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Design, Architecture, and Management of Operations in SeRANIS, a Multifunctional Small Satellite Mission

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This paper presents an in-depth description of the operations concept design of the Athene-1 satellite, developed within the Seamless Radio Access Network for Internet of Space (SeRANIS) project, carried out by the Universität der Bundeswehr München (UniBwM). The SeRANIS project aims to provide a multifunctional space mission, in which the Athene-1 satellite will host more than 20 diverse and innovative payloads, for a payload mass of approximately 90kg, in a sun-synchronous orbit (SSO) at an altitude of about 550km.

In this paper, we analyze the various operational constraints and requirements imposed by the payloads, which include, among others, space communication systems, Global Navigation Satellite System (GNSS) technologies, and Earth observation. In addition to those of the payloads, the constraints of the platform and ground infrastructure are analyzed, the overall system engineering challenges are highlighted, and the corresponding operational design decisions are presented for both the space and the ground segment.

At the core of the operations architecture is the collaborative operational framework between the German Space Operations Center (GSOC), in the role of the platform control center, and UniBwM, as payload control center, responsible for the operations and data management of the onboard payloads.

The paper places particular emphasis on the operational workflows and details how GSOC and UniBwM coordinate to ensure mission success. It also provides a description of the joint scheduling and planning procedures, outlining the workflows from payload activity requests through to their onboard execution. The mission planning system for both the platform and payload is based on the GSOC generic mission planning tool suite, with UniBwM using PintaOnWeb as the user interface for the planning of payload activities.

Through a comprehensive description of the operational workflows, the paper provides insight into the operations strategies and collaborative processes that drive the SeRANIS mission, offering a valuable reference for future missions of this type, contributing to advancements in satellite operations and collaborative mission management.

Abbreviations

AI	Artificial Intelligence
CPA	Coarse Pointing Assembly
DLR	German Aerospace Center
FLD	Flight Director
GECCOS	GSOC Enhanced Command- and Control System for Operating Spacecraft
GLPS	Generic Link Planning System
GNSS	Global Navigation Satellite System
GS	Ground Station
GSOC	German Space Operations Center
HK	House Keeping
IoT	Internet of Things

LCT	Laser Communication Terminal
LEO	Low Earth Orbit
MIB	Mission Information Base
MM	Mission Manager
MOD	Mission Operations Director
MOS	Mission Operations System
MOT	Mission Operations Team
OBSW	On-Board Software
OGS	Optical Ground Station
ORenS	Onboard Close Range Rendezvous Simulation Experiment
PATTS	Passive Tag Tracking by Satellites
PINTA	Program for INteractive Timeline Analysis
POW	PintaOnWeb
PCC	Payload Control Center
PGS	Payload Ground Segment
POM	Payload Operations Manager
POT	Payload Operations Team
ProToS	Procedure Tool Suite
SAT	SatLead
SCC	Satellite Control Center
SeRANIS	Seamless Radio Access Network for Internet of Space
SSL	Satellite Support Lead
SSO	Sun-synchronous Orbit
SST	Satellite Support Team
TC	Telecommand
TM	Telemetry
UniBwM	University of the Bundeswehr Munich
USLP	Unified Space Link Protocol
VAT	Vacuum Arc Thruster

1. Introduction

Seamless Radio Access Network for Internet of Space (SeRANIS) is a technology demonstrator project led by the University of the Bundeswehr Munich (UniBwM), focusing on the research, development, and testing of cutting-edge technologies in communication, navigation, Artificial Intelligence (AI), Earth observation, and space operations. To achieve these ambitious goals, over 20 diverse payloads are integrated onto a small satellite platform developed by LuxSpace. The experimental payloads are the responsibility of UniBwM or the German Aerospace Center (DLR). One additional payload was selected after a start-up challenge and belongs to Talos GmbH. The satellite, named ATHENE-1, is scheduled for launch into Low Earth Orbit (LEO) at an altitude of approximately 550 km, with the mission expected to start in-orbit operations by 2026.

Supporting the mission's operations, the ground segment is structured as a collaborative framework between UniBwM and the German Space Operations Center (GSOC), comprising the Payload Control Center (PCC) and the Satellite Control Center (SCC). While the PCC at UniBwM oversees payload operations, the SCC at GSOC is responsible for platform control, both operating under the directives of the Mission Control.

This paper is organized as follows: Chapter 2 describes the SeRANIS mission, giving insights on both the space and ground segment. Chapter 3 analyzes the mission requirements and constraints, while chapter 4 describes the system engineering challenges derived from them and related design solutions. In chapter 5, the operation design and the collaborative framework among GSOC and UniBwM is outlined, with particular emphasis on the joint scheduling and planning approach. Finally, chapter 6 presents the conclusions, highlighting the role of SeRANIS as a potential reference for future missions of this type.

2. Mission Overview

Figure 1 gives an overview of the SeRANIS Mission, depicting all the elements of the system and their interactions.

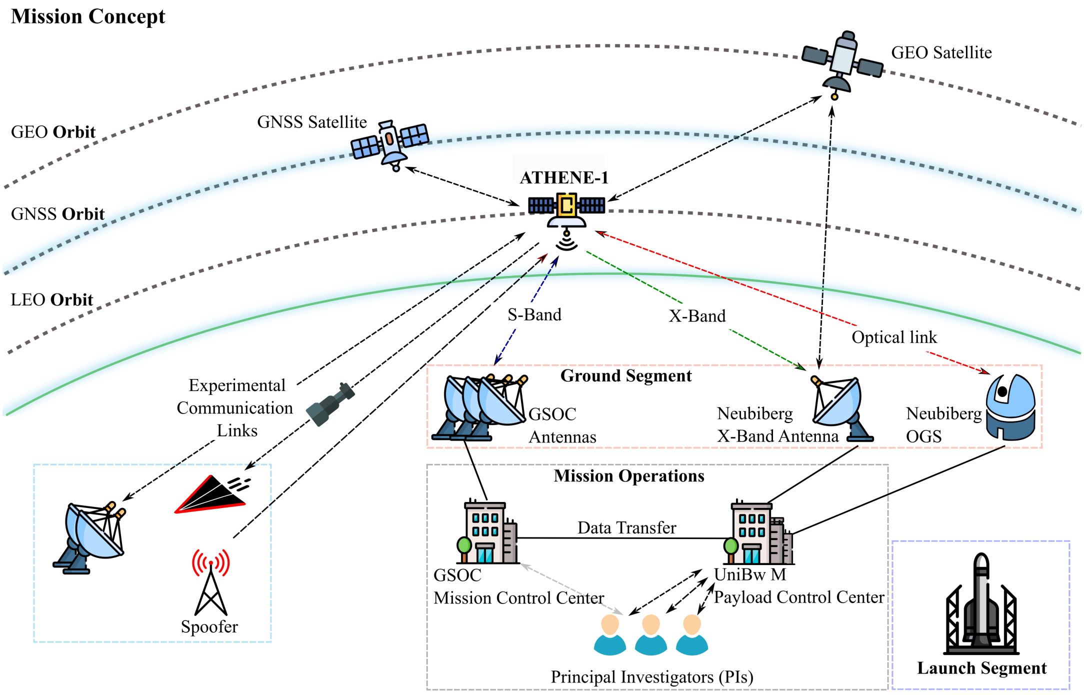


Fig. 1 Mission Architecture.

2.1 Space Segment

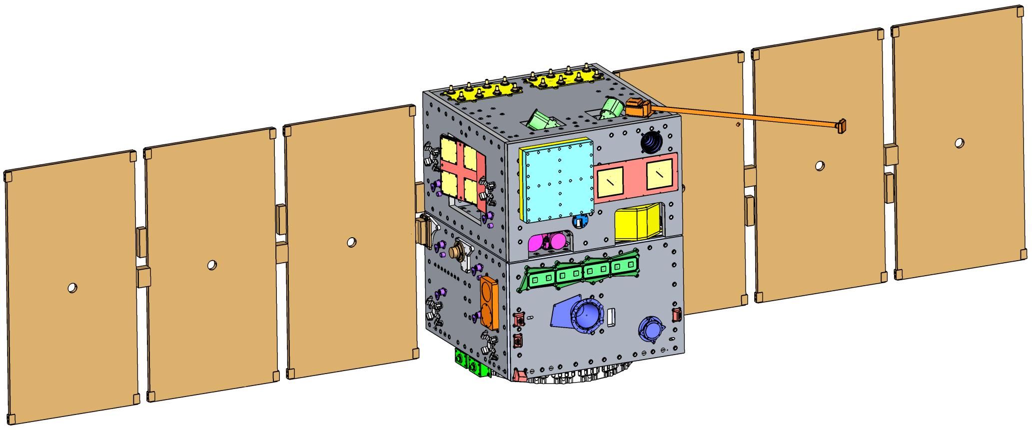


Fig. 2 SeRANIS satellite.

The SeRANIS space segment comprises of the Triton-X platform and the integrated payloads [1], displayed in figure 2, and here listed:

- Experiment 1: Communication Payload 5G (COP5G) [2]
- Experiment 2a: Internet of Things (IoT) via Satellite to Ground Communication Payload (IoT-S2G) [3]
- Experiment 2b: IoT via GEO Communication Payload (IoT-GEO) [3]
- Experiment 3: Laser Communication Terminal (LCT) [4]
- Experiment 4: Phased Array Antennas – Software and Devices (PASAD) [5]
- Experiment 5: Phased Array Antennas – Microwave Technology and High Frequency Components (PAMTEC) [6]

- Experiment 6: Global Navigation Satellite System (GNSS) Software Defined Radio Platform (GNSS-SDR) [7]
- Experiment 7: GNSS Reflectometry and Occultation - Earth and Atmosphere Observation (GNSS-ROX) [8]
- Experiment 8: Multispectral Object Sensing by AI-processed Cameras (MOSAIC) [9]
- Experiment 9: Modern Structures (MOSR) [10]
- Experiment 10a: Radiation Shielding Experiment (RADS) [11]
- Experiment 10b: Resilience of Satellite Systems (RESS) [12]
- Experiment 11b: Electric Propulsion System - Vacuum Arc Thruster (VAT) [13]
- Experiment 12a: Onboard Close Range Rendezvous Simulation Experiment (ORenS) [14]
- Experiment 12d: Onboard Data Analysis and Real-Time Information System (ODARIS) [15]
- Experiment 12e: Ops Concepts (OPC)
  - Responsiveness via RT Satellite Network (OPC-4)
- Experiment 12g: Unified Space Link Protocol (USLP) [16]
- Experiment 13: AI-based Fault Management (AI4FDIR) [17]
- Experiment 14a: Passive Tag Tracking by Satellites (PATTS) [18]
- Experiment 14b: Spaceborne Signal Intelligence (SIGINT) [19]
- Experiment 14c: Autonomous Space Operations Planner and Scheduler (ASOPS) [20]
- Experiment 14d: Seamless Connectivity for Space
- Experiment 15: Radio Spectrum Analyzer (RASP)

The description of the different payloads is beyond the scope of this paper.

The baseline orbit of the SeRANIS satellite is defined by the orbital parameters in table 1. These parameters are subject to change depending on the selected launcher, which has not been fixed at the time of writing this paper.

Parameter	Value
Orbit Type	Frozen SSO LTAN 11:00
Epoch [UTC]	2025-11-01:00-00-00.00
SMA [km]	6882.396
Eccentricity	0.001256
Inclination [deg]	97.4177
RAAN [deg]	201.0892
Aop [deg]	90.0
True Anomaly [deg]	0.0

Table 1 Orbit Information

2.2 Ground Segment

The network of ground stations will comprise both existing stations of DLR and stations of UniBwM developed within the SeRANIS project. The geographical distribution of the stations is shown in figure 3.

The existing ground stations of DLR in Weilheim (S-band), Inuvik and O'Higgins (S-band) will be used as House Keeping (HK) downlink Telemetry (TM) stations as well as for Telecommand (TC) uplink. Additionally, it is planned that KSAT will provide a ground station from Spitzbergen, which shall be used for non-routine operations. Any received HK payload data will be stored and made available for the users (experimenters).

The UniBwM Ground Station (GS) in Neubiberg (X-Band) will be used for the nominal payload data downlink. In a complementary manner to the Neubiberg station, the DLR Inuvik GS is also planned to be used for X-band downlinks, depending on the operational scenarios. Received scientific data will be made available to the experimenters. Additionally to the X-band station, UniBwM in Neubiberg will also host an Optical Ground Station (OGS) that will serve as ground terminal for the experimental Laser Communication Terminal (LCT) onboard the satellite. The optical link will be used as additional downlink path for scientific data. The Neubiberg GS will also serve other telecommunications payloads onboard the SeRANIS platform. Overall, Neubiberg will host:

- Dual-band (X/Ka) full motion antenna, with the following functions:
  - X-band for downlink of payload data
  - Ka-band up- and downlink to support Exp.1
  - Ka-band up- and downlink to support Exp.4-5

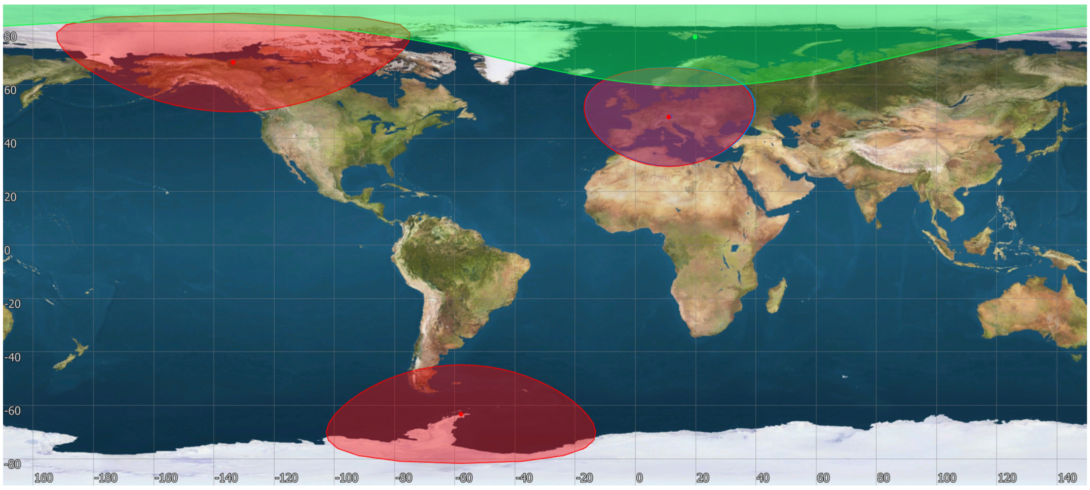


Fig. 3 Preliminary ground stations network. DLR Ground Stations in red: Weilheim, O'Higgins, Inuvik. UniBwM Ground Station in blue: Neubiberg. KSAT Ground Station (GS) in green: Spitzbergen.

- OGS to support Exp.3 (LCT)
- Multi-band (UHF, L-band, S-band) antenna to support:
  - IoT Exp.2a (UHF up-/downlink and S-band up-/downlink)
  - Global Navigation Satellite Systems (GNSS) Exp.6-7 (L-band uplink)
  - Exp.14b and Exp.15 (L-band uplink)

3. Operational Constraints and Requirements

As with every space mission, payloads impose several constraints and requirements, significantly influencing mission operations. With a large number of payloads, complexity increases exponentially, making it nearly impossible to fully satisfy every requirement. Consequently, trade-off analyses are essential to finding viable solutions.

Each payload introduces specific operational constraints based on its scientific objectives, platform resource utilization during activities, duty cycle requirements, and data management needs. Additionally, many payloads require particular satellite attitudes for their operations. For instance, sensing payloads often dictate attitude constraints to ensure proper acquisition over designated regions of interest.

Similarly, the platform design itself imposes operational constraints that impact operations and mission planning. For example, in the SeRANIS mission, the platform must perform GS tracking during S-band and X-band communication links. Additionally, a sun-pointing maneuver at the poles is required to charge the batteries in certain payload configuration modes, more demanding on the energy consumption. These maneuvers at the poles directly impact the approach to orbit maintenance. During sun-pointing at the poles, the atmospheric drag increases, which leads to a faster orbital decay. Consequently, more frequent sun-pointing maneuvers result in a greater need for station-keeping maneuvers to maintain the desired orbit. However, frequent station-keeping maneuvers reduce the time available for payload operations. To manage this trade-off, a compromise was established: sun-pointing maneuvers at the poles must be planned such that they remain compatible with a maximum of one station-keeping maneuver per week.

In addition to payload and platform constraints, the characteristics of the ground segment significantly shape the operations concept of the mission. The geographical distribution of the antennas plays a crucial role. In SeRANIS, both the prime S-band and X-band GS are located in the Upper Bavaria region, Germany, resulting in similar access times.

The SeRANIS mission follows a structured pattern of S-band and X-band passes. Nominal operations include:

- One daily access to the DLR S-band GS for TM and TC (prime station in Weilheim), as routine HK contact.
- Four daily accesses to the dedicated X-band GS in Neubiberg for scientific data downlink.

Due to the geometry of the Sun-synchronous Orbit (SSO), X-band GS access occurs in two consecutive orbits. Meanwhile, only one S-Band GS access opportunity can be utilized due to constraints related to ground station availability and the level of operational support agreed upon with GSOC for the SeRANIS mission.

These factors drive key operational design decisions, directly impacting among the others mission planning and operational workflows.

4. System Engineering Challenges and Solutions

Integrating multiple payloads on a satellite platform presents numerous challenges. Each payload has specific requirements related to power consumption, data storage, thermal conditions, and communication, often competing with the platform's constraints. Ensuring the compatibility of all payloads requires careful trade-off analysis and a comprehensive understanding of both space and ground segment systems. Throughout the project phases, various design adaptations have been necessary to optimize operations. Often, decisions made in one segment directly impact another. Following are some concrete examples illustrating these interdependencies.

S-Band Antenna Modification Due to X-Band Downlink Conflicts Initially, the S-band antenna pattern of the platform was optimized for nadir-pointing operations. However, the X-band transmitter required the platform to actively track the ground station (GS) during downlinks. Since both the nominal S-band GS and the X-band GS are in the same geographical location, every X-band pass results in the platform pointing toward the S-band GS as well. To adapt to this scenario, the S-band antenna had to be modified to function optimally even when the platform is actually tracking the X-band GS.

LCT Operational Adjustments The LCT onboard the satellite is equipped with a Coarse Pointing Assembly (CPA) to enable connections with the OGS, largely independent of the platform's attitude. However, the CPA has an exclusion cone in the nadir direction, which posed a challenge. One of the OGS is in Neubiberg, coinciding with the X-band GS, and every X-band pass results in the satellite pointing towards Neubiberg. This meant that the OGS would fall within the CPA's exclusion cone, preventing the LCT from establishing a successful link. Consequently, operational adjustments were made to avoid conflicts between X-band downlinks and optical communication sessions: the CPA will be deactivated when a parallel downlink (optical/X-band) is scheduled, using only the fine pointing assembly (FPA) of the LCT as the platform will point toward the OGS with the required accuracy to establish the optical link.

Orbit Propagation Accuracy for Optical Links To establish an optical link, the OGS requires precise knowledge of the satellite's orbital position. The propagated orbit data, determined by GSOC from the GNSS telemetry data downlinked from the platform, has an inevitably increasing error over time. Initially, GNSS telemetry was to be only downlinked via S-band, hence once per day, causing orbit propagation errors to exceed acceptable limits after approximately 12 hours. To mitigate this, the On-Board Software (OBSW) of the platform was modified so that the GNSS telemetry is now also transmitted during X-band downlinks, four times a day in nominal operations, continuously ensuring a sufficiently accurate propagated orbit.

Exp.12 - Onboard Close Range Rendezvous Simulation Experiment (ORenS): High-Demand Telemetry Requirements The ORenS experiment, conducted by GSOC, aims to evaluate operational concepts for close-range rendezvous in on-orbit servicing missions. The experiment is conducted by recreating a real-time operational environment in GSOC, where images are generated on board and received via TM during a contact with the satellite. The operational team then executes simulated maneuvers in real-time via a real communication link, allowing a more comprehensive evaluation of risks and limitations than a pure simulation. For reaching its objective, this experiment requires a higher telemetry data rate than the onboard CAN bus can support. To overcome this limitation, during parallel X-band-to-Neubiberg and S-band-to-Weilheim contacts, the payload's telemetry is transmitted via the X-band downlink instead of the standard (S-band) telemetry path. This necessitated substantial ground segment modifications, as real-time data from UniBwM had to be relayed to GSOC for live experiment monitoring and commanding. Normally, data transfer between UniBwM and GSOC occurs offline, but for this experiment, a live link had to be established.

Addressing the Dynamic University Environment One unique aspect of this mission is that it is managed by a university, where the staff - consisting of students and research employees - changes frequently. Given the long duration of the SeRANIS project, after the satellite's launch in 2026, there will be five years of nominal mission operations, during which the university staff will likely undergo complete turnover. It became evident that operations must be structured in a way that allows for seamless knowledge transfer. To address this challenge, operational workflows were designed to be as lean and intuitive as possible, minimizing staff effort and ensuring quick onboarding for new team members.

These examples illustrate how the different elements of the mission are deeply interconnected, where changes in one area impact others. Whether adapting antenna designs, modifying payload operations concepts, improving telemetry

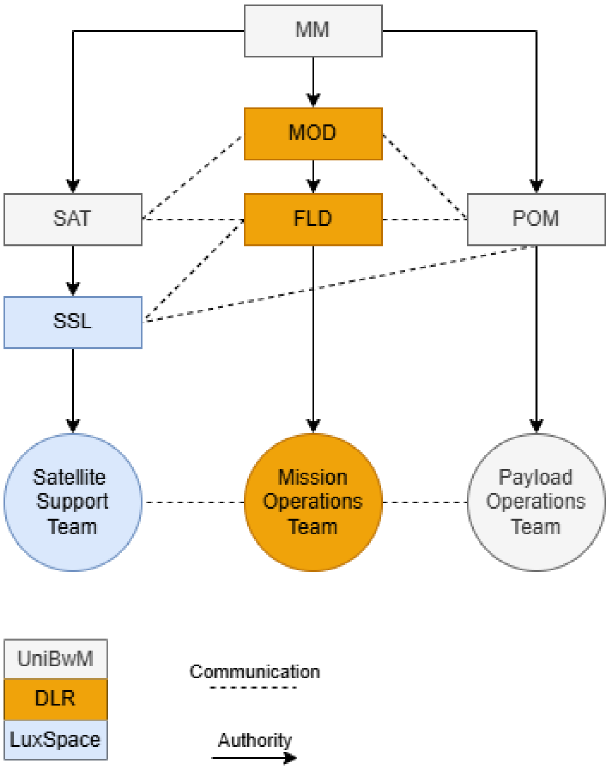


Fig. 4 SeRANIS mission roles.

handling, or defining mission planning and operations management for a university setting, a comprehensive approach is necessary to ensure mission success.

5. Collaborative Operational Framework

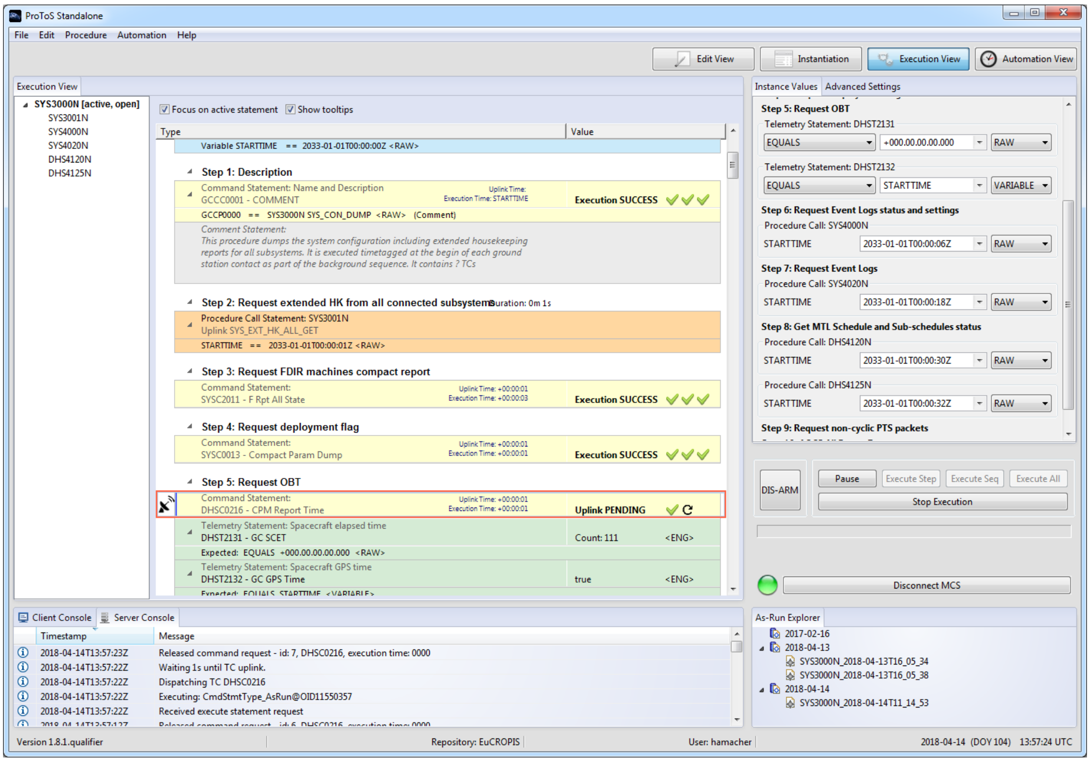
5.1 Personnel, Roles, and Responsibilities

DLR provides the personnel and the infrastructure for the SeRANIS Mission Operations System (MOS) with the goal of servicing the platform operations of the SeRANIS mission. The support is done within the scope of the partnership with the UniBwM, which is in turn responsible for payload operations and hosts the Payload Ground Segment (PGS) at its facilities. The MOS will provide an operational team Mission Operations Team (MOT), while the PGS will provide its own operational team Payload Operations Team (POT). LuxSpace personnel supporting the mission belongs to the Satellite Support Team (SST). Throughout all mission phases, MOS is responsible for the operations and status of the spacecraft's platform with assistance from the SST, whereas PGS is responsible for the operations and status of the payloads. Each side of the ground segment supports its counterpart in their responsibilities and cooperates to plan operations in a conflict-free manner. Figure 4 outlines the different roles and their interactions. At technical level, the MOT provided by DLR is led by the Flight Director (FLD); the SST provided by LuxSpace is led by the Satellite Support Lead (SSL), who answers directly to the SatLead (SAT) provided by UniBwM; and the POT provided by UniBwM is led by the Payload Operations Manager (POM). For major steering operational decisions on management level at the control room during critical phases, the Mission Operations System (MOS) is represented by the Mission Operations Director (MOD) and the Payload Ground Segment (PGS) by the Mission Manager (MM). The MOD will assist the FLD and serve as a backup. Both MM and MOD shall be intermediaries to mediate any conflicts. MM holds the highest authority over both satellite and payload operations, including final decision-making power over the Mission Operations Director (MOD).

5.2 Mission Planning, Scheduling and Execution

5.2.1 Software Components

The collaboration between GSOC and UniBwM promotes not only the exchange of knowledge and joint design decisions but also the sharing of operational tools. Among these are the generic GSOC applications Procedure



SYS3000N [active, open]
SYS3001N
SYS4000N
SYS4020N
DHS4120N
DHS4125N

☑ Focus on active statement ☑ Show tooltips

Type	Value
Variable STARTTIME == 2033-01-01T00:00:00Z <RAW>	
Step 1: Description	
Command Statement: Name and Description GCCC0001 - COMMENT Uplink Time: Execution Time: STARTTIME	Execution SUCCESS ✓✓✓
GCCP0000 == SYS3000N SYS_CON_DUMP <RAW> (Comment)	
Comment Statement: *This procedure dumps the system configuration including extended housekeeping reports for all subsystems. It is executed timetagged at the begin of each ground station contact as part of the background sequence. It contains ? TCs*	
Step 2: Request extended HK from all connected subsystems Duration: 0m 1s	
Procedure Call Statement: SYS3001N Uplink SYS_EXT_HK_ALL_GET	
STARTTIME == 2033-01-01T00:00:01Z <RAW>	
Step 3: Request FDIR machines compact report	
Command Statement: SYSC2011 - F Rpt All State Uplink Time: +00:00:01 Execution Time: +00:00:03	Execution SUCCESS ✓✓✓
Step 4: Request deployment flag	
Command Statement: SYSC0013 - Compact Param Dump Uplink Time: +00:00:01 Execution Time: +00:00:01	Execution SUCCESS ✓✓✓
Step 5: Request OBT	
Command Statement: DHSC0216 - CPM Report Time Uplink Time: +00:00:01 Execution Time: +00:00:01	Uplink PENDING ✓
Telemetry Statement: Spacecraft elapsed time DHST2131 - GC SCET	Count: 111 <ENG>
Expected: EQUALS +000.00.00.00.000 <RAW>	
Telemetry Statement: Spacecraft GPS time DHST2132 - GC GPS Time	true <ENG>
Expected: EQUALS STARTTIME <VARIABLE>	

Step 5: Request OBT
Telemetry Statement: DHST2131
EQUALS +000.00.00.00.000 RAW
Telemetry Statement: DHST2132
EQUALS STARTTIME VARIABLE
Step 6: Request Event Logs status and settings
Procedure Call: SYS4000N
STARTTIME 2033-01-01T00:00:06Z RAW
Step 7: Request Event Logs
Procedure Call: SYS4020N
STARTTIME 2033-01-01T00:00:18Z RAW
Step 8: Get MTL Schedule and Sub-schedules status
Procedure Call: DHS4120N
STARTTIME 2033-01-01T00:00:30Z RAW
Procedure Call: DHS4125N
STARTTIME 2033-01-01T00:00:32Z RAW
Step 9: Request non-cyclic PTS packets

```
Timestamp              Message
2018-04-14T13:57:23Z   Released command request - id: 7, DHSC0216, execution time: 0000
2018-04-14T13:57:22Z   Waiting 1s until TC uplink.
2018-04-14T13:57:22Z   Dispatching TC DHSC0216
2018-04-14T13:57:22Z   Executing: CmdStmtType_AsRun@OID11550357
2018-04-14T13:57:22Z   Received execute statement request
2018-04-14T13:57:12Z   Released command request - id: 6, DHSC0216, execution time: 0000
```

2017-02-16
2018-04-13
  SYS3000N_2018-04-13T16_05_34
  SYS3000N_2018-04-13T16_05_38
2018-04-14
  SYS3000N_2018-04-14T11_14_53

Version 1.8.1.qualifier | Repository: EuCROPIS | User: hamacher | 2018-04-14 (DOY 104) 13:57:24 UTC

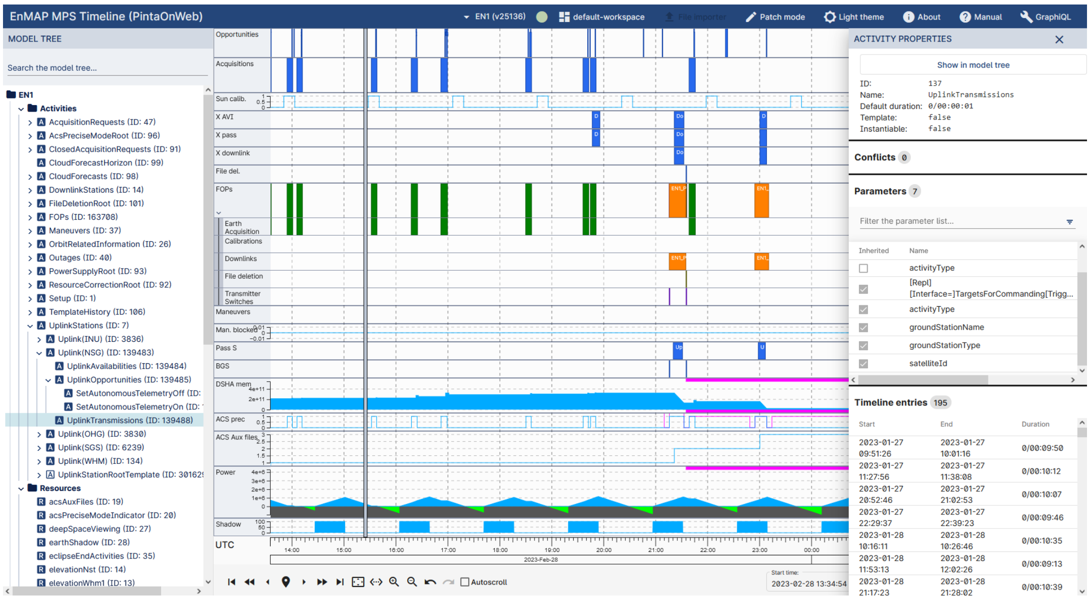
Fig. 5 Exemplary view of ProToS in other GSOC missions.

Tool Suite (ProToS), a specialized tool for creation, instantiation, execution, and management of software-based Satellite Flight Control Procedures (FOPs) by satellite operations engineers (see [21], p.7), and PintaOnWeb (POW), an interactive tool enabling the generation, maintenance and visualization of the planning model and timeline(s) (see [22], p.9). Figures 5 and 6 show exemplary views of them in their application for other current missions at GSOC. These tools, both developed at GSOC, enhance the efficiency and accessibility of mission planning and the operational processes up to commanding the spacecraft and its payloads as fail-safely as possible.

Procedure Tool Suite (ProToS) ProToS is an Eclipse RCP-based software tool developed by DLR RB-MIT to support the full life cycle of FOPs. It integrates with SCOS-2000-based systems, utilizing the Mission Information Base (MIB) for both telemetry and telecommand definitions. ProToS features a graphical user interface for procedure development, validation, and reporting, as well as a procedure-based automated commanding interface to the GSOC Enhanced Command- and Control System for Operating Spacecraft (GECCOS) (see [21], p.4). ProToS allows for the export of SCOS sequences that can be executed directly in SCOS/GECCOS, or alternatively, procedures can be run via ProToS's internal execution engine. This engine manages complex control flows and supports additional statements beyond standard commands. All procedures are stored in a version-controlled repository, and PDF exports are available for convenient reading and test documentation. For more details on ProToS, its functionalities, design, and use cases, see [23] and [24].

In the context of the SeRANIS mission, ProToS will be used by both GSOC and UniBwM to collaboratively develop procedures for platform and payload operations. These procedures will subsequently be provided to the mission planning system and to an automation system. The automation system itself will be another ProToS instance capable of automatically executing inputs from the mission planning system, and regularly initiating and monitoring the according commanding of the satellite.

PintaOnWeb (POW) PintaOnWeb (POW) is part of the most recent generation of the mission planning and scheduling tool suite of GSOC, serving as the new frontend/backend application in the heritage of Program for INteractive Timeline Analysis (PINTA) (see [22], p.5, for a quick introduction, and [25] for an overview of its wide range of past and current applications), providing a convenient UI, e.g. for visualizing and modifying the current timeline and planning model content, incl. activities (templates and parameterized instances incl. timeline entries), resources and their fill-levels, constraints and conflicts, etc., with access rights managed according to the role(s) of the respective user or user groups. POW is based on the Reactive Planning framework (see [22], p.12, for a quick introduction, and [26] for the background ideas and more details) and the Plains library (see [22], p.11, for a quick



ID: 137
Name: UplinkTransmissions
Default duration: 0/00:00:01
Template: false
Instantiable: false

Inherited	Name
☐	activityType
☑	[Repl] [Interface=]TargetsForCommanding[Trigg...
☑	activityType
☑	groundStationName
☑	groundStationType
☑	satelliteId

Start	End	Duration
2023-01-27 09:51:26	2023-01-27 10:01:16	0/00:09:50
2023-01-27 11:27:56	2023-01-27 11:38:08	0/00:10:12
2023-01-27 20:52:46	2023-01-27 21:02:53	0/00:10:07
2023-01-27 22:29:37	2023-01-27 22:39:23	0/00:09:46
2023-01-28 10:16:11	2023-01-28 10:26:46	0/00:10:35
2023-01-28 11:53:13	2023-01-28 12:02:26	0/00:09:13
2023-01-28 21:17:23	2023-01-28 21:28:02	0/00:10:39

Fig. 6 Exemplary view of POW in other GSOC missions.

introduction, and [27] for more details) in the backend, e.g. for setting-up, maintaining and persisting the current planning model, and for providing generic functionality, such as resource and constraint modelling and conflict checking, or the interfaces to the orbit information services, ground station services, and to ProToS for instantiation of FOPs and thus commanding the planned spacecraft and payload activities. For more details and explanations about POW and its design, see [28].

For SeRANIS, both the so-called PlatformMPS (used within the SCC for regularly automatically planning the platform background sequence activities, and managing that), as well as the PayloadMPS, that will be available for the experimenters and payload coordinators within the PCC, will be project-specific configurations of this generic component setup. The planning result and further information contained in the PlatformMPS will be available within the PayloadMPS, together with the available set of FOPs for payload planning. The interactive, access-restricted POW frontend will enable the experimenters to request and preliminary plan the activities and commanding of their payloads with the knowledge of the satellite state and e.g. affected resource availabilities, while the payload coordinators will be able to e.g. de-conflict and refine the timeline, and trigger the command timeline export after having made the necessary consistency checks. Furthermore, it is foreseen that in later project phases, a further POW derivate, the so-called Generic Link Planning System (GLPS) (GLPS, see [29] for more details) will be included into the overall setup and interfaced via the PayloadMPS, for operationally utilizing the LCT for experiment data downlink.

5.2.2 Workflows

A key outcome of this collaboration is the establishment of a structured operational framework, particularly in mission planning and scheduling workflows. Given the mission's constraints, including a single S-band contact per day, the uplink of the mission timeline follows a weekly planning cycle.

This structured approach ensures efficient coordination for SeRANIS operations, as illustrated in Figure 7, streamlining scheduling and execution.

Each week, GSOC provides UniBwM with the background sequence, including planned outages such as orbit maintenance maneuvers and platform maintenance. Additionally, GSOC supplies key mission data, such as the predicted orbit. Based on this, experimenters submit requests for payload operations to the planning engineers at UniBwM.

The process outlined in Figure 7 is further detailed in Figure 8, which represents the workflow within a nominal working week.

Preliminary GS availabilities are typically known two weeks in advance, with final confirmations provided four days prior to the execution week. At this stage, the background sequence is locked, allowing payload operations to be finalized. UniBwM is responsible for generating a conflict-free timeline and submitting it to GSOC, which then generates and uplinks the mission timeline every Friday.

To schedule payload operations, each payload-responsible submits execution requests via POW to the planning engineers at UniBwM. These requests must be submitted by Tuesday of the preceding week, allowing sufficient

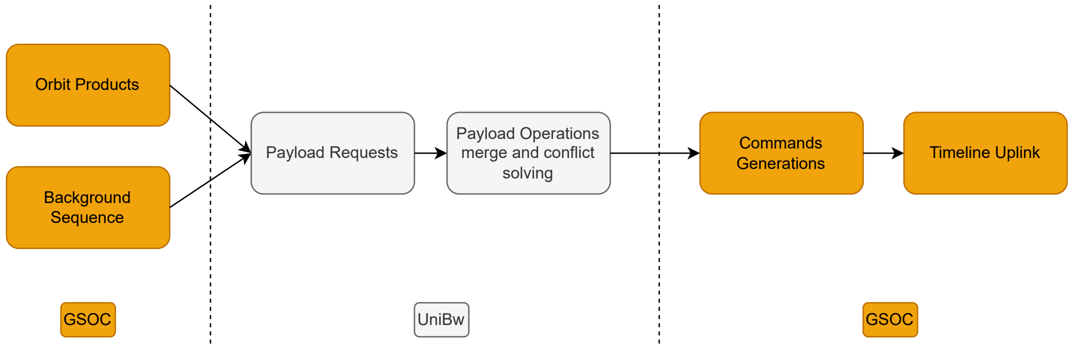
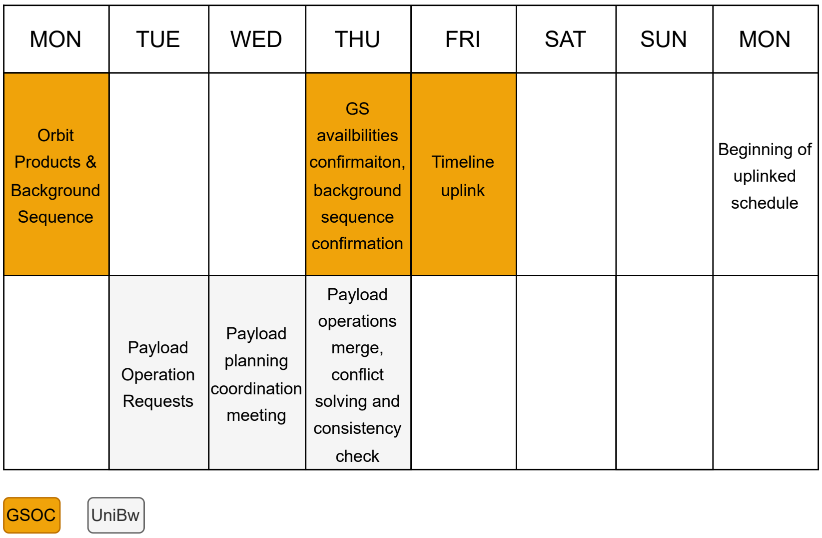


Fig. 7 Operations planning workflow.



MON	TUE	WED	THU	FRI	SAT	SUN	MON
Orbit Products & Background Sequence			GS availbilities confirmaiton, background sequence confirmation	Timeline uplink			Beginning of uplinked schedule
	Payload Operation Requests	Payload planning coordination meeting	Payload operations merge, conflict solving and consistency check				

Fig. 8 Weekly Operations Planning.

time to integrate all inputs, resolve conflicts, and harmonize any unresolved scheduling issues. Once the finalized timeline is conflict-free, it is forwarded to GSOC for uplink.

This approach requires experimenters to plan activities at least one week in advance. For instance, if a payload requires fly-over calculations for specific regions of interest, it must generally be able to determine these at least a week ahead with the necessary accuracy. Similarly, operations of additional ground terminals or equipment needed for specific payload operations must be planned in advance.

Exceptions to this structured planning process apply to payloads requiring a more dynamic scheduling approach. For example, the GNSS-Reflectometry payload (Exp. 7) cannot determine exact operation times using week-old orbit data. However, a designated time window can still be included in the nominal weekly plan to ensure that later telecommands do not cause conflicts in the overall timeline.

The collaboration between GSOC and UniBwM has enabled the definition of an efficient, scalable operational framework for SeRANIS, and workflows to coordinate payload operations, platform constraints, and ground station availability. Furthermore, these workflows are designed to enhance the adaptability and robustness of the SeRANIS operational concept, finally aiming at demonstrating the effectiveness of joint planning methodologies in a complex multi-payload satellite mission.

As the mission progresses, these operational approaches will not only support the successful execution of SeRANIS but will also serve as a valuable reference for future space missions of this kind.

6. Conclusions

The SeRANIS mission represents a significant use case in the development of a multifunctional small satellite platform capable of hosting diverse experimental payloads. Through the collaboration between UniBwM and GSOC, a structured operational framework has been established to manage the complex interaction between payloads, platform constraints, and ground segment infrastructure. This collaboration has led to the integration of innovative mission planning and scheduling tools, such as POW. While it allows the mission to manage operations requests from a large number of users, the operational application by this variety of external users and the specialty of the mission will help to gather further experience and enhance the generic tool.

The mission planning and scheduling process is designed to accommodate the operational constraints imposed by the SeRANIS mission, including limited contact opportunities and reduced personnel. By implementing a weekly planning cycle, combined with a clear division of responsibilities between GSOC and UniBwM, the mission ensures an organized and scalable approach to managing the satellite operations.

Furthermore, several engineering challenges have been addressed to optimize mission execution, such as real-time telemetry adjustments, antenna modifications for communication optimization, and operational adaptations for optical and radio-frequency links. These adjustments highlight the dynamic nature of space mission operations, where cross-disciplinary coordination is crucial for overcoming technical and logistical challenges.

Beyond its immediate operational objectives, SeRANIS serves as a demonstrator for future satellite missions, particularly in the areas of AI-driven space operations, GNSS-based experiments, and advanced communication technologies. The mission also provides a valuable framework for knowledge transfer and long-term operational sustainability, addressing the challenges imposed by frequent personnel turnover in academic and research environments.

The outcomes of this mission will furthermore provide insights into the management of multi-payload satellite missions, and the lessons learned from SeRANIS will serve as a reference for future academic, governmental, and commercial space initiatives, reinforcing the role of small satellites in cutting-edge space research.

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