



The SVOM Satellite: System Design, Critical Technologies, and In-orbit Performance Assessment

Dong Li¹, Yonghe Zhang^{1,7}, Ruifeng Su^{1,7}, Xiaofeng Zhang¹, Wen Chen¹, Jianyan Wei^{2,3}, François Gonzalez⁴, Yulei Qiu², Shuangnan Zhang⁵, Junwang He¹, Genjian Qin¹, Yang Gao¹, Xuliang Duan¹, Jiangjiang Huang¹, Kun Chen¹, Qingyun Mao¹, Zhengyang Bian¹, Xin Chen¹, Fei Li¹, Yong Hu¹, Jian Zhang⁶, Yongwei Dong⁵, Jingsong Deng^{2,3}, Martine Joutet⁴, Karine Mercier⁴, Philippe Guillemot⁴, Adrien Fort⁴, Stefano Crepaldi⁴, Hu Jiang¹ SVOM consortium

¹ Innovation Academy for Microsatellites, Chinese Academy of Sciences, Shanghai 201304, China; zhangyh@microstate.com, surf@microstate.com

² National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100101, China

³ School of Astronomy and Space Science, University of Chinese Academy of Sciences, Beijing 101408, China

⁴ Centre National d'Etudes Spatiales, 18 avenue Édouard Belin—31401 Toulouse, France

⁵ Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China

⁶ Xi'an Institute of Optics and Precision Mechanics, Chinese Academy of Sciences, Xi'an 710119, China

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Abstract

The Space-based multi-band Variable Objects Monitor (SVOM) is a major Sino-French collaborative space science mission designed to detect and rapidly localize various types of gamma-ray bursts. Following its launch on 2024 June 22, the satellite successfully completed its in-orbit commissioning and verification tests by 2025 January. This paper provides a comprehensive overview of the SVOM satellite, focusing on its key capabilities: multi-wavelength joint observation, autonomous response, rapid slewing, and high-stability attitude control. The paper particularly emphasizes the attitude control system, which, augmented by the Fine Guidance Sensor, achieves a pointing stability of better than 0.85'' per 100 s. To facilitate space-ground synergy, the satellite employs dual communication links—the Chinese BeiDou short-message system and the French VHF network—to distribute burst alerts in near-real time to ground-based telescopes and other space observatories. Based on in-orbit test data, all platform-level performance metrics meet or exceed their design specifications. The successful validation of the SVOM platform establishes a robust technical foundation for its scientific operations and demonstrates the effectiveness of the Sino-French cooperative framework in advanced space science missions.

Key words: Astronomical Instrumentation, Methods and Techniques – methods: data analysis – space vehicles – space vehicles: instruments

1. Introduction

Gamma-ray bursts (GRBs) rank among the most energetic and rapidly evolving transient phenomena in the universe. They release enormous amounts of energy as electromagnetic radiation and may also be accompanied by non-electromagnetic messengers such as neutrinos and gravitational waves. However, their rapid variability, short durations, and the need for broad multi-wavelength coverage make their observational characterization and efforts to constrain the underlying physics particularly challenging (Zhang 2018). Over the past few decades, successive space-based observatories—including CGRO, BeppoSAX, HETE-2, and Swift, along with more recent Chinese missions such as HXMT, GECAM, and EP—have delivered transformative insights into the nature of these extreme events (Yuan et al. 2018; Chen et al. 2020; Zhang et al. 2020). More broadly, the advent of time-domain astronomy has revolutionized our understanding of the dynamic universe,

particularly transient phenomena associated with explosive astrophysical processes (Zhang 2006).

To further advance GRB research, the Chinese and French teams, represented by CNSA/CAS and CNES, respectively, jointly proposed the Space-based multi-band Variable Objects Monitor (SVOM) mission and conducted comprehensive trade-off studies to define its architecture (Paul et al. 2008; Mandrou et al. 2008; Basa et al. 2008; Godet et al. 2012). The mission pursues several primary scientific objectives: detecting a broad population of GRBs, with particular emphasis on high-redshift events ($z > 6$); providing rapid and reliable localizations; characterizing the broadband spectral and temporal properties of prompt emission; and enabling the rapid follow-up and identification of optical and X-ray afterglows, including those of high-redshift GRBs (Wei et al. 2016; Cordier et al. 2026a).

Compared with Swift, EP, and other space missions capable of detecting and following up GRBs, SVOM combines several distinctive capabilities, including coordinated multiwavelength

⁷ Corresponding authors, these authors contributed equally to this work.

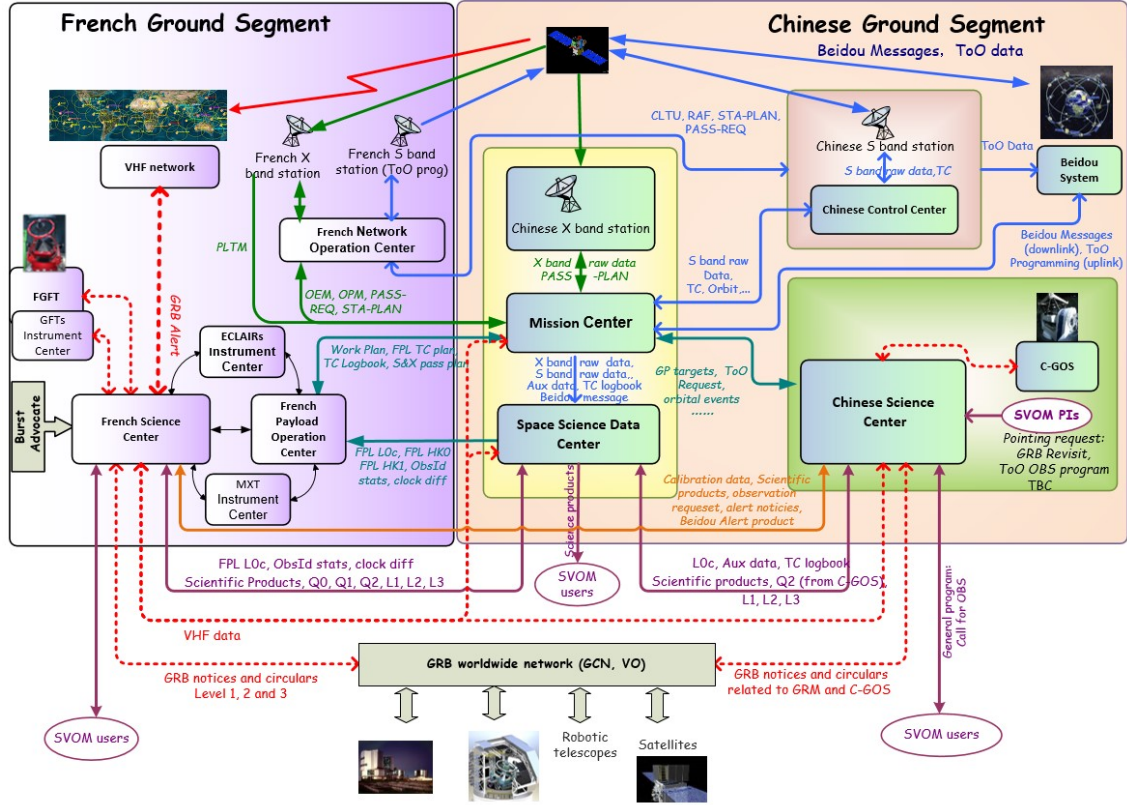


Figure 1. Functional architecture of the SVOM system.

observations, rapid autonomous slewing, low-latency space-to-ground alert transmission, and a dedicated ground-based follow-up network; in particular, the BeiDou-based fast ground-to-space command uplink enables near-real-time GRB observation for responding to time-critical targets. These scientific objectives and operational capabilities impose the following requirements on the SVOM satellite platform:

1. Support coordinated operations of multiple instruments across different wavelength bands.
2. Perform onboard burst detection and localization and enable rapid autonomous slewing.
3. Rapidly downlink localization data to support follow-up observations by ground-based telescopes and other space observatories.
4. Maintain high pointing stability during long-exposure observations of faint targets.

The resulting satellite design addresses these scientific and operational challenges while maximizing scientific return within the available resource constraints (Wei et al. 2016; Yu et al. 2020).

This paper presents a comprehensive overview of the SVOM satellite, focusing on its system design, critical technologies, and in-orbit performance. In particular, we

describe the Fine Guidance Sensor (FGS)-in-the-loop attitude control scheme, the dual-link (BeiDou/VHF) alert communication architecture, and the autonomous onboard mission management strategy. The in-orbit validation results demonstrate that the SVOM platform meets all platform-level design requirements and provides a solid technical foundation for the mission's scientific operations.

2. Overview of the SVOM System

2.1. System Architecture

To meet the mission's scientific requirements, SVOM employs a complex system architecture that integrates a broad range of functions and interfaces, as illustrated in Figure 1. In addition to the satellite, the mission includes dedicated Chinese and French ground segments. The Chinese ground segment comprises the Mission Center, the Science Data Center, the Science Center, the Satellite Control Center, telemetry, tracking, and command (TT&C) Stations, X-band ground stations, the Ground-based Wide Angle Camera (GWAC) system, the Visible Telescope (VT) Instrument Centers, Gamma Ray Monitor (GRM) Instrument Centers, and the Chinese Ground Follow-up Telescope (C-GFT). The French ground segment comprises the French Network

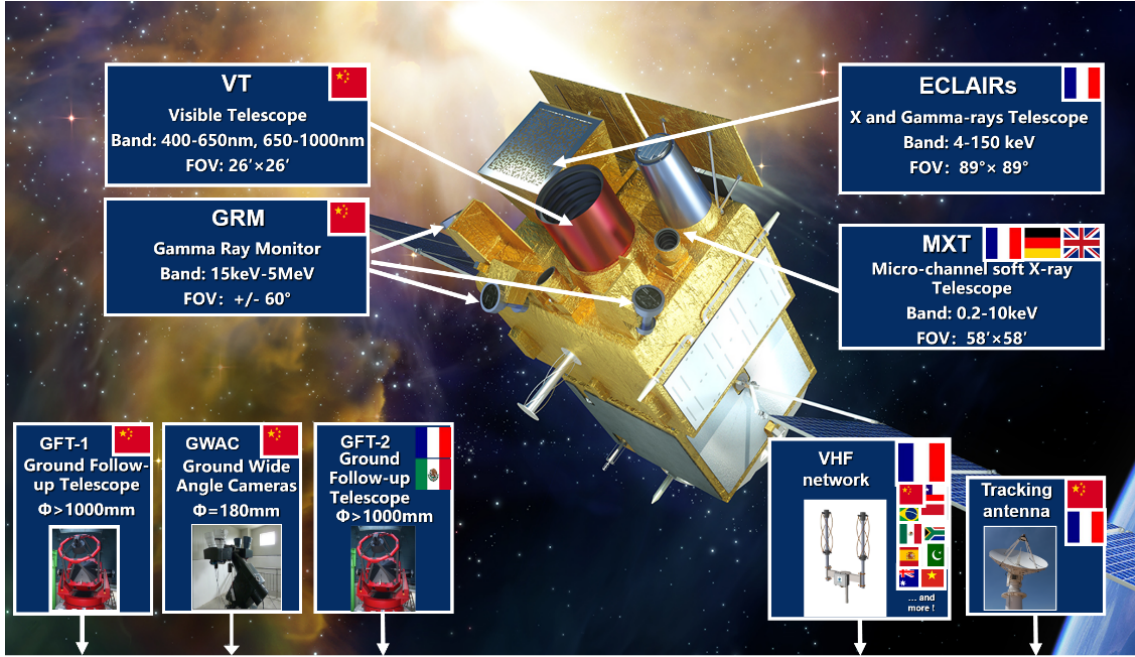


Figure 2. Onboard instruments and ground-based telescopes of the SVOM mission.

Operation Center, TT&C and X-band ground stations, the VHF ground network, the French Science Center, the ECLAIRs and MXT Instrument Centers, the French Payload Operation Center, and the French-Mexican Ground Follow-up Telescope (F-GFT; Liu et al. 2026).

The SVOM system also interfaces with the BeiDou short-message communication service and the General Coordinates Network (GCN) to support rapid alert distribution. The VHF alert network consists of approximately 50 stations distributed within the satellite's ground-track coverage region between latitudes 30°S and 30°N (Cordier et al. 2026a).

The SVOM system, as illustrated in Figure 2, has been validated through in-orbit operations. It consistently delivers scientific data and supports coordinated worldwide multi-wavelength follow-up observations by space-based and ground-based facilities (Liu et al. 2026).

2.2. Orbit and Pointing

SVOM operates in a low Earth orbit at an altitude of approximately 635 km, with an inclination of 30° and an orbital period of approximately 96 minutes. This orbit facilitates communication with the ground-based VHF network and provides frequent visibility opportunities for the VHF ground stations.

The satellite adopts an anti-solar pointing strategy, as illustrated in Figure 3. This strategy serves two purposes. First, it prevents direct sunlight from entering the fields of view of the optical instruments. Second, it ensures that most detected GRBs are located in the night sky as viewed from Earth,

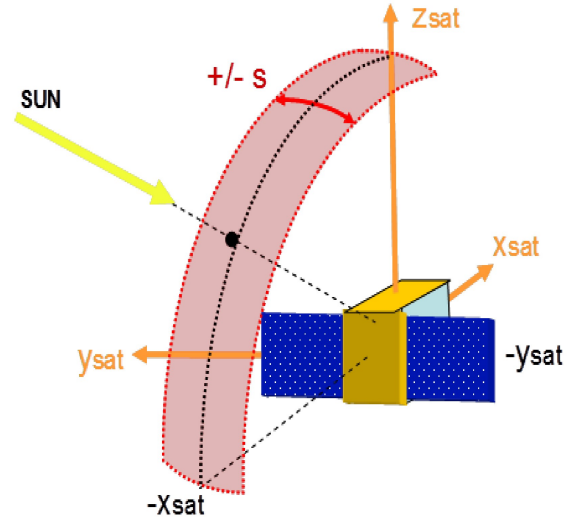


Figure 3. Anti-solar pointing configuration of the SVOM satellite.

thereby facilitating rapid and contemporaneous follow-up observations by space-based and ground-based telescopes.

Within the constraints of the anti-solar pointing strategy, a reference attitude law designated B1 is applied to avoid pointing toward the Galactic plane and the bright X-ray source Sco X-1, both of which can introduce significant background contamination. This attitude law reduces background contamination and thus improves the GRB detection efficiency (Cordier et al. 2026a). Figure 4 illustrates the B1 pointing

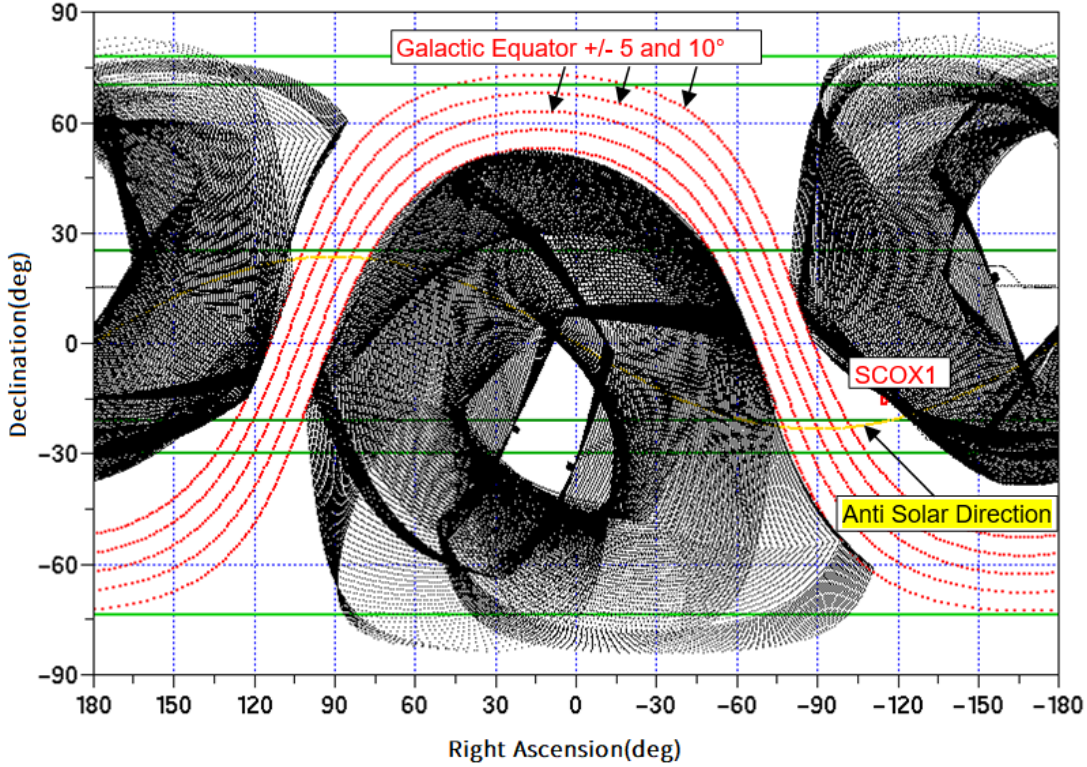


Figure 4. Annual evolution of the ECLAIRs field of view in Galactic coordinates under the B1 pointing law.

law by showing the annual evolution of the ECLAIRs field of view (FOV) in Galactic coordinates.

2.3. Configuration of Onboard Instruments and Ground-based Telescopes

The configuration of the onboard instruments and ground-based telescopes used for coordinated space-ground observations is illustrated in Figure 2.

The SVOM satellite carries four scientific instruments. The X-ray and Gamma-ray Camera (ECLAIRs), developed by France, and the GRM, developed by China, are wide-field instruments for GRB detection. The VT, developed by China, and the Microchannel X-ray Telescope (MXT), developed by France, are narrow-field instruments for follow-up observations (Götz et al. 2009; Dong et al. 2010; Perinati et al. 2012; Sun et al. 2026; Godet et al. 2026; Götz et al. 2026; Qiu et al. 2026).

ECLAIRs is a coded-mask hard X-ray and soft gamma-ray telescope that operates over the energy range of approximately 4–150 keV. It has an FOV of $89^\circ \times 89^\circ$, corresponding to approximately 2.0 sr, and is designed to autonomously detect and localize GRBs with an onboard localization accuracy of approximately $12'$. Its low-energy threshold of 4 keV facilitates the detection of soft events, such as X-ray flashes and high-redshift GRBs (Cordier et al. 2026a; Godet et al. 2026).

GRM extends the spectral coverage of prompt emission to higher energies and operates over the energy range from ~ 15 keV to ~ 5 MeV. Each GRM module has an angular coverage of $\pm 60^\circ$, and the combined FOV is approximately 2.6 sr. GRM also triggers independently of ECLAIRs (Sun et al. 2026).

MXT operates over the energy range of approximately 0.2–10 keV and has an FOV of $58' \times 58'$. It refines onboard GRB localizations to an accuracy of a few tens of arcseconds and provides detailed X-ray spectroscopy of GRB afterglows (Götz et al. 2026).

VT is a 44 cm Ritchey-Chrétien telescope that observes the optical afterglows simultaneously through two channels: a blue channel covering 400–650 nm and a red channel covering 650–1000 nm. It has an FOV of $26' \times 26'$ and reaches a limiting magnitude of approximately 22.5 with a 300 s exposure. Its deep-depletion CCD in the red channel extends the spectral response toward longer wavelengths and enhances sensitivity to the afterglows of high-redshift GRBs, including those at $z > 6.5$ (Qiu et al. 2026).

Together, the four instruments provide broad spectral coverage from gamma-rays to the near-infrared and support coordinated multiband observations of GRBs and their afterglows.

In addition to the space segment, the SVOM mission includes a dedicated ground-based follow-up system for rapid

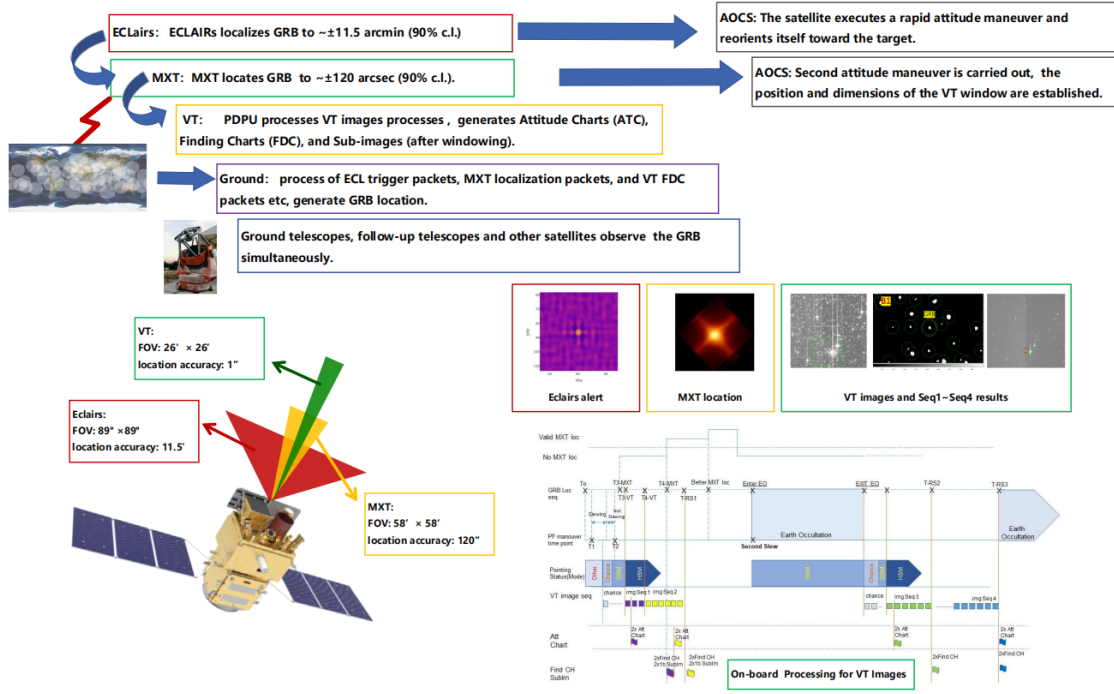


Figure 5. Schematic of the coordinated space-ground workflow of GRB observations.

observations of transients detected onboard (Cordier et al. 2026a). The system comprises the GWAC array, which observes optical prompt emission, and two 1-m class robotic telescopes: the C-GFT and the F-GFT. C-GFT and F-GFT conduct rapid follow-up observations in the optical and near-infrared bands. Together, the onboard instruments and ground-based telescopes form an integrated space-ground observing system.

2.4. Coordinated Space-ground Observation Strategy

The core observing program of SVOM comprises GRB detection, localization, and follow-up. The overall observation workflow is illustrated in Figure 5. Once ECLAIRS detects and localizes a GRB onboard, burst alert messages are transmitted to the ground through the VHF and BeiDou links. At the same time, the satellite autonomously initiates a slew maneuver to bring the target into the FOVs of MXT and VT. The slew is initiated within 2–3 minutes after the trigger, following verification of attitude constraints, including the Sun and Moon avoidance angles (Cordier et al. 2026a).

After target acquisition, MXT refines the localization of the transient source. Once a valid MXT position is obtained, the satellite performs a secondary slew to center the target within the VT FOV. The satellite then maintains its pointing toward the source for five orbits to observe the GRB afterglow. Concurrently, the Payload Data Processing Unit (PDP) automatically processes the VT images onboard and generates

data products such as attitude charts, finding charts and sub-images.

Time-critical data, including the initial ECLAIRS alert, GRM general trigger, refined MXT positions, and processed VT data products, are transmitted to the ground in near real time through the VHF network and the BeiDou short-message system. For 63% of events, alert packets reach the science centers within 30 s. The science centers then disseminate these alerts through GCN notices to the SVOM ground-based facilities, including GWAC and GFTs, and to the broader scientific community (Cordier et al. 2026a). The resulting source positions typically have a localization accuracy better than $1''$, supporting rapid spectroscopic follow-up with large ground-based telescopes and subsequent redshift determination (Wei et al. 2016).

The BeiDou short-message system also supports command uplink. Commands can be transmitted from the ground to the satellite through the BeiDou link within several minutes, improving the mission's response to time-critical targets (Cordier et al. 2026a; Bai et al. 2026).

2.5. Onboard Observation Management Strategy

In addition to the core GRB observing program, SVOM conducts observations under the General Program (GP) and three categories of Target-of-Opportunity (ToO) programs: nominal ToO (ToO-NOM), exceptional ToO (ToO-EX), and multi-messenger ToO (ToO-MM). These observing programs are assigned different priorities. Figure 6 shows the actual sky

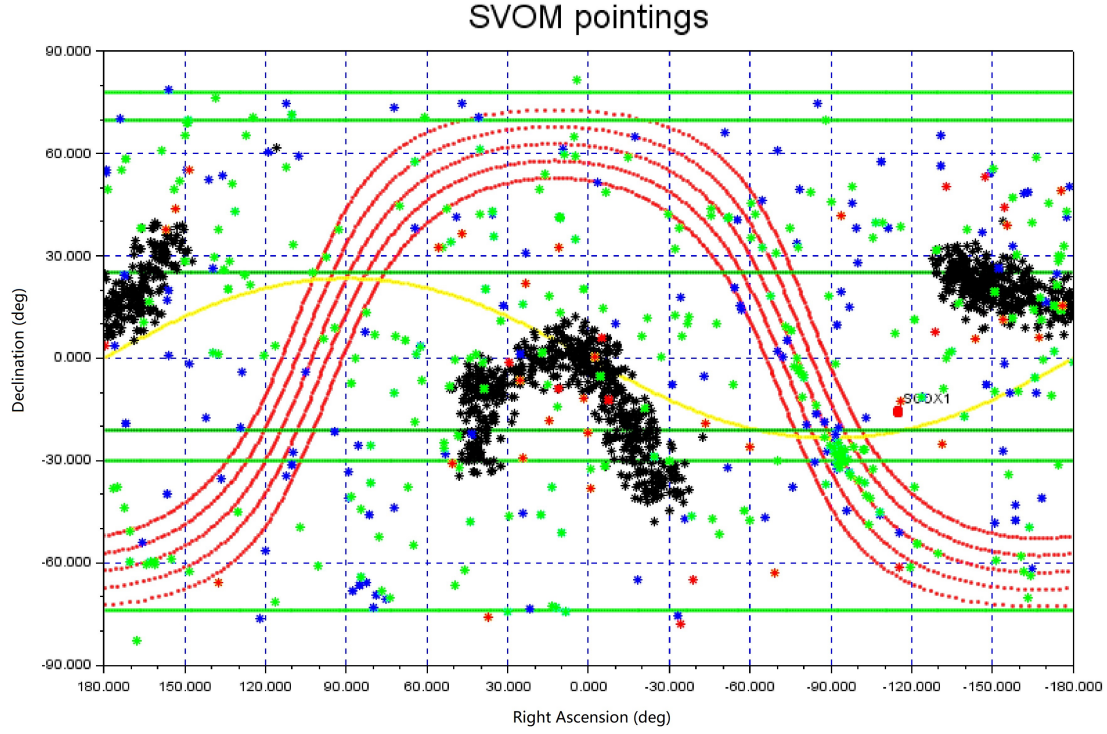


Figure 6. In-orbit sky distribution in Galactic coordinates of SVOM pointings for the GRB (red), ToO (green), and GP (dark and blue) observing programs.

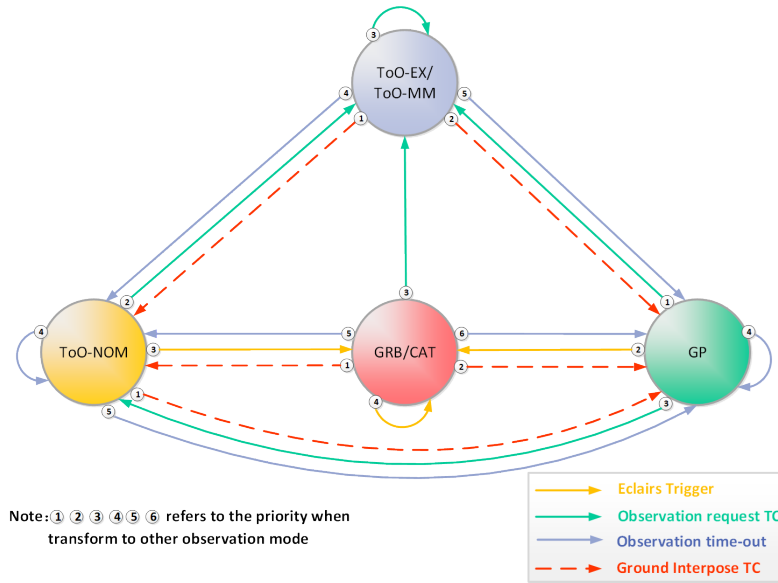


Figure 7. Onboard management and switching scheme for the SVOM observing programs.

distribution of SVOM pointings for the different observing programs. GRB-triggered pointings are shown in red, and ToO pointings are shown in green. GP pointings are divided into two categories: those that remain close to the B1 pointing law, shown as

dark dots, and those that deviate substantially from it, shown as blue dots.

The onboard observation management and program-switching scheme is illustrated in Figure 7.

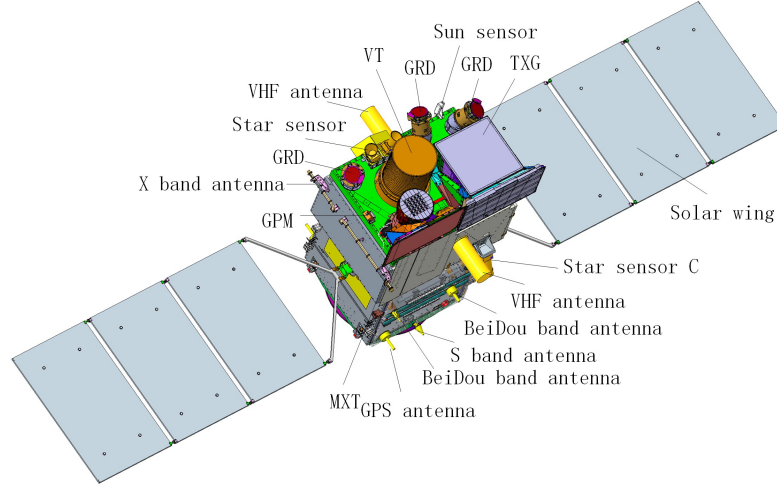


Figure 8. SVOM satellite CAD view.

3. Satellite Configuration and Operations

3.1. Overall Configuration

The SVOM satellite was developed by the Innovation Academy for Microsatellites of the Chinese Academy of Sciences (IAMC, CAS). It has a total mass of 977 kg and consists of a payload module and a platform module. A CAD view and the product tree of the SVOM satellite are shown in Figures 8 and 9, respectively.

The payload module houses the four scientific instruments: VT, developed by the Xi'an Institute of Optics and Precision Mechanics of the Chinese Academy of Sciences (XIOPM, CAS); GRM, developed by the Institute of High Energy Physics of the Chinese Academy of Sciences (IHEP, CAS); and ECLAIRS and MXT, developed under the responsibility of the French Space Agency CNES. The payload module also includes the Payload Interface Module (PIM), the PDPUs, and the X-band and VHF communication subsystems.

The platform module provides standard satellite bus functions, including structural support, thermal control, electrical power, attitude and orbit control, onboard data handling, S-band TT&C, and BeiDou short-message communication. A photograph of the fully integrated SVOM satellite is shown in Figure 10, and its key design parameters are summarized in Table 1. The satellite has a nominal design lifetime of three years, with a goal of extending operations to five years.

3.2. Operational Modes of SVOM

The satellite supports a set of operational modes tailored to different mission scenarios, as summarized in Table 2. The main operational modes include Safe Mode, Standby Mode, Orbit Control Mode, and Observation Mode. Observation

Mode is further divided into GRB Mode, Catalog (CAT) Mode, ToO Mode, and B1-Law Mode. When no specific observation task is scheduled, the satellite operates in B1-Law Mode by default, following the B1 pointing law.

Transitions among these operational modes, as illustrated in Figure 11, are controlled by onboard autonomy logic and ground commands, allowing the satellite to respond to both scheduled observations and transient events (Chen et al. 2022).

3.3. In-orbit Operational Phases

The mission lifetime of the SVOM, from launch to the end of the mission, is divided into the following phases, as illustrated in Figure 12:

1. The Launch and Early Orbit Phase (LEOP) lasted approximately 40 days and was completed in 2024 July. Its nominal duration was approximately 20 days.
2. The Commissioning Phase lasted approximately two months and concluded with the In-orbit Acceptance Review (IAR) in 2024 September.
3. The Verification Phase was conducted partly in parallel with the Commissioning Phase. It lasted approximately six months and concluded with the Verification Acceptance Review (VAR) in 2025 January.
4. The satellite is currently in the Operational Phase, which is scheduled to continue until 2027 September.
5. An Extended Operational Phase of approximately two years will follow the current Operational Phase.
6. At the end of the mission, the satellite will be passivated and is expected to re-enter Earth's atmosphere.

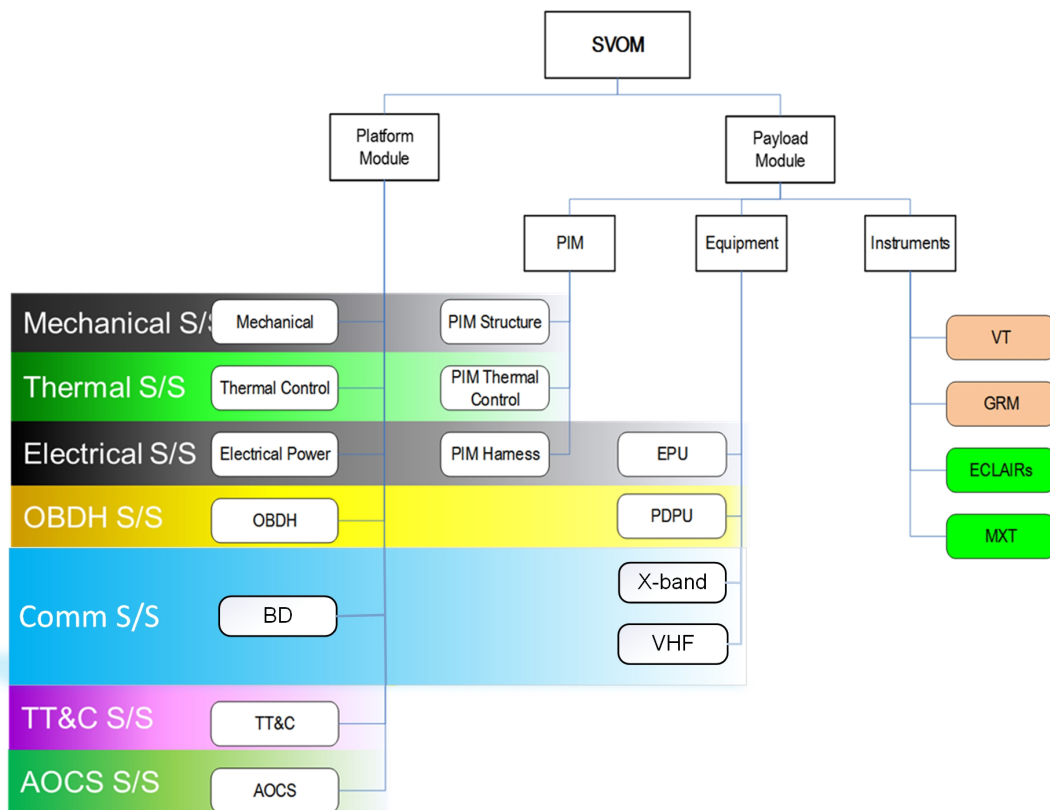
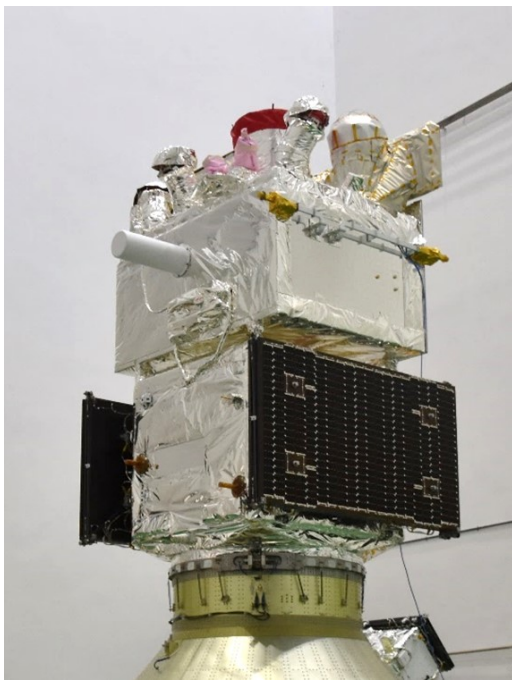


Figure 9. SVOM satellite product tree.



(a) The fully integrated SVOM satellite



(b) The SVOM payload module

Figure 10. Overview of the SVOM satellite and its payload module.

Table 1
Key Design Parameters of the SVOM Satellite

Parameter	Value
Total mass	≤ 1000 kg
Solar array power (EOL)	≥ 1600 W
Battery capacity	135 Ah
Average/peak power consumption	800 W/1300 W
Attitude stability (YZ, 3σ)	$\leq 1.6''/100$ s
Pointing accuracy (YZ, 3σ)	$\leq 50''$
X-band data rate	120/240 Mbps (selectable)
VHF data rate	600 bps
Design lifetime	3 yr (nominal)/5 yr (goal)

Table 2
SVOM Operational Modes

No.	Operational Mode	Description
1.	Power-Off Mode	All subsystems are powered off.
2.	Power-Deficient Safe Mode	An intermediate state between Power-Off Mode and Safe Mode, entered automatically when the satellite experiences a severe power shortage. In this mode, the Satellite Management Unit (SMU), the Electrical Power Subsystem (EPS), the TT&C subsystem and certain components of the Attitude and Orbit Control Subsystem (AOCS) operate normally, while the Thermal Control Subsystem (TCS) maintains only the operating temperature of the batteries.
3.	Safe Mode	Ensures satellite safety by executing predefined procedures to maintain basic operations of the EPS, the TCS, the AOCS, and the TT&C.
4.	Minimum Mode	The satellite state corresponding to the minimum operating configuration of the SMU. The payload module enters Payload Safe Mode; the Solar Array Drive Assembly (SADA) returns to the zero position; the TCS enters Safe Thermal Control Mode; the AOCS enters Magnetic Control Spin Sun-Pointing Mode.
5.	Payload Safe Mode	A mode of the payload module that is entered when the satellite is in either Safe Mode or the PDPU Minimum Mode. The payloads (VT, GRM, ECLAIRs, MXT) and the VHF subsystem are powered down, while other platform units operate normally.
6.	Standby Mode	A preparatory mode for transitioning to other modes. The satellite completes initialization and maintains normal operational capability. It is commanded into a ready state by telecommand before entering other operational modes.
7.	Orbit Control Mode	The satellite performs orbital adjustment and control. The payloads operate in their configuration mode, and the other platform subsystems operate in their normal mode.
8.	Observation Mode	GP Mode (Guaranteed Time / Pointed Mode)
9.		GRB Mode (Gamma-ray Burst Mode)
10.		CAT Mode (Catalog Mode)
11.		ToO Mode (Target of Opportunity Mode)
12.		B1-Law Mode

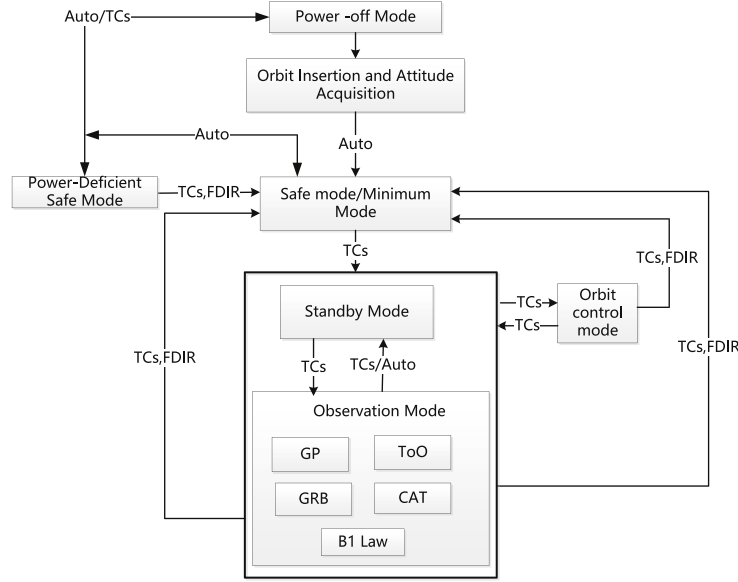


Figure 11. Operational mode transition diagram.

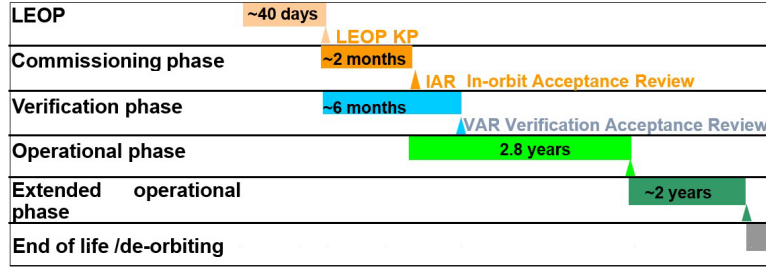


Figure 12. SVOM in-orbit operations schedule.

4. In-orbit Performance Characterization

The SVOM satellite was launched aboard an LM-2C rocket from the Xichang Satellite Launch Center at 15:00 Beijing Time on 2024 June 22. Following the successful deployment of the solar panels, the Thermal Control Subsystem (TCS) autonomously transitioned to a safe mode. It subsequently completed the LEOP, Commissioning Phase, and Verification Phase test campaigns as planned.

During the in-orbit test campaign, the functions and performance of the SVOM satellite platform were systematically evaluated. This section presents the key test results.

4.1. Attitude and Orbit Control Subsystem

The Attitude and Orbit Control Subsystem (AOCS) is a performance-critical subsystem of the SVOM platform because it directly determines the satellite's ability to acquire and track astronomical targets. The AOCS consists of three main functional elements: attitude sensors, an attitude controller, and attitude actuators.

The attitude sensors include three star trackers, an FGS located in the focal plane of VT, two gyroscope assemblies, two three-axis magnetometers, and a Sun sensor suite consisting of six analog probes and two Type-01 probes. These sensors provide measurements for determining the satellite's attitude relative to defined reference frames. The attitude controller is implemented in the onboard computer. It processes the sensor measurements and calculates actuator commands according to predefined control laws. The actuators include five reaction-wheel assemblies, magnetorquers, and a set of thrusters. The hardware configuration of the AOCS is illustrated in Figure 13.

4.1.1. Fine Guidance Sensor Performance

The FGS, integrated into the VT focal plane as shown in Figure 14, provides FGS-derived attitude measurements directly to the platform control system, enabling an FGS-in-the-loop control scheme that substantially improves pointing stability. Figure 15 compares the in-orbit stellar-position

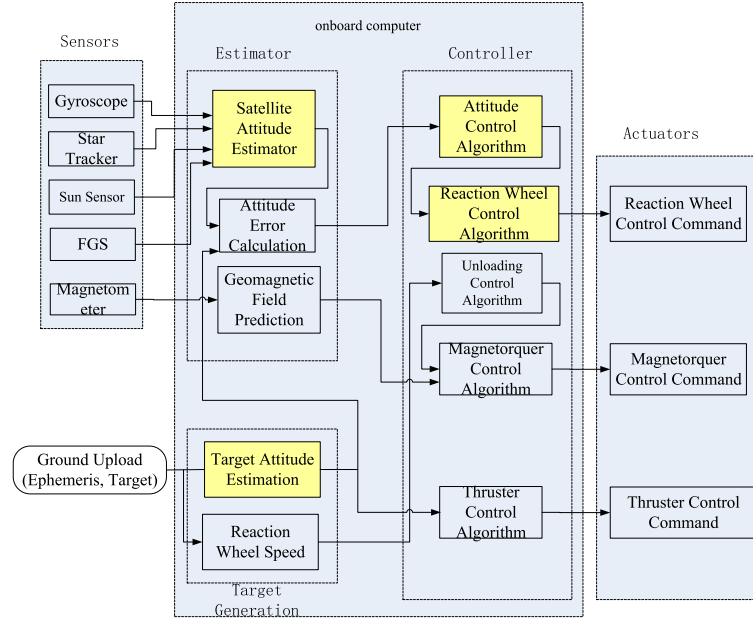


Figure 13. Hardware architecture of the AOCs.

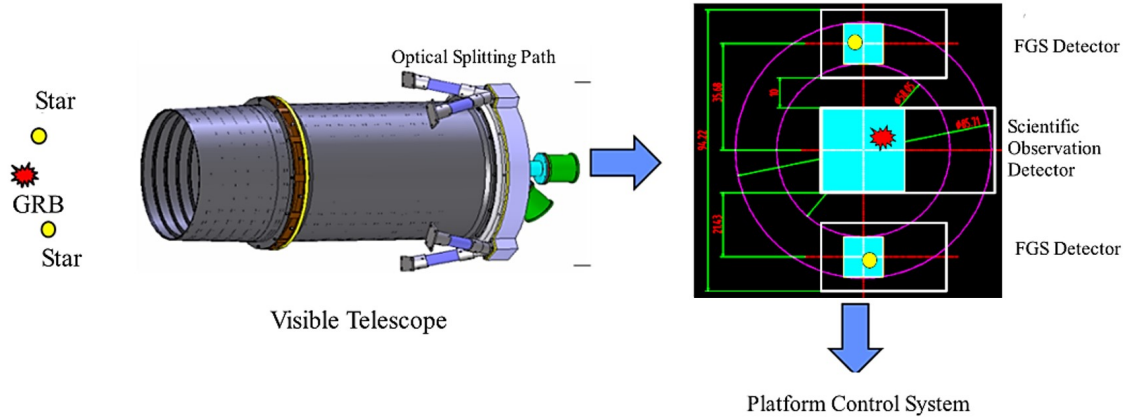


Figure 14. Installation and configuration of the FGS detector.

measurements obtained by the FGS with those derived from ground processing of the FGS images. The residual errors are less than $0.15''$, as shown in Figure 16.

4.1.2. Pointing Stability with the Star Trackers

In the general pointing mode, attitude determination is performed by fusing measurements from the star tracker STA-A and the gyroscope using an Extended Kalman Filter, while the reaction wheels provide attitude control. The resulting pointing accuracy and stability are presented in Figure 17. The pointing stability over a 100 s interval is $1.0''$ about the Y-axis and $1.2''$ about the Z-axis.

4.1.3. Pointing Stability with the FGS

In the high-stability pointing mode, FGS measurements are incorporated into the attitude determination and control loop, and the reaction wheels provide attitude control. The resulting pointing accuracy and stability are presented in Figure 18. The pointing stability over a 100 s interval is $0.85''$ about the Y-axis and $0.82''$ about the Z-axis, while that about the X-axis is less than $8''$. These values are better than the corresponding design requirements of $1.6''$ about the Y and Z axes and $12''$ about the X-axis over the same interval.

This pointing performance directly benefits scientific observations. It limits jitter-induced image degradation during

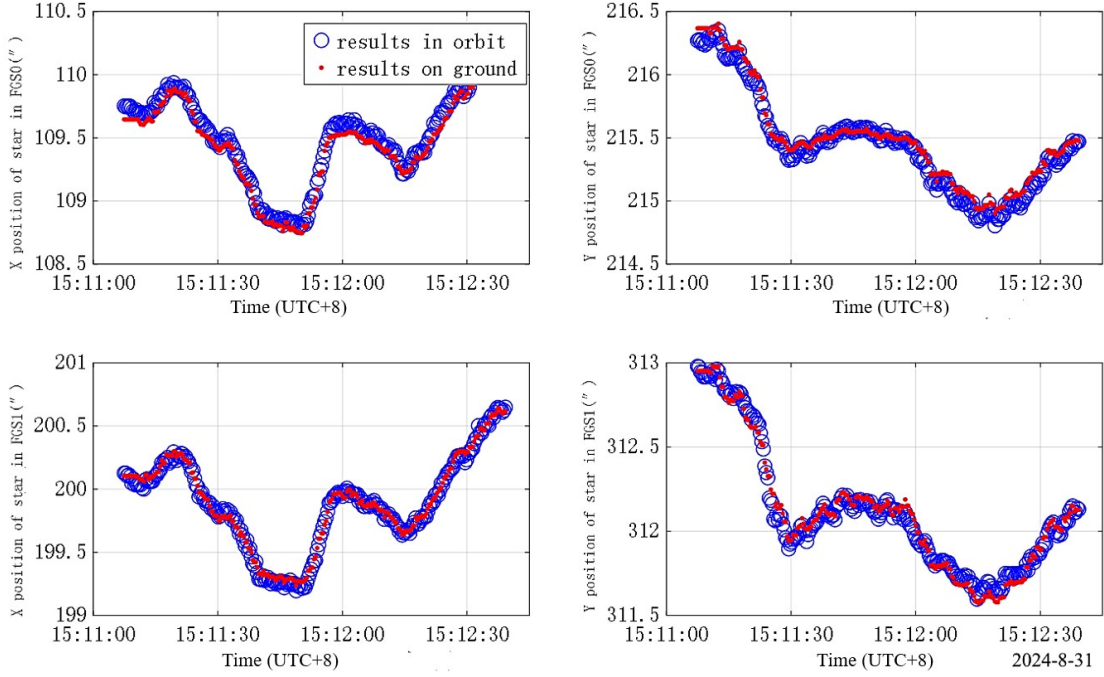


Figure 15. Comparison of stellar positions determined onboard and through ground processing within FGS image windows.

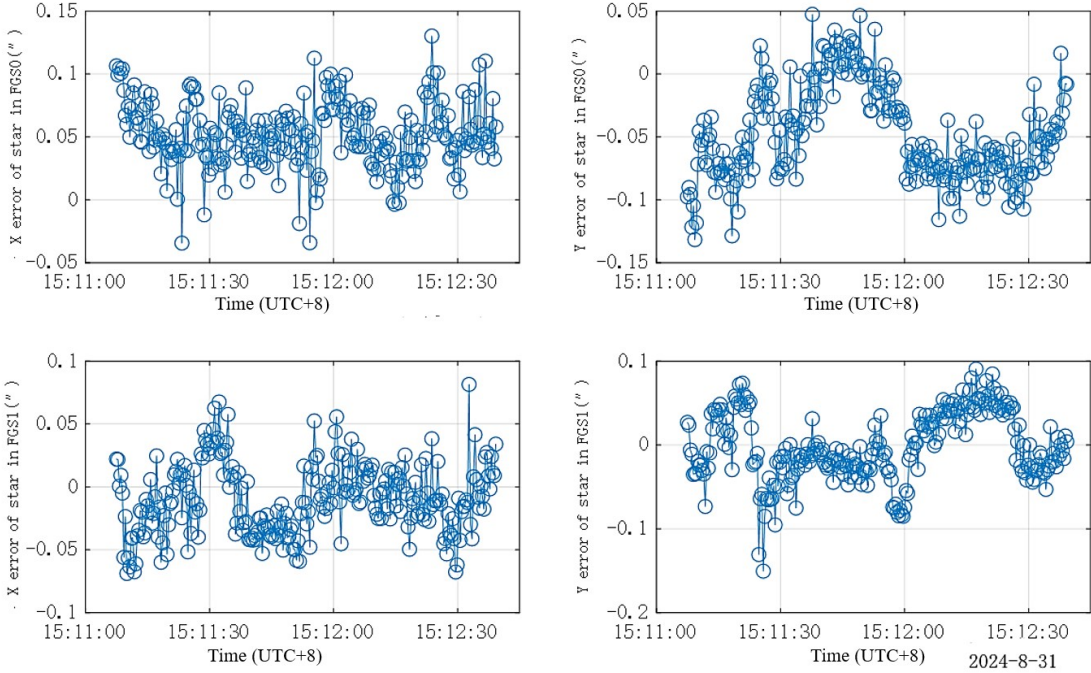


Figure 16. Position residuals between the onboard and ground-processed FGS stellar-position measurements.

long-exposure observations of faint afterglows with the narrow-field instruments. By preserving VT image quality, it also contributes to subarcsecond astrometric localization of GRB afterglows.

4.1.4. Slew Capability

Following a GRB trigger, SVOM must rapidly slew to re-point its narrow-field instruments toward the localized source. The in-orbit test results presented in Figures 19 and 20 show

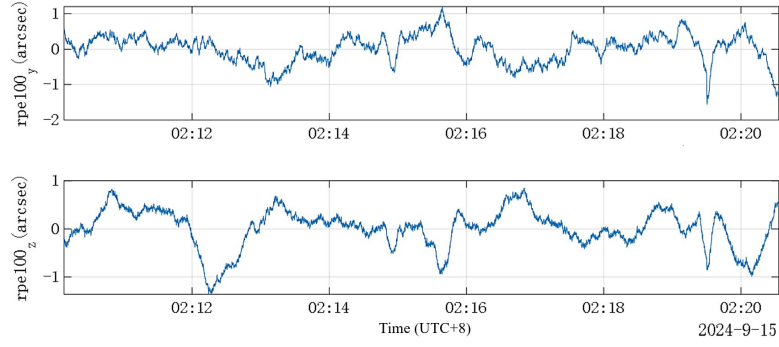


Figure 17. YZ-axis 100 s stability curves obtained with the STR-A.

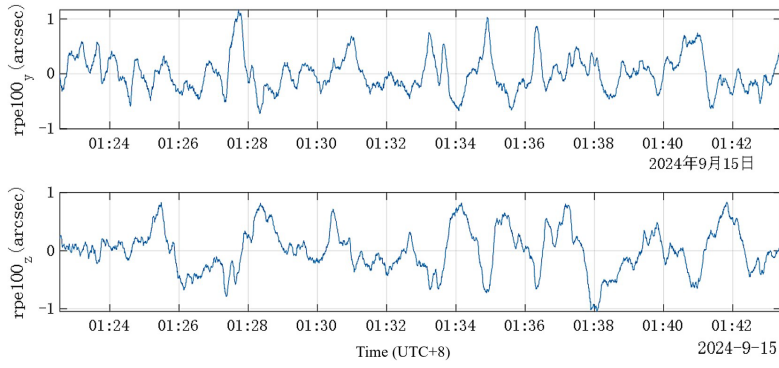


Figure 18. YZ-axis 100 s stability curves obtained with the FGS.

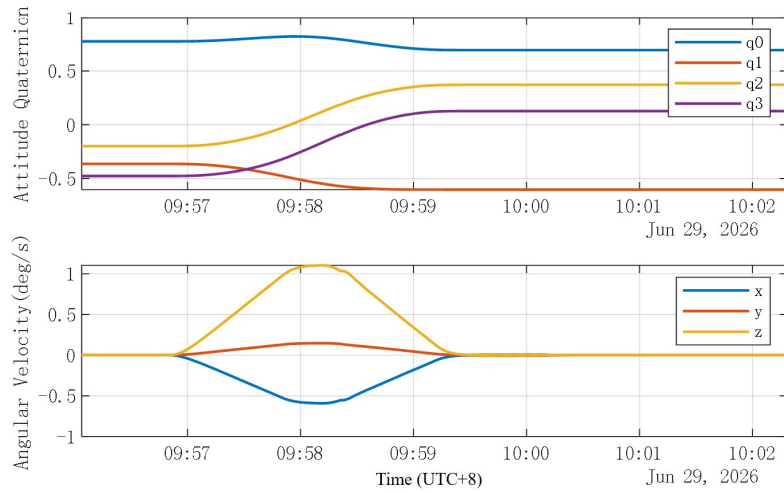


Figure 19. Attitude angle and angular rate profiles during a 51.45° slew maneuver.

that the satellite completed a 51.45° slew and reduced its angular rate to $0.0005^\circ \text{ s}^{-1}$ within 150 s. For a 94.4° slew, the corresponding settling time was 220 s.

4.1.5. Summary

The results of SVOM AOCS in-orbit performance are listed in Table 3. Although the current in-orbit performance of the

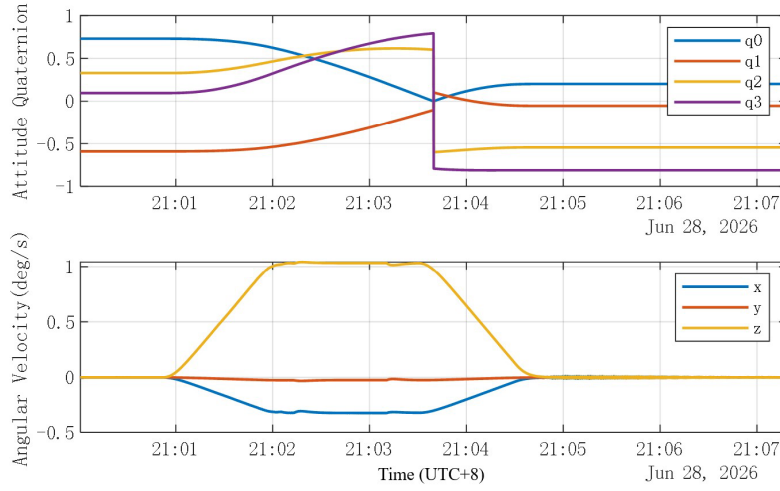


Figure 20. Attitude angle and angular rate profiles during a 94.4° slew maneuver.

Table 3
In-orbit Performance of SVOM AOCS

Parameter	Requirement		In-orbit Test Result
AME	Based on STR-A&B	$\pm 20''$ (Y,Z) (3σ)	5''
		$\pm 40''$ (X) (3σ)	10''
	Based on STR-C	$\pm 40''$ (Y,Z) (3σ)	5''
		$\pm 200''$ (X) (3σ)	10''
RPE	Based on STR-A&B	$\pm 50''$ (Y,Z) (3σ)	<12''
		$\pm 150''$ (X) (3σ)	<30''
	Based on STR-C	$\pm 80''$ (Y,Z) (3σ)	<30''
		$\pm 280''$ (X) (3σ)	<35''
RPE based on FGS	1.6''/100 s (Y,Z)		0.85''/100 s (Y,Z) (3σ)
	12''/100 s (X)		6''/100 s (X)
Slew Capability	60°/3.5 minutes		160 s for slew
	100°/5 minutes		230 s for slew
	180°/8 minutes		360 s for slew

SVOM AOCS meets all mission requirements, further improvements in pointing stability and settling time can be anticipated through iterative algorithm refinement and fine-tuning of the control parameters.

4.2. Electrical Power Subsystem

The in-orbit test results of the Electrical Power Subsystem (EPS) are summarized in Table 4. The EPS regulates the 30 V bus voltage with a variation of less than ± 1 V. The average and peak power consumptions are below 800 W and 1180 W, respectively, both well below the 1300 W peak design limit. The battery depth of discharge (DoD) remains below 20%, with an average value of 11.11%. In addition,

Table 4
Summary of SVOM EPS In-orbit Test Results

Item	Requirement	In-orbit Test Result
Bus Voltage	30 V $\pm$ 1 V	30.356–30.638 V
Average/Peak Power	800 W/1300 W	<800 W/1180.45 W
Current	0–48 A	15.879–37.89 A
DoD	<20%	11.11%

the solar arrays provide sufficient power-generation margin. These results demonstrate that the EPS can provide sufficient power to support the satellite's long-term in-orbit operations.

Table 5
Summary of SVOM Thermal Control In-orbit Test Results

Item	Requirement	In-orbit Test Result
FPL mounting point	$\Delta T < 2^\circ\text{C}$ for mounting points	4.7°C–5.3°C for MXT mounting points 4.7°C–6.7°C for ECL mounting points
UGTS & ELS	-20°C to $+40^\circ\text{C}$	UGTS: 0°C to $+25^\circ\text{C}$ ELS: -10°C to $+8^\circ\text{C}$
MDPU & FEE	MDPU: -20°C to $+40^\circ\text{C}$ FEE: -20°C to $+50^\circ\text{C}$	MDPU: -13°C to $+1^\circ\text{C}$ FEE: -12°C to $+7^\circ\text{C}$
Units on PIM+Y	-20°C to $+45^\circ\text{C}$	-4°C to $+25^\circ\text{C}$
Units on PIM-Y	-20°C to $+45^\circ\text{C}$	-14°C to 0°C
Units on Platform	-10°C to $+45^\circ\text{C}$	0°C – 20°C
Battery	10°C – 30°C	19.2°C – 20.4°C
Propulsion system	5°C – 60°C	10°C – 35°C

4.3. Thermal Control Subsystem

The TCS maintains all platform and payload units within their specified temperature limits using active and passive thermal control methods. In-orbit test results, summarized in Table 5, confirm that the thermal gradients across the French instrument interfaces and the battery temperatures remain well within their allowable ranges. The TCS thus provides a stable and well-regulated thermal environment for both the satellite platform and its scientific instruments.

4.4. Payload Data Processing Unit

The PDPU serves as the central hub for managing the Chinese and French scientific instruments, processing data, and formatting downlink telemetry. It interfaces with the four scientific payloads—GRM, VT, ECLAIRs, and MXT—and the dual-band VHF and X-band transmitters. Furthermore, the PDPU continuously monitors the operational health of all payloads and its own internal state. It is responsible for real-time onboard data processing, data storage, and data routing.

During GRB operations, the PDPU processes VT image data to generate three key products: attitude charts (VT-ATC), finding charts (VT-FDC), and sub-images (VT-SUBIM). The image processing pipeline is computationally intensive. It requires complex algorithms for onboard calibration, full-image acquisition, windowed image tracking, and real-time source extraction, all of which execute within the resource-constrained environment of the PDPU. Since launch, the satellite has autonomously responded to multiple GRB triggers, and the corresponding VT data processing has consistently met performance expectations.

Table 6 presents a detailed timeline for a representative test case, GRB-INIT-104, which was triggered on 2024 September 7 and illustrates the end-to-end performance of the PDPU processing. All planned sequences were completed successfully.

Table 6
GRB-INIT-104: Timeline of Observation and Image Processing Sequences

Event	Time (UTC)
First ECLAIRs alert received by PDPU (no slew request)	00:33:33
First slew request received by PDPU and forwarded to SMU	00:35:35
Observation request passed constraint checks; satellite began slew; GRB observation initiated with Earth occultation during slew	00:35:36
Opportunity pointing stability achieved	00:35:57
Slew completed	00:37:07
Nominal pointing stability achieved	00:37:25
VT commenced 15 s exposure in opportunistic pointing mode	00:37:41
High-precision pointing stability achieved	00:38:45
VT commenced 100 s exposure (Sequence 1 started at 00:37:33)	00:39:21
Conditions met for Sequence 1 ATC processing	00:54:30
Sequence 1 ATC processing completed	00:54:51
Sequence 1 VT-ATC VHF packet transmission to ground started	00:55:13
Conditions met for Sequence 1 FDC and sub-image processing (QF = 4)	00:57:49
Sequence 1 FDC and sub-image processing completed	00:58:49
First image of Sequence 2 acquired; ATC processing started	00:59:20
Sequence 1 FDC transmission to ground started	00:59:41
Sequence 2 ATC processing completed	00:59:51
All 6 images of Sequence 2 acquired; FDC processing started	01:00:29
Sequence 2 FDC and sub-image processing completed	01:11:21
Second slew at first Earth occultation exit	01:28:27
Conditions met for Sequence 3 ATC processing	02:31:25
Sequence 3 ATC processing completed	02:31:47
All 6 images of Sequence 3 acquired; FDC processing started	02:39:45
Sequence 3 FDC and sub-image processing completed	02:41:33
Second Earth occultation began; Conditions met for Sequence 4	03:05:39
Sequence 4 ATC processing started	03:06:09
Sequence 4 ATC processing completed	03:06:25
Sequence 4 FDC processing started	03:06:25
Sequence 4 FDC processing completed; sub-image processing started	03:07:29

Time-critical events, including the receipt of ECLAIRs alerts, slew maneuvers, and altitude stabilization, occurred within their expected timelines. To satisfy science operations constraints, the image processing pipeline must complete FDC and sub-image processing within 300 s per sequence. In the GRB-INIT-104 test, the actual processing times remained well below this threshold: ATC processing took approximately 20 s, while FDC and sub-image processing took approximately 120 s. These results demonstrate that the PDPU fully meets its scientific requirements.

4.5. Satellite Management Unit

The Satellite Management Unit (SMU) provides centralized platform control and implements onboard autonomous mission management, including mission planning and priority management. As shown in Figure 6, SVOM executes a complex set of

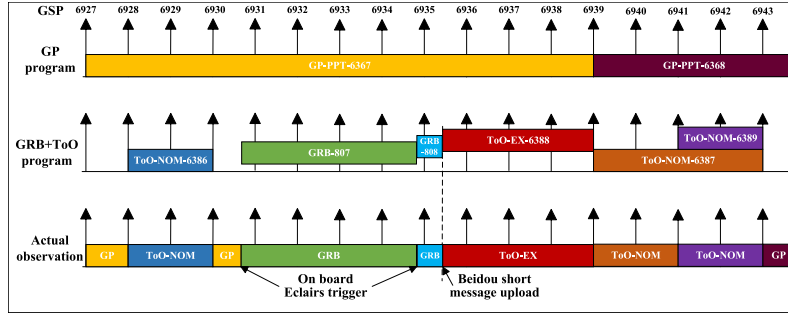


Figure 21. Example of in-orbit observation program management.

onboard tasks across four major observation types: GP, GRB, ToO-NOM, and ToO-EX/MM, while the B1 law serves as the default pointing mode when no observation task is scheduled. The mission management scheme must handle various operational constraints, including task priority, Sun and Moon avoidance angles, and power availability (Mao et al. 2022), and it was thoroughly tested during the in-orbit test phase.

Figure 21 illustrates the onboard observation execution from 2025 October 2 to 3. The sequence between General Slew Point (GSP) 6927 and 6943 involves a dynamic switching among GP, GRB, ToO-NOM, and ToO-EX tasks. The actual execution matches the mission design and fulfills the scientific requirements.

At GSP 6927, the satellite begins executing a GP task (GP-PPT-6367, priority P5). At GSP 6928, this task is preempted by a higher-priority ToO-NOM task (ToO-NOM-6386, priority P4), which executes until GSP 6930. Upon its completion, the satellite resumes the suspended GP-PPT-6367 task.

During the resumed GP execution, a GRB alert (GRB-807, priority P3) is triggered, prompting the satellite to switch to the GRB observation. While executing GRB-807, a subsequent GRB alert (GRB-808) arrives. Although GRB-808 has the same priority as GRB-807, it preempts the ongoing observation because the execution time of GRB-807 has exceeded the onboard GRB inhibition time of 97 minutes.

Between GSP 6935 and 6936, a ToO-EX task (ToO-EX-6388, priority P2) is uploaded via the BeiDou command uplink. The satellite immediately halts the current GRB observation and begins executing the ToO-EX task. After ToO-EX-6388 is completed, the satellite proceeds with the scheduled ToO-NOM and GP tasks according to the mission plan.

4.6. Data Transmission Subsystem

The data transmission subsystem is responsible for downlinking high-volume scientific data, such as VT images and GRM spectral data, through the X-band transmitter. Guided by the onboard autonomous mission management logic, data

transmission tasks are planned through a combination of ground-based scheduling and onboard computation (Cordier et al. 2026b). A key innovation of the SVOM mission is the use of a data transmission ephemeris to determine geometric visibility between the satellite and ground stations. The onboard system performs real-time attitude-dependent computations to ensure that the transmission antenna maintains the required pointing toward the ground stations throughout the downlink window.

In-orbit tests confirm that the onboard computation for data transmission antenna selection performs nominally (Jiang et al. 2018). The subsystem maintains sufficient link margin to ensure robust and reliable downlinks of scientific data.

4.7. VHF Subsystem

Because GRBs are short-lived transient events, the scientific success of the mission relies on the rapid delivery of localization data to the scientific community. This enables ground-based and space-based facilities to conduct follow-up observations and characterize the transients. To ensure rapid and continuous data transfer from the spacecraft to the ground, SVOM employs a dedicated VHF alert network. The onboard VHF transmitter receives GRB alerts generated by the payload and forwards them to the ground in near-real time.

On the ground, a network of 53 VHF receiving antenna stations has been deployed to capture these alerts, ensuring that the satellite-derived coordinates are rapidly relayed to the scientific community for follow-up observations.

Since the start of in-orbit operations, the onboard VHF transmitter has demonstrated long-term stability. Link budget tests indicate a margin of more than 4 dB, which ensures the quality of the transmitted signal. The ground receiving network has also performed reliably (see Figure 22). Statistical analysis of the in-orbit data shows that for 63% (113/180) of the triggers, the first alert packets reached the ground within 30 s of the event. Furthermore, 100% of the initial alert packets were delivered within 7 minutes (Cordier et al. 2026b).



Figure 22. VHF ground station data reception statistics.

4.8. BeiDou Short-message Subsystem

The BeiDou short-message subsystem provides both uplink and downlink capabilities, playing an essential role in the real-time responsiveness of the SVOM mission. For uplink operations, the command upload time has been reduced from the traditional 12 hr to the order of minutes. This greatly improves the satellite's ability to respond to time-critical science targets and ground commands (Bai et al. 2026).

For downlink operations, the BeiDou subsystem transmits one satellite platform telemetry packet every 4 minutes, allowing ground operators to continuously monitor the satellite's health in near real time. This high-frequency downlink ensures the stable operation of the BeiDou link itself and provides robust telemetry support for timely operational decisions.

5. Conclusion

The SVOM satellite was successfully developed and launched and has completed commissioning and a comprehensive in-orbit test campaign. All platform subsystems have been verified against their respective design requirements, with performance margins demonstrated in key areas, including pointing stability and accuracy, power management, thermal control, and communication link performance. In particular, the FGS-in-the-loop attitude control scheme achieved pointing stabilities of $0''.85$ and $0''.82$ over 100 s about the Y and Z axes, respectively, both better than the specified limit of $1''.6$ over 100 s. This performance limits jitter-induced image degradation during long integrations with the narrow-field instruments and supports precise astrometric localization.

The validated in-orbit performance of the satellite platform provides a technical foundation for ongoing scientific operations. All platform-level performance metrics evaluated in the in-orbit test campaign meet or surpass their corresponding design requirements, supporting the mission's objectives in

GRB detection, localization, and multiband follow-up observations. During the operational phase, the SVOM team will continue to refine the onboard trigger algorithms and ground-based data-processing pipelines. Over its nominal three-year lifetime, the mission is expected to detect and characterize GRBs, including high-redshift events, and to contribute to the identification of electromagnetic counterparts of multi-messenger events and to broader studies of the time-domain and high-energy transient Universe.

The SVOM mission demonstrates the effectiveness of the Sino-French collaboration in the development and operation of a complex space science mission, by bringing together complementary technical capabilities from Chinese and French institutions. The lessons learned from the resolution of technical anomalies, although beyond the scope of this paper, will inform the design of future astronomical satellite missions.

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Despite differences in technical standards, language, and working practices, the joint team shared a common goal, overcame numerous challenges, and worked openly and collaboratively. Through continuous mutual adaptation, the team developed a productive working relationship and strong team spirit, which contributed significantly to the success of the SVOM mission.

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ORCID iDs

Hu Jiang  <https://orcid.org/0000-0003-2711-9995>

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