HuskySat-2 Mission Operations Plan

MOP-001

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1.0 Introduction

1.1 Purpose

The HuskySat-2 (HS-2) Mission Operations Plan (MOP) defines the processes, procedures, responsibilities, and resources required to operate HS-2 throughout its mission. This document serves as an operational reference for the HS-2 operations team, covering activities from initial satellite acquisition and on-orbit checkout through payload commissioning and nominal mission operations.

The primary responsibility of the operations team is to maintain satellite safety and health while accomplishing mission objectives. The MOP establishes the procedures for planning and executing satellite passes, monitoring satellite state, communicating with HS-2, executing authorized commands, collecting mission data, responding to anomalies, and documenting operations. It also defines the roles and responsibilities of personnel involved in mission operations and establishes the training and testing required for operators.

The MOP is intended to provide a consistent and repeatable framework for HS-2 operations while allowing individual procedures to be updated as additional testing, analysis, and flight experience become available.

2.0 Mission Operations Overview

2.1 Operations Concept

HuskySat-2 (HS-2) will be operated through a structured ground-based operations process designed to maintain satellite safety while accomplishing mission objectives. Mission activities will be planned according to the experiment plan and translated into weekly operations plans and individual satellite passes. During each pass, the operations team will establish communication with HS-2, verify satellite health and state, execute approved commands, and collect telemetry and mission data. Following each pass, the team will review satellite performance and mission data, document the results, and use these findings to inform subsequent operations.

The operations team will be organized around defined roles, including the Flight Director (FD), Operational Engineer (OE), Mission Planner (MP), Payload Lead (PL), Subject Matter Experts (SMEs), and Ground Team. The FD will retain final authority over satellite commanding and operational decisions, while other team members will provide the technical expertise and operational support necessary to safely execute mission activities.

HS-2 operations will progress through several mission phases, beginning with initial acquisition and satellite checkout, followed by commissioning of satellite systems and the LOST and

FOUND payloads, and ultimately nominal mission operations. Operational procedures and constraints will be adjusted as the satellite transitions between these phases.

2.2 Operations Flow

HS-2 operations will follow a repeating cycle of planning, preparation, execution, and review. Mission and payload objectives will be translated into operational activities and scheduled around available satellite passes.

The general operations flow is:

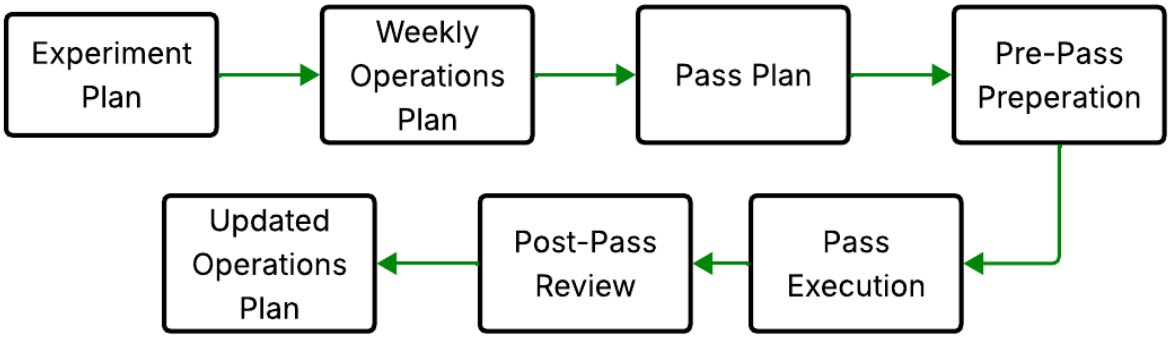


Fig. 1 Mission Operations Flow

Each pass will be divided into three primary operational periods: **Pre-Pass, Pass, and Post-Pass**.

During the **Pre-Pass** period, the operations team will review the current satellite state, establish objectives for the upcoming pass, prepare and verify required commands, and consult relevant subject matter experts (SMEs) as needed. The Flight Director (FD) and Operations Engineer (OE) will be briefed on the planned activities prior to the pass.

During the **Pass**, the team will first establish communication with HS-2 and verify that the spacecraft is in a healthy and expected state. Planned commands and payload activities will only proceed after spacecraft health has been confirmed, while telemetry and mission data are continuously monitored and collected.

During the **Post-Pass** period, during which they will conduct a debrief, review collected telemetry and mission data, identify any anomalies or unexpected behavior, and document the results in the appropriate operational logs. Findings and lessons from each pass will then be incorporated into planning for subsequent operations as necessary.

2.3 Operations Philosophy

The primary objective of HS-2 operations is to maintain satellite safety and health while accomplishing mission objectives. Satellite safety takes precedence over payload or

experimental objectives. If satellite health, operational constraints, or unexpected behavior indicate that an activity may pose a risk to the satellite, the activity may be delayed, modified, or terminated.

HS-2 operations will emphasize structured planning, verification, clear command authority, and thorough documentation. Commands will be reviewed and verified before execution, satellite state will be assessed before conducting mission activities, and operational decisions will be made using the best available telemetry and subsystem expertise.

Operations will also prioritize repeatability and continuous improvement. Each pass will be documented through shift and pass logs, including personnel, activities performed, commands executed, anomalies, and recommendations for future operations. Lessons learned from testing and on-orbit operations will be incorporated into subsequent procedures and planning.

3.0 Operations Organization

3.1 Operations Team

The HuskySat-2 (HS-2) operations team is responsible for planning, executing, and documenting all satellite operations throughout the mission. The team is structured to provide clear command authority while ensuring that the appropriate technical expertise is available for each operational activity. Personnel may fulfill multiple roles depending on staffing and mission phase, provided that responsibilities and command authority remain clearly defined. The roles of FD and OE must not be shared by the same individual.

3.2 Roles and Responsibilities

3.2.1 Flight Director (FD)

The Flight Director is the primary authority during a satellite operations shift and is responsible for the overall safety of HS-2 during operations. The FD:

- Leads the operations shift and coordinates the operations team.
- Accepts operational responsibility for the satellite during the shift.
- Has final authority to approve, modify, or terminate satellite commands and activities.
- Ensures that satellite safety takes priority over mission objectives.
- Coordinates with the OE and relevant SMEs when making operational decisions.
- Ensures that operational activities and decisions are properly documented.

3.2.2. Operational Engineer (OE)

The Operational Engineer is responsible for the direct technical interaction between the operations team and the satellite. The OE:

- Interfaces with satellite command and control systems.
- Monitors satellite telemetry and state of health.
- Prepares and executes authorized satellite commands.
- Verifies satellite state before and after commanding.
- Reports satellite status and unexpected behavior to the FD.
- Supports troubleshooting and anomaly response during operations.

3.2.3 Mission Planner (MP)

The Mission Planner is responsible for translating mission objectives into an operational schedule. The MP:

- Develops and maintains the weekly operations schedule.
- Schedules satellite passes based on mission needs and available ground station opportunities.
- Coordinates planned activities with the FD, OE, PL, and SMEs.
- Identifies required personnel, resources, and operational constraints for planned activities.
- Maintains the schedule as mission priorities and satellite conditions change.

3.2.4 Payload Lead (PL)

The Payload Lead is responsible for coordinating operations associated with the HS-2 payloads and serves as the primary subject matter expert for payload activities. The Payload Lead does not have to be the Payload subsystem lead. The PL:

- Owns and maintains the payload experiment plan.
- Coordinates LOST and FOUND experiment activities.
- Defines payload objectives and required mission data.
- Coordinates payload activities with the MP and operations team.
- Provides payload expertise during pass planning and execution.
- Reviews and evaluates payload data and performance.

3.2.5 Operations Lead (OL)

The Operations Lead is responsible for the overall readiness and organization of the HS-2 operations team. The Operations Lead:

- Coordinates operational readiness activities.

- Develops and maintains the weekly operations plan.
- Ensures operational procedures and documentation are maintained.
- Coordinates operator training and qualification.
- Identifies operational staffing and resource requirements.
- Incorporates lessons learned from testing and previous operations into procedures.

3.2.6 Program Manager (PM)

The Program Manager provides program-level support for mission operations. The Program Manager:

- Oversees program resources and funding.
- Supports operations facility and infrastructure requirements.
- Coordinates program-level decisions affecting mission operations.
- Supports resolution of resource, staffing, and organizational constraints.

The Program Manager does not normally direct real-time satellite operations; operational command authority remains with the Flight Director.

3.2.7 Subject Matter Experts (SMEs)

Subject Matter Experts provide specialized technical expertise to the operations team. SMEs are typically subsystem leads or other personnel with detailed knowledge of a satellite system. SMEs:

- Provide technical guidance during mission planning and operations.
- Review activities involving their respective subsystems.
- Support troubleshooting and anomaly investigation.
- Advise the FD when subsystem-specific decisions are required.
- Assist in developing and validating operational procedures.

SMEs do not independently command the satellite unless specifically assigned an operational role and authorized by the FD.

3.2.8 Ground Team

The Ground Team is responsible for managing the interfaces between HS-2 operations and the commercial ground station provider. Because HS-2 utilizes a commercial ground station service, the Ground Team does not directly maintain the ground station's physical infrastructure. Instead, the Ground Team is responsible for ensuring that the service is properly configured, available, and integrated with the HS-2 ground data system. The Ground Team:

- Coordinates with the commercial ground station provider to schedule and support satellite passes.

- Maintains HSL-controlled ground hardware and software used to interface with the commercial ground station.
- Verifies ground station availability and readiness before scheduled passes.
- Configures and verifies communication parameters required for satellite passes.
- Monitors ground station status during operations and identifies communication issues.
- Troubleshoots issues at the HSL-controlled portion of the ground system and coordinates with the provider when issues occur outside HSL's control.
- Supports the OE during satellite passes and data transfer.
- Maintains documentation of ground station configuration, access, and operational procedures.

The Ground Team does not have independent authority to command HS-2. Satellite commanding remains under the authority of the Flight Director and is executed by authorized operators.

3.3 Staffing

HS-2 operations staffing will be based on the requirements of each mission phase and operational activity. Staffing will ensure that sufficient personnel are available to safely monitor the satellite, execute commands, coordinate mission activities, and provide technical support when required.

A nominal satellite pass is expected to include, at minimum, a Flight Director and Operational Engineer. Additional personnel, including the Mission Planner, Payload Lead, and relevant Subject Matter Experts, will participate as required by the objectives and complexity of the pass.

Personnel may fulfill multiple operational roles when staffing is limited, provided that the separation of command authority and responsibilities is maintained. Higher-risk activities, anomaly response, and significant payload operations may require additional staffing or SME support.

The final staffing requirements for each mission phase and pass type are TBD and will be established as HS-2 operations procedures and mission requirements mature.

Role	**Nominal Requirement**	**Primary Responsibility**
Flight Director (FD)	1	Shift authority and satellite safety
Operational Engineer (OE)	1	Satellite commanding and telemetry
Mission Planner (MP)	TBD	Pass and mission planning
Payload Lead (PL)	TBD	Payload operations

SME	TBD	Subsystem technical support
Ground Team	TBD	Ground station interface

Table 1: Mission Operations Staffing

At the beginning of the mission, the operations team will be larger as they gain understanding of the satellite. As time goes on, the nominal requirements for roles present during passes will decrease and some part of the pass process may be automated.

3.4 Operator Training

All personnel performing satellite operations shall complete appropriate training and demonstrate proficiency in their assigned operational responsibilities prior to independently participating in flight operations. Training will familiarize operators with HS-2 satellite behavior, operational procedures, ground systems, command and telemetry interfaces, flight rules, and anomaly response.

Operator training will be conducted progressively, beginning with mission and satellite familiarization and advancing to hands-on operational activities and simulated passes. Training will incorporate lessons learned from satellite testing and ground system validation.

The anticipated operator training process is TBD:

Training will include TBD:

- HS-2 mission objectives and CONOPS
- Satellite subsystem behavior and constraints
- Roles and responsibilities during operations
- Ground station and ground data system interfaces
- Command and telemetry procedures

Operators will demonstrate their ability to perform assigned responsibilities during simulated operations before being qualified for flight operations. Qualification requirements and the specific criteria for operator certification are TBD.

Operators will also receive periodic refresher training and additional training following significant changes to satellite procedures, ground systems, or operational documentation.

4.0 Mission Phases

4.1 Deployment and Initial Charge (~5 min)

The inhibit switches will be activated at the start. EPS powers the spacecraft in a minimal-power configuration (Safe mode), in which the satellite will see that the solar panels aren't deployed, and deploy them. Upon solar exposure, the BMS starts MPPT charging; the EPS verifies rail voltages and battery state of health using hardware logic. This phase establishes power and health monitoring– it does not authorize payload activity or Downlink.

4.2 Bus Commissioning (~1 week)

CDH boots the flight computer and ADCS powers the IMU, magnetorquers, and sun sensors. Magnetorquers reduce the expected worst-case 10 deg/s tumble rate to the 0.5 deg/s experiment-mode requirement; the current estimate is approximately 110 minutes. The spacecraft then uses magnetorquers to orient the two solar-panel faces toward the Sun, verifies solar generation and battery charging, and periodically uses the star tracker to correct attitude drift.

Comms beaconing begins approximately 45 minutes after deployment every second. The two patch antennas support nearly omnidirectional communications before detumbling is complete. A Leaf Space prediction is only a planning input: the ground must receive and validate the beacon, return the defined response, and CommsApplication must report the contact-established event before the state machine may enter Standby/Downlink. Daily health and telemetry review continues throughout commissioning. A ground command is required to advance to Payload Commissioning.

4.3 Payload Commissioning (~1 week)

Checkout 1 verifies ADCS pointing by slewing to a known nadir or star-field attitude using magnetorquers and sensor feedback.

Checkout 2 activates the LOST camera, captures a star-field image, runs the Arcsec Sagitta comparison, and verifies the less-than-35 ms runtime and less-than-1 MiB memory targets.

Checkout 3 powers the FOUND camera, captures an Earth-limb image, detects edges, and logs position-data outputs.

Checkout 4 commands simultaneous LOST and FOUND imaging to compare the optical axes against the Arcsec Sagitta truth measure; the current alignment target is within 0.05 degrees.

Checkout 5 verifies the complete beacon-response chain through the assigned Leaf Space station, including ground identity validation, the CommsApplication contact event, and

end-to-end transfer of selected images and data through payload, CDH, COMMS, and ground processing. A ground command is required to enter the Experiment Phase.

4.4 Experiment Phase (~2 weeks)

Experiments execute only in Standby/Science after the Flight Director approves the experiment configuration and available raw EPS/BMS, thermal, storage, ADCS, and payload data are acceptable. For LOST, ADCS slews to a star-pointing attitude that avoids the Earth limb and Sun; centroiding requires at least four stars in the field of view and uses the Tetra/Pyramid identification path with the preloaded catalog. For FOUND, ADCS maintains an Earth-pointing attitude so CEDA/SEDA edge detection can isolate the limb; GPS and magnetometer coarse pointing remains TBR, while star-tracker data supplies fine attitude knowledge.

Experiment A tests LOST by recording a star image, Arcsec Sagitta truth attitude, and time; it runs LOST, saves the output, and downlinks the attitude result, truth data, and timestamp. Experiment B tests FOUND independently by recording an Earth-limb image, GPS truth position, and time; it runs FOUND and returns the position vector with truth data. Experiment C captures the star field and Earth limb with truth measures, runs LOST first, passes the resulting attitude into FOUND, and returns both attitude and position products. A valid contact-established event may preempt Science for Downlink; Safe preempts every experiment. Raw, uncompressed images are approximately 4.8 MB, but will be downsampled to approx 1.3 [TBR] MB. CDH currently allocates 64 GB total, with 56 GB reserved for images and capacity for approximately 45,000 images.

These experiments are only done when operators send commands from Ground to schedule experiments. They signify the type of experiment to be performed, the end result, and the algorithms specifically within LOST and FOUND to run, and a unique experiment ID. The spacecraft will queue these experiments, and run them only when it enters Science mode. If an error occurs, the queue is discarded. The Ground team can also batch many experiment commands together by signifying the number of experiments to perform of that type.

4.5 Decommission

After ground-directed completion of the Experiment Phase, the spacecraft enters Safe to halt payload operations and minimize load. The mission then relies on natural orbital decay, targeting re-entry within 25 years under debris rules.

4.6 Phase Completion and Operational Authority

The Flight Director authorizes phase advancement after the responsible operators and SMEs accept the required evidence. A phase may be held or returned to the applicable safe/commissioning configuration whenever safety evidence is unavailable, a protected fault is active, or the defined exit criteria are not met.

Operations Table A: Phase Completion Evidence			
Phase	**Operations evidence**	**FD decision**	**Carry-forward item**
Deployment	EPS rails and battery SOH verified; MPPT/initial charge evidence retained.	Authorize Bus Commissioning or hold in protected configuration.	Any unavailable EPS/BMS evidence or power-protection event.
Bus Commissioning	CDH/ADCS health; 10 deg/s to 0.5 deg/s detumble evidence; solar charging; ~45 min beacon and ground response result.	Authorize Payload Commissioning only after health and configuration acceptance.	Detumble, beacon-response, power, attitude, or thermal anomaly.
Payload Commissioning	CO.1–CO.5 results: pointing; LOST <35 ms/<1 MiB; FOUND edge result; 0.05 degree alignment; end-to-end contact/data transfer.	Authorize Experiment Phase, repeat checkout, or return to commissioning/Safe.	Failed checkout, unverified data chain, or unresolved interface mismatch.
Experiment	Experiment A/B/C products, truth data, timestamps, processing status, storage/transfer record, and success-criteria evidence.	Continue, stop, or decommission after payload/SME review.	Unmet success evidence, guard violation, incomplete downlink, or anomaly.
Decommission	Safe entry, payload halt, and final operations record.	Close mission operations and initiate disposal plan.	Any required final record or disposition decision [TBR].

Table 2: Different phases for the mission

5.0 Pass Planning and Operations

Satellite operations will be organized around scheduled communication passes between HS-2 and the commercial ground station. Each pass will have defined objectives, assigned personnel, planned activities, and required commands and telemetry. Pass operations will follow a standardized process consisting of planning, preparation, execution, and post-pass review.

The level of planning and staffing required for a pass will depend on the activities being performed. Routine passes may require only the nominal operations team, while passes involving payload activities, satellite configuration changes, or higher-risk operations may require additional personnel or SMEs.

5.1 Pass Scheduling

Passes will be scheduled based on satellite visibility from the available commercial ground station, mission priorities, satellite constraints, and planned payload activities. The Mission Planner will coordinate the operations schedule and identify communication opportunities required to accomplish upcoming mission objectives.

When scheduling a pass, the operations team will consider [TBD]:

- Ground station availability
- Expected pass duration and pass window
- Mission and payload priorities
- Satellite operational constraints
- Required personnel and SMEs
- Commands and data planned for the pass
- Dependencies on previous operations or satellite state
- Ground station and satellite configuration requirements

Passes that are anticipated to be shorter than 3 [TBR] minutes will not be scheduled.

The final process for requesting and confirming passes with the commercial ground station provider is [TBD].

5.2 Pass Objectives

Each satellite pass will have clearly defined objectives before operations begin. Objectives will be derived from the current mission or experiment plan and may include satellite checkout, subsystem testing, payload data collection, satellite configuration, or routine health monitoring.

Pass objectives will identify [TBD]:

- Required activities
- Expected satellite state
- Required commands
- Required telemetry or payload data
- Success criteria
- Personnel and SMEs required
- Constraints or conditions that must be satisfied

The Flight Director (FD) will review the planned objectives before execution.

5.3 Pre-pass Planning

Prior to each pass, the operations team will develop and review a pass plan describing the activities to be performed during the pass. The pass plan will be derived from the current weekly operations plan and will identify the commands, telemetry, personnel, and procedures required to accomplish the pass objectives.

The Mission Planner will coordinate the planned activities with the FD, OE, PL, and relevant SMEs. The OE will prepare the required command sequences and verify that they are consistent with the planned satellite state and operational constraints.

Before the start of a pass, the operations team will complete the following general activities:

1. Review the pass objectives and operational plan.
2. Verify the expected satellite state and relevant subsystem constraints.
3. Review and prepare required commands.
4. Verify command sequences and parameters.
5. Review expected telemetry and satellite responses.
6. Confirm required personnel and SMEs are available.
7. Verify commercial ground station availability and configuration.
8. Review current satellite anomalies or operational restrictions.
9. Brief the FD and OE on planned activities.
10. Obtain a final GO/NO-GO decision from the FD.

5.4 Pass Execution

During a pass, the ground system will autonomously establish and verify communications with HS-2 through the Leaf Space ground station network and perform an initial satellite health assessment. The OE will monitor the automated pass and intervene only when required, while the FD retains authority over mission activities and commanding.

The general pass sequence is [TBD]:

1. Leaf Space activates the scheduled communication service and HSL verifies provider and ground-system readiness.
2. CommsApplication transmits its configured beacon at the approved cadence.
3. The ground system receives and validates the beacon, confirms spacecraft identity, and returns the defined response.
4. CommsApplication validates the response and reports the contact-established event to the flight state machine.
5. Only if Safe is not active and the approved power, thermal, storage, and ADCS guards are permissive may the spacecraft enter Standby/Downlink.

6. The OE reviews raw battery and BMS status, rail-current data, battery temperature, thermal status, fault events, storage state, and communications status. If an onboard estimated SoC implementation exists, its value and validity status are reviewed; a ground-only SoC estimate is not a flight decision input.
7. After FD GO and command review, the OE releases authorized commands and verifies positive acknowledgment, expected telemetry, and state changes.
8. The spacecraft transfers prioritized housekeeping, events, command responses, experiment products, and files according to the approved queue policy and available link time.
9. An anomaly, a safety guard failure, or invalid energy-estimator data stops nonessential activity and invokes the applicable response procedure.
10. A contact-lost event, inactivity timeout, or planned session completion ends Downlink and returns the spacecraft to the otherwise eligible Standby submode; Safe remains available throughout.

5.6 Post-pass Activities

Following each pass, the operations team will review the results of the pass and document any relevant observations. The team will [TBD]:

- Confirm the satellite is in the expected post-pass state.
- Review telemetry and command responses.
- Verify receipt of required mission and payload data.
- Identify and document anomalies or unexpected behavior.
- Conduct an operations debrief.
- Record recommendations or lessons learned.
- Identify activities that must be carried into the next pass.
- Update the weekly operations plan as necessary.

Data requiring further analysis will be transferred to the appropriate subsystem or payload team for evaluation.

5.7 Pass documentation

Each satellite pass will be documented in a pass log to provide traceability of satellite operations. At minimum, the pass log will record [TBD]:

- Date and time of the pass
- Ground station used
- Personnel present and operational roles
- Pass objectives
- Commands executed and their order
- Relevant satellite telemetry and state
- Mission and payload data received

- Anomalies or unexpected behavior
- Objectives completed or not completed
- Post-pass satellite state
- Shift conclusions and recommendations

Pass documentation will provide a record of satellite operations and will be used to inform subsequent mission planning and identify lessons learned. The specific pass log format is [TBD].

6.0 Satellite Operations

6.1 State Monitoring

HS-2 uses Safe and Standby as top-level modes. Standby contains Charge, Science, and Downlink submodes. Sunlight, eclipse, ground-station visibility, and thermal conditions are environmental or contact conditions, not separate spacecraft states. Operators record the reported top-level mode, Standby submode, contact-established/contact-lost events, fault events, and active experiment state.

6.2 Power/Thermal Constraints

The EPS supplies 3.3 V, 5 V, and 12 V rails from a 75 Wh Li-ion battery and solar arrays currently estimated at approximately 12.124 W per orbit. Operators use raw pack and available cell voltage, rail-current, battery-temperature, charge/SOH status, and BMS protection status. The satellite does not directly emit SoC telemetry; flight software may estimate SoC from these measurements. The 100 percent/empty voltage endpoints, temperature and load compensation, estimator validity, and Safe/Science/Downlink/recovery thresholds are TBR with EPS.

6.3 ADCS Operations

During Bus Commissioning, magnetorquers reduce the expected worst-case 10 deg/s tumble rate to the 0.5 deg/s experiment-mode requirement; the current estimate is approximately 110 minutes. Before a payload run, operators verify approved pointing, rate, sun-exclusion, camera status, and required truth-measure availability.

6.4 Communications Operations

The S-band configuration uses 2025–2110 MHz uplink and 2200–2290 MHz downlink, a 2 W transmitter, 125 kbps uplink and 25 kbps downlink assumptions, and calculated margins of 16.61 dB uplink and 17.60 dB downlink against the 6 dB UNP requirement. CCSDS command and telemetry frames use the selected F Prime SDLS flight-side framework; the crypto implementation, Security Associations, key procedure, and provider/ground interoperability remain TBR.

6.5 Payload Operations

LOST and FOUND operations run only in Standby/Science under an approved experiment configuration. LOST checkout validates the Arcsec Sagitta pipeline against the less-than-35 ms runtime and less-than-1 MiB memory targets. FOUND checkout verifies Earth-limb imaging and edge detection. Alignment checkout targets 0.05 degrees between LOST and FOUND optical axes. Experiment products are stored and queued for transfer; a valid contact event preempts Science for Downlink.

6.6 Data Management

CDH stores raw, uncompressed experiment images of approximately 1.2 MB each. The 64 GB storage allocation, including 56 GB reserved for images, supports approximately 45,000 images in the current design. Operators prioritize health and command evidence before payload products, preserve raw CCSDS frames and processing status, and reconcile packet gaps, duplicates, and file-transfer results after each pass.

7.0 LOST and FOUND Operations

7.1 Entry Conditions and Configuration

LOST and FOUND operations are enabled only in Standby/Science with an approved experiment configuration. Before commanding a run, the Operations Engineer verifies the selected experiment, active camera and truth-measure configuration, pointing plan, Sun exclusion, attitude rate, raw EPS/BMS and thermal status, storage availability, and any active anomaly restriction. The satellite does not emit a direct SoC telemetry item; an onboard estimated SoC, if implemented, must be accompanied by its validity status and cannot replace raw protection telemetry. Safe remains available at all times.

7.2 LOST Star Tracker Operation

LOST captures a star-field image with the Arcsec Sagitta truth-measure path available for validation. The pipeline performs centroiding, star identification, and attitude estimation. Centroiding uses center of gravity; star identification uses Tetra or Pyramid with preloaded catalogs and a minimum of four visible stars; attitude estimation uses DQM or QUEST to produce quaternions. The pass record shall retain the image identifier, commanded attitude, Arcsec truth attitude, LOST attitude output, timestamp, pipeline status, runtime, memory result, and any star-identification fault.

7.3 FOUND Horizon Tracker Operation

FOUND captures an Earth-limb image while ADCS maintains an Earth-pointing attitude. CEDA/SEDA extracts limb edge points and SPDA converts the position vector into the planetary

coordinate system. The current validation path records the FOUND image, GPS truth position, truth time, selected algorithm status, output position vector, and failure flags. GPS and magnetometer use for initial coarse pointing remain TBR; star-tracker data provides the fine attitude knowledge used for experiment validation.

7.4 Experiment Execution and Product Set

Experiment A produces LOST attitude results against Arcsec truth. Experiment B produces a FOUND position vector against GPS truth without LOST input. Experiment C produces a FOUND position vector using the LOST attitude derived from the same combined observation. For each run, the team records the commanded experiment, camera image IDs, all truth-measure data, time, LOST and/or FOUND output, algorithm and processing status, and the required success-criteria evidence. Products are retained in CDH before their place in the prioritized downlink queue is approved.

7.5 Downlink and Ground Analysis

Payload data transfer begins only after the validated beacon-response exchange generates the CommsApplication contact-established event and the applicable power, thermal, storage, and ADCS guards are permissive. Ground receives the selected CCSDS frames through the Leaf Space service, retains raw-frame metadata and packet order, processes the products and stores data in Yamcs, and reviews telemetry in Grafana. The ground team reconciles packet gaps, duplicates, file-transfer results, and command acknowledgments before using LOST and FOUND products for error calculations. CCSDS protection uses the selected F Prime SDLS framework; Security Associations, key procedures, and provider-to-ground interoperability remain TBR.

7.6 Operational Transition Record

For every transition into Safe, Standby/Charge, Standby/Science, or Standby/Downlink, the pass log shall record the triggering command or event, source timestamp, pre-transition and post-transition state, relevant raw EPS/BMS/thermal/ADCS/storage evidence, command acknowledgment when applicable, and the Flight Director authorization or anomaly reference. This record is the operational trace from the MDD mode-transition baseline to DitL evidence.

8.0 Flight Rules

Flight rules define the operational constraints and decision-making authority used to ensure safe and consistent operation of HuskySat-2. They establish the conditions under which satellite activities may proceed and provide guidance for responding to unexpected satellite behavior. Flight rules apply to all HS-2 operations and take precedence over individual mission or payload objectives when necessary to protect the satellite.

The flight rules defined in this section are preliminary and will be refined through satellite testing, operations rehearsals, and development of the final CONOPS.

8.1 Command Authority

The Flight Director has final authority over real-time satellite operations and commanding during an operational shift. The Operational Engineer is responsible for preparing and executing authorized commands, after receiving permission from the FD, and monitoring the resulting satellite telemetry.

The following principles apply:

- Only authorized operators may issue satellite commands.
- Commands shall be reviewed and verified before execution.
- The FD shall authorize planned satellite commanding.
- The OE shall execute commands approved by the FD.
- The FD may modify, delay, or terminate planned activities based on satellite health or changing conditions.
- SMEs may provide technical recommendations but do not supersede the FD's operational authority.
- Emergency commands may be executed according to established anomaly procedures when required to protect the satellite.

The specific command authorization process for HS-2 is [TBD].

8.2 Satellite Safety Rules

Satellite safety takes precedence over mission and payload objectives. Operators shall not intentionally execute an activity when available telemetry indicates that the activity could exceed established satellite operational limits.

Operators shall:

- Verify satellite state before executing planned activities.
- Monitor satellite health throughout commanding.
- Maintain satellite power and thermal conditions within approved limits.
- Observe ADCS and communications constraints.
- Stop or modify operations if satellite behavior differs significantly from expected behavior.
- Consult the appropriate SME when a subsystem condition is not understood.
- Escalate significant anomalies to the FD.
- Preserve a safe satellite state when mission objectives cannot be completed safely.

Do not enter or remain in Science or high-rate Downlink when BMS protections are active, raw EPS data are unavailable or inconsistent, or an onboard estimated-SoC implementation reports invalid data.

8.3 Payload Constraints

LOST and FOUND operations shall only be conducted when satellite and payload conditions satisfy the requirements established for the planned observation. Payload activities shall not compromise satellite safety or interfere with higher-priority satellite operations.

Prior to initiating a payload activity, operators shall verify applicable constraints, including TBD:

- Satellite power availability
- Satellite thermal state
- Required satellite attitude
- Payload configuration
- Camera operational status
- Available onboard storage
- Communications and downlink availability
- Required lighting or observation conditions
- Any applicable ADCS or satellite pointing constraints

The PL and relevant SMEs shall provide guidance regarding payload-specific constraints and objectives.

8.4 Go/No-Go Criteria

A GO decision indicates that the satellite, ground system, personnel, and planned activities are ready to proceed. A NO-GO decision indicates that one or more required conditions have not been satisfied and that the planned activity shall not proceed until the condition is resolved or the activity is modified.

Prior to a planned operation, the FD shall verify that [TBD]:

- The satellite is in an appropriate operational state.
- Required telemetry is available and indicates acceptable satellite health.
    - For power decisions, this includes raw battery voltage, rail current, battery temperature, charge/SOH status, and BMS protection status.
- Required ground systems are operational.
- The planned commands have been prepared and verified.
- Required personnel are present.
- Applicable satellite and payload constraints are satisfied.
- No unresolved condition prevents safe execution of the planned activity.
- Required mission objectives and procedures have been reviewed.

8.5 Command Verification

All satellite commands shall be verified before execution to reduce the likelihood of incorrect or unintended satellite operations. Command verification shall include confirmation of the command, parameters, intended satellite state, and expected response.

For planned commanding, the OE shall TBD:

1. Confirm the command is included in the approved pass plan.
2. Verify command parameters and sequencing.
3. Confirm that applicable satellite constraints are satisfied.
4. Review the expected satellite response.
5. Obtain required authorization from the FD.
6. Execute the command.
7. Monitor telemetry for the expected response.
8. Document the command and resulting satellite behavior.

9.0 Anomaly Response

Anomalies are unexpected satellite, payload, ground system, or operational conditions that may affect the safety or performance of HuskySat-2. The anomaly response process is intended to protect the satellite, establish the cause and severity of the condition, and restore normal operations when possible. Satellite safety takes priority over mission and payload objectives during anomaly response.

The general anomaly response process is [TBD]:

9.1 Anomaly Detection

Anomalies may be identified through telemetry, command responses, payload data, ground system status, or observations made by operators. Operators shall continuously monitor relevant satellite and ground system data during operations and compare observed behavior against expected values and operational limits.

Examples of potential anomaly indicators include [TBD]:

- Telemetry outside established operational limits
- Unexpected satellite mode or state
- Unexpected response to a command
- Loss or degradation of communications
- Unexpected power or thermal behavior
- ADCS or attitude behavior outside expected limits
- Payload malfunction or unexpected data

- Ground station or ground system failures

When an anomaly is detected, the operator shall first verify that the condition is genuine and not the result of an instrumentation, communications, or ground system issue.

9.2 Anomaly Classification

Once an anomaly has been verified, the operations team will assess its severity and potential impact on satellite safety and mission objectives. Anomalies may be classified based on their impact to [TBD]:

- Satellite safety
- Satellite functionality
- Mission objectives
- Payload performance
- Ground system operations

The specific HS-2 anomaly severity classifications and associated response criteria are TBD.

9.3 Immediate Response

The immediate priority during an anomaly is to maintain or restore a safe satellite state. Operators shall avoid executing additional commands that could worsen the condition until the satellite state and appropriate response have been established.

Depending on the anomaly, the immediate response may include [TBD]:

1. Stop the current operation or command sequence.
2. Verify the satellite state and anomaly.
3. Place the satellite in an appropriate safe or stable configuration, if required.
4. Notify the FD and relevant SME.
5. Preserve relevant telemetry and operational data.
6. Determine whether additional commanding is safe.
7. Initiate the appropriate troubleshooting or recovery procedure.

9.4 Troubleshooting and SME Consultation

Following the initial response, the operations team will work to determine the cause and impact of the anomaly. The OE will collect relevant telemetry, command history, and other available data, while the appropriate SME will provide subsystem-specific technical guidance.

Troubleshooting may include [TBD]:

- Reviewing recent commands and satellite state changes

- Comparing current telemetry against expected behavior
- Reviewing previous operational data
- Checking for related subsystem anomalies
- Assessing potential ground system causes
- Evaluating whether the condition is transient or persistent
- Developing and reviewing potential recovery actions

9.5 Recovery

Once the anomaly has been sufficiently characterized, the operations team may execute an approved recovery procedure. Recovery actions will be selected based on the severity and cause of the anomaly and will prioritize preservation of satellite health.

Before executing recovery commands, the FD and OE shall confirm TBD:

- The proposed recovery action is understood.
- Required satellite conditions are satisfied.
- The expected response is known.
- Relevant SMEs have been consulted when necessary.

Following recovery, operators shall verify satellite telemetry and state to confirm that the satellite has returned to an acceptable operating condition.

If recovery cannot be safely performed, the satellite will remain in safe mode while the team develops a further response plan.

9.6 Post-Anomaly Documentation

All significant anomalies shall be documented following the resolution or stabilization of the condition. Documentation will provide traceability of the event and support future troubleshooting and operations planning.

The anomaly record should include [TBD]:

- Date and time of anomaly
- Personnel involved
- Subsystem affected
- Initial observed condition
- Relevant telemetry
- Commands executed before, during, and after the anomaly
- Initial classification and severity
- Immediate actions taken
- SME consultation
- Troubleshooting performed

- Recovery actions
- Final satellite state
- Mission or payload impact
- Root cause, if determined
- Lessons learned

Anomaly records will be reviewed by the appropriate operations and subsystem personnel, and lessons learned will be incorporated into future procedures and flight rules where appropriate.

10.0 Ground Operations Interfaces

10.1 Ground Data Handling System

The Ground Data Handling System (GDHS) provides the primary interface between the HSL mission operations team, the Leaf Space ground station network, and the satellite. The GDHS is responsible for receiving, processing, storing, and distributing satellite telemetry and payload data, as well as preparing and transmitting commands to the satellite.

The ground system interfaces with the Leaf Space Leaf Line service through the interfaces provided by Leaf Space, including the Leaf API and MQTT interfaces. These interfaces support the exchange of satellite communications between the HSL ground system and the Leaf Space network.

The GDHS shall provide the following capabilities:

HSL's current operations stack uses Yamcs for mission control, command generation, telemetry processing, event logging, operator web interface, and the shared mission database; and Grafana for read-only telemetry visualization. The released CTL, F Prime flight-software dictionary, Yamcs Mission Database, packet layouts, calibration, and telemetry identifiers shall remain configuration-controlled together.

- Receive satellite telemetry and payload data from Leaf Space.
- Store received telemetry and mission data in the ground system database.
- Process and organize telemetry for monitoring and analysis.
- Prepare satellite commands for uplink.
- Transmit commands through the Leaf Space network.
- Support automated and on-demand pass scheduling through the Leaf Line service.
- Track communication sessions and confirm successful data transfer.
- Provide mission operators with satellite status and communication history.
- Support data downlink and image retrieval from the satellite.
- Maintain appropriate logs of commands, telemetry, communications, and ground-system events.

Leaf Space provides data backhaul between its ground stations and the customer's designated endpoint as part of the Leaf Line service. The Leaf Line service supports both TT&C communications and mission/payload data communications.

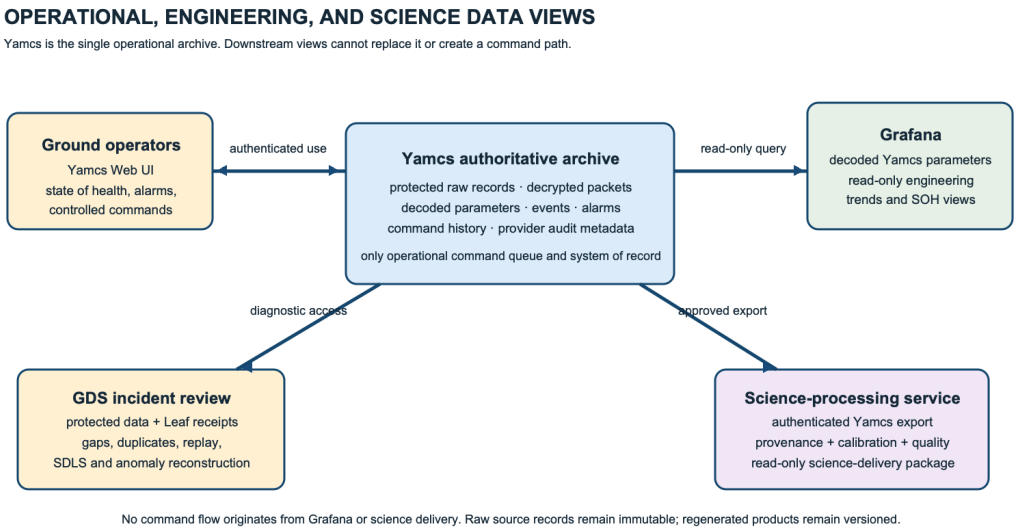


Fig. 2: Showcase of GND tools and different teams

10.2 Ground-to-Satellite Command Interface

The GDHS shall generate commands according to the satellite command dictionary and transmit them through the Leaf Line network. Commands may include satellite mode changes, payload operations, ADCS operations, communications configuration, telemetry requests, and other satellite functions.

Commands shall include sufficient information for the satellite to identify and execute the requested operation, including the command identifier and any required parameters. The ground system shall record the command transmission and associated response or acknowledgment when available.

Commands shall be formed as CCSDS packets and protected using the approved F Prime SDLS (with AES256 as the protocol)-compatible ground configuration before Leaf Space handoff. The operations record shall distinguish ground release, SDLS processing or protection failure, provider handoff, spacecraft receipt, and command completion.

10.3 Satellite-to-Ground Telemetry Interface

The satellite shall transmit housekeeping, subsystem, and payload telemetry during scheduled communication passes. The GDHS shall receive and decode this telemetry and make it available to mission operators and subsystem teams.

Telemetry should include, as applicable [TBD]:

- Satellite operating mode
- Electrical power and battery status
- ADCS state and attitude information
- Thermal measurements
- Communications subsystem status
- Payload status
- Fault and error information
- Experiment status
- Data storage utilization
- Communication link status

10.4 Command and Telemetry List

The Command and Telemetry List (CTL) defines the information exchanged between the satellite and the ground system during mission operations. The complete command definitions, telemetry definitions, packet structures, parameters, data types, identifiers, and expected responses are maintained in the Command and Telemetry List Document. The CTL serves as the authoritative interface between ground operations and satellite flight software.

The Ground System shall support the transmission of satellite commands and reception of satellite telemetry through the commercial ground station service.

The command and telemetry interface shall support, as applicable:

- ADCS operations
- EPS and thermal monitoring + control
- Payload operations
- Satellite configuration + state management
- Health and status monitoring
- Data and image downlink
- Fault recovery and satellite reset

10.5 Ground Stations

HSL will use a commercial ground station network provided by Leaf Space through the Leaf Line service. The ground station network provides the RF interface between the satellite and the HSL ground system for both telemetry/command (TT&C) and payload data.

Leaf Space is responsible for selecting and coordinating the ground stations required to support the mission based on the satellite's orbit, communication requirements, and mission profile. Leaf Space also manages ground station licensing, scheduling, and ground station operations.

The ground station network shall support the satellite's approved RF configuration and provide sufficient coverage and pass opportunities to meet mission communication requirements.

10.6 Commercial Ground Station Interface

The HSL ground system interfaces with the Leaf Space Leaf Line service rather than directly controlling individual ground stations. Leaf Space provides the network infrastructure, pass scheduling, RF communications, and data backhaul required to connect HSL with the satellite.

The interface between HSL and Leaf Space includes the Leaf API and MQTT interfaces, which are used to exchange mission data and support ground-system operations. The Leaf Line service provides:

- Ground station pass scheduling
- Command uplink and telemetry downlink
- Payload data downlink
- Data backhaul to the HSL ground-system endpoint
- Ground station activation and licensing
- RF compatibility and end-to-end testing
- Mission support during operations

HSL is responsible for operating its ground software, preparing satellite commands, processing received data, and managing mission data. Leaf Space is responsible for the underlying commercial ground station network and associated infrastructure.

Detailed Leaf Line service requirements and interfaces are defined in the Leaf Space Ground Segment Service Agreement and associated service documentation.

10.7 Operations Software

The Operations Software provides the software interface through which HSL operators monitor and control the satellite and manage mission data. It interfaces with the Ground Data Handling System and the commercial ground station service to support routine and contingency operations.

The Operations Software shall provide functionality for:

- Monitoring satellite health and status
- Sending satellite commands
- Scheduling and monitoring communication passes
- Monitoring telemetry in near-real time
- Managing payload and experiment data
- Tracking satellite modes and operational state
- Viewing communication and command history

- Identifying and responding to satellite faults
- Managing mission configuration and operational parameters
- Providing relevant data to the science and engineering teams

The Operations Software shall use the Command and Telemetry List (CTL) as the authoritative definition of satellite commands and telemetry. Detailed command definitions, packet formats, and telemetry parameters are maintained in the applicable command and telemetry documentation rather than duplicated within this document.

The Operations Software architecture shall be designed to separate mission operator functions from the underlying ground-station infrastructure, allowing operators to interact with the satellite without requiring direct control of individual Leaf Space ground stations.

11.0 Operations Testing

Operations testing will verify that the satellite, ground segment, and operations team can execute nominal and off-nominal mission activities as an integrated system. Testing will focus on validating operational interfaces, command and telemetry flow, autonomous operations, and the ability to respond appropriately to satellite anomalies. Detailed subsystem and hardware test procedures are maintained in their respective verification documentation.

11.1 Ground Station Validation

Ground station validation will verify that the selected ground station network can establish communication with HS-2 and support the required command, telemetry, and mission data interfaces. Validation will include communication link verification, command uplink, telemetry downlink, data transfer, and compatibility with the satellite communications system. Where applicable, Leaf Space will provide ground station services and perform the associated network-side configuration and validation.

11.2 End-to-End Testing

End-to-end testing will verify the complete operational chain from Yamcs through the Leaf Space interface, ground station, satellite, and return archive. Testing shall demonstrate beacon acquisition, ground response, CommsApplication contact-established/contact-lost events, authorized commanding, command acknowledgment, telemetry and payload-data receipt, raw-frame preservation, and reconciliation. The test shall also verify the F Prime/ground SDLS configuration, Security Association selection, key-handling procedure, protection failure reporting, and the distinction between provider receipt, spacecraft receipt, and command completion. Battery charge-cycle tests shall compare the onboard estimated SoC, if implemented, with raw EPS measurements and validate estimator-validity handling.

11.3 Pass Simulations

Pass simulations will exercise the expected sequence of activities during a satellite communication pass. Simulations will verify that routine operations can be conducted within the available pass window, including autonomous communication establishment, satellite health assessment, command execution, telemetry collection, and payload operations. Simulated passes will be used to validate operational timelines and identify issues before flight operations.

11.4 Anomaly Simulations

Anomaly simulations will evaluate the operations team's ability to recognize and respond to unexpected satellite behavior. Scenarios may include missed commands, unexpected telemetry, communication loss, subsystem faults, and transitions into safe mode. Responses will follow the satellite's defined FDIR and operational procedures, with priority given to maintaining satellite safety over completion of mission objectives.

11.5 Operator Qualification

Operators will demonstrate proficiency in the systems and procedures required to support mission operations. Qualification activities will include command and telemetry interpretation, pass execution, anomaly response, and use of the ground operations software. Operators will be required to demonstrate the ability to execute nominal procedures and respond appropriately to simulated off-nominal conditions.

11.6 Day in the Life Verification

Day-in-the-Life testing verifies the fully integrated operational sequence, not just individual interfaces. Each case shall use the controlled command and telemetry definitions, the actual ground-service configuration where available, and a reproducible pass log. A failed case shall identify the affected CONOPS rule, mode/phase criterion, ground interface, or budget assumption before retest.

Operations Table B: Day in the Life Verification Matrix			
Scenario	**Starting condition and sequence**	**Pass criteria and retained evidence**	**Open item or owner**
Nominal deployment and Bus Commissioning	Inhibit activation -> EPS minimal power/MPPT -> CDH/ADCS enable -> detumble -> solar pointing -> ~45 min beacon.	Rails, battery SOH, raw EPS/BMS, 10 deg/s to 0.5 deg/s evidence, ~110 min estimate/check, beacon/response log, and phase gate record.	Detumble timing allocation, beacon cadence, and final phase-gate thresholds [TBR].
Validated contact and Downlink	Scheduled Leaf Space service -> beacon received/validated -> defined response -> CommsApplication contact-established -> Downlink -> command/telemetry/file transfer -> contact lost/session close.	No Downlink before contact event; SDLS/frame and command evidence retained; correct exit to eligible Standby submode.	SDLS Security Associations, key handling, provider/ground interoperability, and RF/data-rate reconciliation [TBR].
Experiment A/B/C	Enter Standby/Science with permissive guards; collect selected star/Earth-limb images, truth data, and time; run LOST and/or FOUND; store and queue products.	A: LOST attitude vs Arcsec truth. B: FOUND vector vs GPS truth. C: FOUND using LOST attitude. Image IDs, outputs, timing, status, and success evidence retained.	Per-mode energy/storage thresholds, truth-measure availability, and final experiment success thresholds [TBR].
Contact loss during Downlink	Enter Downlink after valid contact event; introduce contact-lost/inactivity/session-close condition.	Payload transfer stops or is reconciled; state exits to eligible Charge or Science; packet gaps/duplicates and partial file status are logged.	Timeout value, resume/retry policy, and queue prioritization [TBR].

Operations Table B: Day in the Life Verification Matrix			
Scenario	**Starting condition and sequence**	**Pass criteria and retained evidence**	**Open item or owner**
Energy, thermal, or estimator-invalid guard	During Science or planned Downlink, inject a protected BMS condition, raw EPS/thermal violation, or invalid onboard energy-estimator status.	Nonessential activity stops; transition to Charge or Safe follows defined priority; raw data remains available even when estimated SoC is invalid.	Voltage/temperature/load mapping, estimator validity criteria, and mode thresholds owned by EPS [TBR].
Safe entry and authorized recovery	Inject protected subsystem fault or SAFE command -> Safe -> ground diagnosis -> authorized recovery command.	Payload remains off; minimum-load beacon/command reception and watchdog behavior observed; recovery records raw health evidence and FD authorization.	Final Safe hardware rates/configuration and recovery acceptance criteria [TBR].

Table 3: Day in the Life of the spacecraft

The DitL suite shall be maintained as the verification baseline for the MDD CONOPS tables. Each test procedure shall cite its scenario, controlled configuration, expected telemetry/event sequence, success criteria, anomaly handling, and resulting change request when a CONOPS assumption changes.

12.0 Operations Documentation

Operations documentation will provide the records and planning information required to support satellite operations throughout the mission. Detailed procedures and technical requirements are maintained in their respective subsystem and operations documents.

12.1 Experiment Plan

The Experiment Plan will define the planned execution of LOST and FOUND experiments, including experiment objectives, required satellite configuration, planned activities, and required telemetry or mission data. The plan will be used to coordinate experiment execution with satellite and ground-system constraints.

12.2 Weekly Operations Plan

The Weekly Operations Plan will summarize planned satellite activities and communication passes for the upcoming operational period. It will identify planned commands, experiments, telemetry collection, and other activities requiring ground-system support.

12.3 Shift Log

The Shift Log will provide a record of activities performed during each operations shift. Entries will document significant commands, satellite state, operational decisions, and relevant observations made during satellite operations.

12.4 Pass Log

The pass Log will record satellite communication passes and relevant pass information. Records may include pass timing, communication status, commands executed, telemetry received, and any notable issues encountered during the pass.

12.5 Anomaly Reports

Anomaly Reports will document unexpected satellite or ground-system behavior observed during operations. Reports will capture the observed condition, relevant telemetry or operational context, actions taken, and resolution or follow-up actions. Anomalies will be tracked in accordance with the mission's defined anomaly response and FDIR processes.

Revision Tracker

Date	Author	Description
8/17/2026	Addison Milne	Created
8/28/2026	Lauren Wetzel	Updated Mission Operations Overview
9/10/2026	Mahir Emran	Updated satellite phases, GND plans