these telemetry packets are sent via the Internet to the FSC, where the original message is reconstructed and immediately transmitted to the GFTs robotic telescopes. The original message is also distributed with the GCN Notices to the scientific community. This information can also be verified by the Burst Advocate (BA) and communicated to the science community through GCN Circulars. It is expected that 65% of the SVOM alert messages are delivered within less than 30s, and that 95% of them reach the observers within less than 20 minutes.

Some alerts can also be transmitted through the Beidou network via inter-satellite communications. Information such as trigger information in case of detection, position and sub-images are sent through this mean. Commands can be sent to SVOM with the Beidou short messages communication service. This is used to program Target of Opportunity observations towards active high-energy sources or towards neutrinos or gravitational waves transient sources to shorten the satellite reprogramming time.

4.3.2 *X-band and S-band stations*

X-band and S-band stations are used to communicate a larger volume of information. S-band ground stations are the ground elements which implement the telemetry download and telecommand upload via the ground antennas and emitter. SVOM satellite has an orbit with a 30-degree inclination. There are two French and three Chinese S-band stations scattered around the globe. Both are used to upload the Target of Opportunity observation requests to the satellite, with a maximum latency of 12 hours. However, as SVOM might also use the Beidou system to communicate with the ground, this latency could be reduced to < 5 hours.

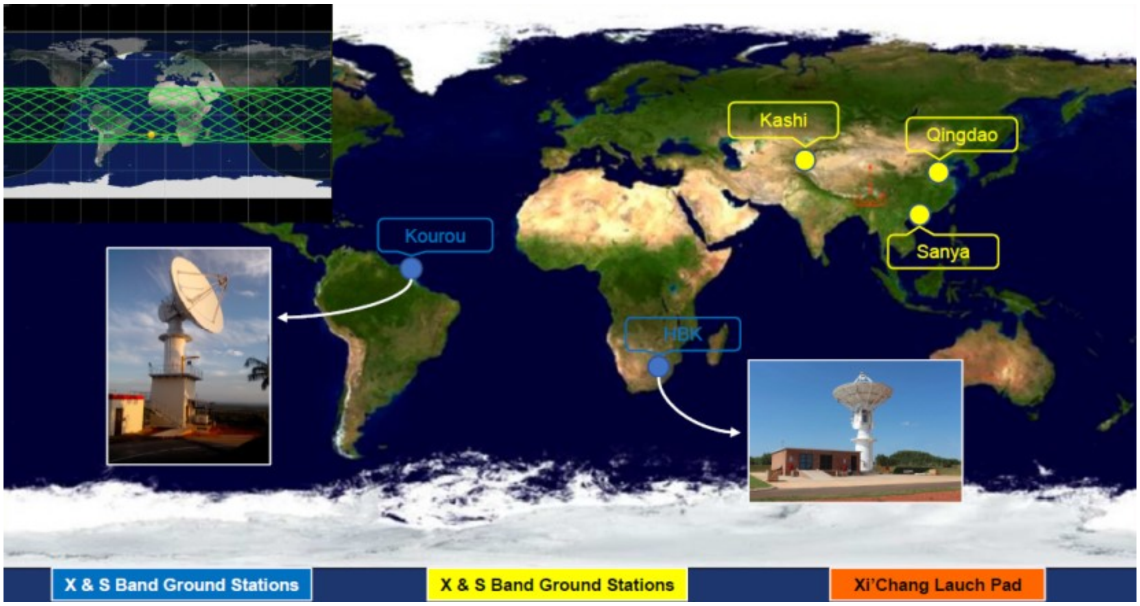

Fig. 8. X-band and S-band stations

The Chinese S-band station(s) which can be used by the SVOM mission are located in Sanya, Kashi and Qingdao. Chinese ground stations are the main stations used in each phase. The CNES S-band stations will be used for supporting satellite operation for exceptional ToO programming on a best effort basis. The French S-band station(s) are located in Kourou (French Guiana) and Hartebeeshoek (South Africa).

The three Chinese S-band stations are used for routine telecommand upload. These telecommands can be, for example, configuration changes of the on-board instruments or modifications of the flight software. A large majority of the S-band data is allocated to the status of the plateform and payload management interface.

SVOM mission use French X-band ground stations which are located in Hartebeeshoek and Kourou. They collaborate with Chinese X-band station located in Sanya for science data receiving. The three X-band stations allow 8 passes per day.

4.3.3 *GCN system*

The Gamma-Ray Coordinates Network (GCN) is a system that distributes the locations of GRBs and other transients detected and reports the follow-up observations. As GRB astronomy is a domain where the timing of the observations is crucial, this network has been created to inform the potential observers as soon as possible. The GCN Notices send the location of the GRB/transients without any humans-in-the-loop, meaning that the notice is distributed to the users with a 2−10 seconds delay depending on the real-time downlinks constraints. On the other hand, the GCN Circulars allow the GRB community to distribute messages to the entire GRB community. They are prose-style messages that the follow-up observers write.

5. SVOM mission operations concept

5.1 Observing Programs

The SVOM observation program is divided into three categories: Core Program (CP), General Program (GP) and Target of Opportunity (ToO) Program.

The **Core Program** regroups observations related to the detection and characterization of the prompt and afterglow emission of GRBs detected by SVOM instruments.

The **General Program (GP**) deals with observations that have been pre-planned, open to all scientists answering the SVOM yearly calls for observation proposals. A Time Allocation Committee (TAC) evaluates them based on their scientific merit. The GP considers the constraints set by the Core program, allowing pointing only towards sources close to the B1 attitude law. Observations outside the B1-law constraint during 10% of the GP useful time could be allowed to increase the scientific interest of the program. This program includes known-source observations with the narrow-field-of-view instruments (MXT, VT, and GFTs) such as X-ray binaries (XRBs), AGNs, blazars, ultra-luminous X-ray sources, and cataclysmic variables, as well as wide-field surveys with ECLAIRs and GRM.

The **Target of Opportunity (ToO) Program** manages unplanned observations of transient and variable sources and sent from the ground that interrupt the current GP observation of the SVOM instruments. The scientific community can apply for ToOs, and their scientific interests will be evaluated and approved by the SVOM PIs. Once the observations are accepted, they can be performed within several hours. ToO are not subject to reference attitude law, but only to normal operational constraints.

ToO are declined into three types to cover the scientific needs: Nominal ToO, Exceptional ToO and Multi-Messenger ToO.

Nominal ToO (ToO-NOM) covers multiple scientific needs, essentially the GRB revisit, the General Program sources approved by the TAC and unplanned observations of astrophysical sources. Nominal ToO shall be performed within 48 hours from ToO acceptance. Nominal ToO are interrupted by GRB observations and cannot interrupt ongoing GRB observations. ToO-NOM are interrupted by ToO-EX and ToO-MM observations and cannot interrupt ongoing ToO-EX or ToO-MM observations. Observation duration ranges from 1 to 14 consecutive orbits with a typical value of 1 orbit. The ToO-NOM is the most frequent ToO. It covers the scientific needs for GRB revisit, the pre-selected ToO approved by the General Program selection procedure (TAC (Time Allocation Committee)), unplanned observations of astrophysical target and additional calibration. The maximum average amount of ToO-NOM is one per day on average.

Exceptional ToO (ToO-EX) covers the need for a fast follow-up of a major astrophysical event. Exceptional ToO shall be performed within 12 hours from acceptance. Exceptional ToO shall not be interrupted by GRB observations and can interrupt ongoing GRB observations. Observation duration ranges from 1 to 14 consecutive orbits with a typical value of 14 orbits. The expected rate of the Exceptional ToO is one per month on average.

Multi-messenger ToO (ToO-MM) covers the need for a fast follow-up of a multi-messenger alert with a poorly localized source and a fast feedback to the ground. Multi-messenger ToO shall be performed within 12 hours from validation. Multi-messenger ToO shall not be interrupted by GRB observations and can interrupt ongoing GRB observations. They should permit to cover the error box of the source by performing multiples tiles. Observation duration ranges from 1 to 14 orbits with a standard value of 14 orbits. Relevant information should be sent to the ground in less than 1 orbit to allow source detection from the ground. The average rate of the Multi-messenger ToO is one per week.

5.2 Mission Planning Process

5.2.1 Mission Planning Process for General Program

A Call for Observation (Obs) process is carried out once a year. It provides a data base with the users' requests from which a General Program observation schedule is produced over the whole year by using a dedicated planning process and tools that implement some criteria and rules. Calls for observations are elaborated by the General Program Manager under the responsibility of the two SVOM PIs and are issued every year by the CSC. GP observation requests can be divided into two types: Pre-Planned Target observations (GP-PPT, known and prepared in advance) and Calibration observations (GP-CAL). Only one GP target at the most can be observed during one given orbit.

Proposals are evaluated by a joint Chinese-French Time Allocation Committee. This committee is equally shared between France and China and its composition is validated by the PIs. The selected targets are provided by the CSC to MC through an interface file so-called GP-CATALOG, including all the characteristics needed to program the observations. The planning and scheduling of the General Program observation sequences is implemented by the Mission Center and validated using an operational tool (GP mission planning tool). From the initial GP-CATALOG, a GP observation timeline is then provided.

Each week, a work plan is deduced from the pre-planned GP observations schedule and related TCs are uploaded to the satellite for the next programming timespan. It is also expected that this process takes into account the results of the on-board execution of GP observation sequences during the week before and, in particular, considers the ones that are not or partially performed because of GRB events or ToO scheduling. The scheduling process is flexible enough to modify every week the GP observation timeline to take into account the impacts of the unpredictable Core Program observations (GRB detection) as well as the ToO observations with higher priority in order to plan again the missing parts of GP observation sequences. Some of these observations have to be planned again and the remaining part of the one-year timeline for the General Program has to be fully rebuilt.

5.2.2 Mission Planning Process for ToO requests

ToO requests are short term observations to be planned generally as soon as possible. The mission planning process has to be able to modify the global observation timeline to take into account urgent observing needs (including GRB revisits) that are submitted with ToO requests (Nominal or Exceptional or Multi-Messenger ToO). These requests have to be agreed by the PI or a ToO scientist and are elaborated by the CSC. Furthermore, non-routine calibration needs will also be fulfilled by these asynchronous ToO requests.

Once PIs agree on the ToO proposal, ToO request is then sent to MC who will engage the ToO programming process depending on ToO category as mentioned above. Mission planning tools for ToO implemented at MC are quite specific to each type of ToO request. If one of the ToO sequence has not been executed as foreseen, CSC is responsible to propose a new ToO request to plan it again.

5.3 Orbits and pointing

The pointing strategy has been designed to favour the detection of extragalactic transients and their immediate observability by ground-based telescopes. The SVOM spacecraft is placed in a quasi-circular low-earth orbit with an inclination of about 30. This attitude has been optimised to follow the so-called "the B1 law" which ensures an anti-solar pointing in order to protect the payload from the Sun light and guarantees that the field of view is simultaneously observable by ground instruments in the night hemisphere of the Earth. The Earth will regularly cross the field of view of the instruments and influence their background level and shape.

5.4 South Atlantic Anomaly (SAA) management

The satellite crosses the South Atlantic Anomaly (SAA), a region around the Earth where the concentration of trapped protons and electrons is much higher. The background becomes so large that it prevents any observation inside this zone. Moreover, the so-called activation effect creates an additional noise component that persists and decay for several tens of minutes after exiting it. The on-board trigger algorithms of ECLAIRs and GRM will be deactivated during this phase, and the high-voltage applied on the detection plane will be switched off for the longest SAA crossings to prevent the polarization of the detection plane.

5.5 Mission phases

The SVOM operations are planned for three years but the mission could be extended to an additional period of two years. SVOM mission is designed to cover several sequential phases as below:

- The Launch Early Orbit Phase (LEOP) covers the special configurations of the satellite during launch and several days after the separation. During this phase, the solar arrays are deployed and the AOCS nominal control mode is established after a series of actions.
- The In-flight Commissioning Phase starts at the end of LEOP when the satellite and instrument systems are functionally certified, the satellite is in its operational orbit and the ground system is ready to operate routinely.
- The Verification Phase overlaps the In-flight Commissioning Phase and continues until the data and processing algorithms are satisfactorily calibrated and validated.
- The Nominal Operational Phase begins after completion of the In-flight Commissioning Phase and is consistent with the three-year mission design life.
- The Extended Operational Phase. Assuming useful data are still being collected. This phase extends the mission an additional two years or any additional period that may be agreed by the Parties. This phase will include end of life activities.
- At the end of SVOM mission life, the spacecraft reenters the earth (de-orbiting).

6. SVOM in operational phase

6.1 Summary of commissioning and verification phases results

During commissioning and verification phases, many activities and results have been performed and achieved resulting from works in close collaboration between system, development, scientific and operational teams, from both Chinese and French sides. The verification phase ended at the end of January 2025, which marks the beginning of the operational phase. These phases have been completed successfully and the results of these phases were very conclusive.

The summary of results of these phases is described below:

- Each component of SVOM system, including satellite, board to ground and ground segments, is fully operational and working well.
- The SVOM system performance has been verified during commissioning and verification phases. It has been shown that the system performance with mission and system requirements.
- All operational and science centers on both French and Chinese sides are well organized and ready to operate satellite and instruments and to analyze all types of data to ensure the SVOM mission operations.
- On-board autonomous detection of transient events with all instruments in the loop allows to retrieve alerts and quick products in almost real time.
- The observations program (General Program and Target Of Opportunities) are requested and programmed efficiently. Follow up observation campaign engages ground telescopes and scientific partners (inside and outside SVOM)

From July to December 2024, the mission has already detected 78 GRBs and 472 GCN circulars referring to SVOM have been published. These first science results are very promising for a rich scientific return.

6.2 Organization and management in operational phase

The SVOM program is organized in three main committees: SVOM JSC (Joint Steering Committee), SVOM JSWG (Joint Science Working Group) and SVOM JPO (Joint Project Office). In each committee Chinese and French members will equally participate.

The SVOM Joint Steering Committee (JSC) is the highest level in project organization for making decision. The JSC is composed of representatives from French and Chinese sides on the basis of equality. CNSA/CAS (Chinese side) and CNES (French side) co-chair the JSC.

The scientific exploitation of the SVOM mission will be coordinated by the SVOM Joint Science Working Group (JSWG) whose activities are organized by the two PIs (Principal Investigator). It is composed of the Chinese and French members: PIs, Co-PIs, Instrument PIs, ToO Scientists, Mission Scientists and General Program Manager.

The SVOM Joint Project Office (JPO) is in charge of all activities regarding mission operations all along the mission lifetime. This JPO is responsible for any component of the SVOM system and its operations according to the agreed sharing of responsibilities between partners. The JPO is chaired jointly by both Chinese and French SVOM Project Managers. It is composed of the Chinese and French members.

6.3 Operations Coordination Group

Joint daily meetings are held to coordinate all operations and activities at the mission implementation level using the Operations Coordination Group (OCG) led by Mission Center (MC) with representatives from all French and Chinese operational teams. This operational entity validates all operations during operational phase. The goal of the OCG is to produce a report on past activities, health status of all components (spacecraft, instruments, space to ground links availabilities) and to validate that the next planned operational activities are compatible with the status of the system or the next programming week. OCG meetings are conducted on a daily and weekly basis.

Joint NSSC and CNES contingency operations are performed using procedures outlined to ensure the health and/or safety of the platform and the payload. Contingency situation status and actions taken are coordinated during an exceptional OCG meeting. Anomaly status shall be reviewed during weekly OCG meetings or during exceptional OCG meetings devoted to anomaly resolution. A formal report shall be developed and provided in response to a mission or system level anomaly.

6.4 French Payload Operations Center (FPOC)

FPOC is operated on working hours, 5 days a week from Monday to Friday. Most of processes is automated and run 24 hours a day, 7 days a week. Instrument operations, operational readiness, software and tools maintenance, and operation and monitoring of infrastructure and network resources are carried out during standard hours (8 a.m. to 5 p.m.) and on working days.

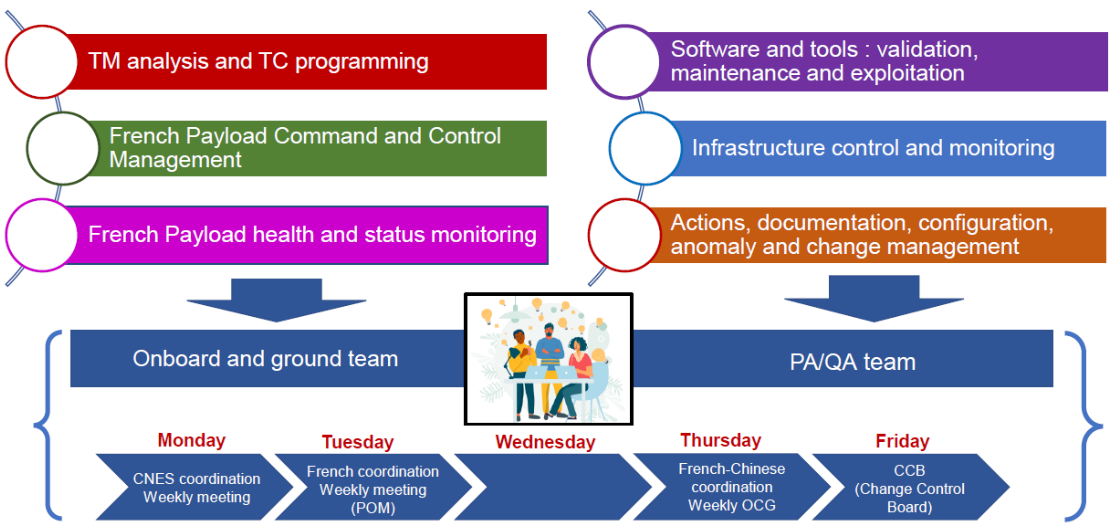

Fig. 9. FPOC operations and activities overview

6.4.1 Functional architecture

The FPOC functional architecture is based on a SVOM configuration of the SPIRIT orchestrator, facilitating interactions between all integrated tools.

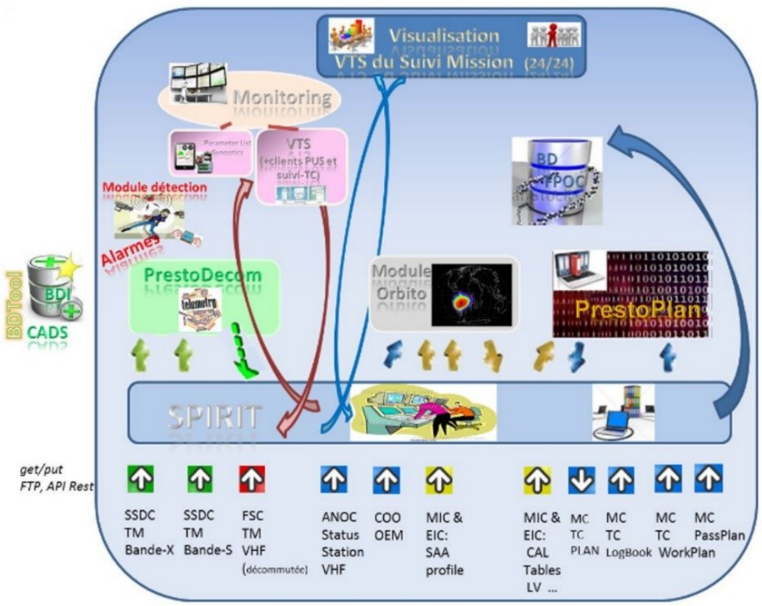

Fig. 10. FPOC functional architecture

The FPOC is composed of:

- **Generic tools :** SPIRIT, PrestoDecom, SBMT/VTS, PrestoPlan, CheckTM, CADS.
  - **SPIRIT** ensures the following functions:
    - ✓ Receives and transmits the data interfaces, catalog and manage them.
    - ✓ Activate the applications and processes
    - ✓ Alert in case of unavailability of critical products or data
  - **SBMT/VTS** (SVOM Broker Mission Tracker) is a tool developed to synchronize visualization clients to provide support tailored to the needs of operators and experts in their analysis and exploitation of satellite data.
- **Specific tools** :
  - OET (Orbital Events Tool) product, based on the PATRIUS generic library.
  - TC generation
  - Other tools developed as part of the FPOC industrial integration contract, for example, processing to transform the output formats of a generic product into input formats understandable by another generic tools.
- RedHat operating system
- CNES shared resources infrastructure (VM (Virtual Machine) infrastructure, network infrastructure, NAS storage, Netbackup backup, Centreon monitoring, IPA directory, PostgreSQL database).
- CNES's network based on multi-mission resources.

6.4.2 Technical architecture

The technical architectural principles adopted for the design of FPOC has been based on the following elements:

- Software architecture is based on SPIRIT orchestrator that allows it to be deployed on CNES shared resources infrastructure
- Full compatibility with CNES shared resources and technical infrastructure
- Simple and automated installation (Ansible).

FPOC platform are hosted exclusively on virtual machines (VMs) of the CNES shared infrastructure.

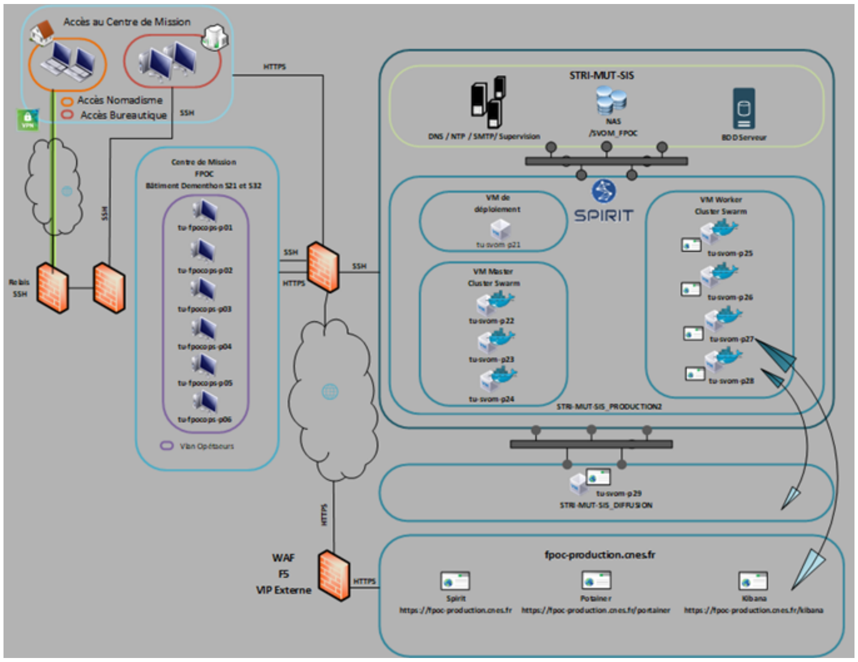

Fig. 11. FPOC technical architecture

6.4.3 Collaboration tools

Confluence, a collaborative workspace tool is used to share and organize information more efficiently between CNES team and all French centers.

Jira is used to plan and track the actions management, and anomaly and change management. The JIRA workspaces tool are shared between CNES team and all French centers.

7. **Conclusions**

The commissioning and verification phases results have shown that all operational and science centers on both French and Chinese sides are fully functional, operational, well organized and ready to operate satellite and instruments and to analyze all types of data to ensure the SVOM mission operations.

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