UNIVERSITY OF GEORGIA
Small Satellite Research Laboratory

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Concept of Operations

A Guide to SPOC Functionality

Revision Table

Changes	Authors	Version
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Philosophy & Overview

The Spectral Ocean Color (SPOC) operational concept is grounded in three core principles:

1. Safe operation of satellite. [1]
2. Obtain telemetry, payload, and end-product data to meet mission requirements.
3. Maximizing efficiency of satellite and payload by minimizing time latency between the first two points.

These points are the foundation of the operational behavior of SPOC, and are the cornerstone of providing the end-data products of SPOC. Overall, mission assurance is the primary concern. The SPectral and Ocean Color (SPOC) Satellite shall acquire moderate resolution imagery across a wide range of spectral bands to monitor coastal ecosystems and ocean color. SPOC will acquire image data between 433 and 866 nm to monitor 1) coastal wetlands status, 2) estuarine water quality including wetland biophysical characteristics and phytoplankton dynamics, and 3) near-coastal ocean productivity. SPOC shall use multispectral remote sensing techniques to quantify vegetation health, primary productivity, ocean productivity, suspended sediments, and organic matter in coastal regions.

[1] *Safe operations:* Operations must be conducted so as to avoid doing harm to itself, people, property, or the environment.

Automation

Automation of satellite missions like SPOC can prolong the nominal mission lifetime, enhancing the quantity and quality of end data products. Where appropriate, automation also allows the number of required ground support staff to be reduced. However, automation of different SPOC segments, both in-flight and on the ground, requires serious developmental legwork. While automation can reduce human and operational error, with such a complex system, we still allow full ground control of the satellite.

Because SPOC serves as an experiential learning mission for undergraduates at the University of Georgia and as a technology demonstration mission, varying levels of automation are found onboard the satellite. Its most automated operation is the acquisition of the multispectral imagery data, which requires only a scheduled mode transition into Scan Mode. Image acquisition involves pointing nadir, booting the payload, data acquisition, data handling, and payload shutdown; all of these are automated processes. Hardware watchdogs and onboard failure detection and correction mechanisms are also automated to constantly monitor SPOC's health. This alleviates the need for immediate action on the ground, and thus the need for a distributed ground station network, so a central ground station in one location can better handle the majority of circumstances. When corrections cannot be safely made onboard, and ground intervention is unavoidable, the satellite enters a Failsafe state, in which all automation besides command and data handling is ceased.

The command and data handling automation performed on the OBC involves logger, monitor, scheduling, and facilitation modules which facilitate telemetry gathering and scheduling is highly automated. These modules constantly monitor the OBC health and implement any automatic error correction needed.

To further alleviate the need for a distributed ground network, a schedule of operations is uplinked to SPOC during data downlink to the University of Georgia ground station. This allows a level of pseudo-autonomy on-orbit with automated transitions between modes and operations. This is pseudo-autonomous as the mission operations team has planned and scheduled these operations beforehand. Ground automation, uplinking a relevant schedule based on accurate satellite health data gathered at the beginning of data downlink, can further decrease the latency of on-orbit operations.

Mission Operations Team

The Mission Operations team oversees in-flight operations. As SPOC matures, the team will host mission planners, ground and satellite systems engineers, and flight operators. As they dictate certain hardware configurations, Mission Operations must communicate closely with the Electronics and Mechanical teams. They will also work closely with core leadership, particularly the Chief Engineer, to promote smooth collaboration across SPOC teams. The responsibilities of the Mission Operations team include:

- Development and implementation of the concept of operations and experiment plan.
- Ensuring data downlink/uplink requirements can be met.
- Building of appropriate ground station support equipment.
- Ensuring on-orbit power needs can be met.
- Performing mission assurance analysis.
- Following the licensing process with the FCC and NOAA.
- Analysis of link budgets and antenna gain patterns.
- Develop satellite and payload command procedures.
- Providing support and analysis during Simulated Communication testing.
- Assuring mission success through Day In The Life testing.
- Lead ground station software development.
- Processing satellite telemetry.
- Training of flight controllers for day-to-day operations.
- Authorizing operators to process commands.
- In-depth training for Safe Mode/anomaly handling.
- Rehearsing nominal, special, and emergency flight operations.
- Scheduling 24/7 availability during critical on-flight operations.
- Performing on-flight operation planning, execution, analysis, and reporting.
- Handing over appropriate data to NOAA prior to release.
- Ensure on-flight operations do not violate flight rules.
- Maintain operation logs.
- Decommission SPOC.

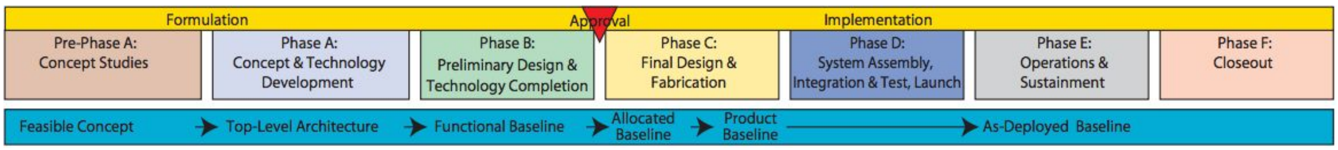
The Mission Operations team will be active throughout SPOC's lifetime, with activity picking up approximately L-1.5 years. No later than L-4 months, the ability to perform full on-orbit operations will be demonstrable. This is also called the Day in the Life (DITL) tests. As launch preparations continue, the mission operations team will become more mission operator focused.

Phases & Modes

Phases

Formulation (Pre-Phase A-Phase B)

The Formulation level of system maturity includes the beginning stages of the technical design process. The Concept Studies phase (Pre-Phase A) serves to identify ideas and missions from which new projects can be selected. Mission concepts, system-level requirements, and potential technological needs are drafted in preparation for the Concept and Technology Development phase Phase A). Simulations, models, and analyses are made in order to show system concept definition used in the development of the project in more mature phases. In the Preliminary Design and Technology Completion phase (Phase B), these system concept definitions are developed into trade study results, interface documents, and prototypes for the Implementation level of system maturity.

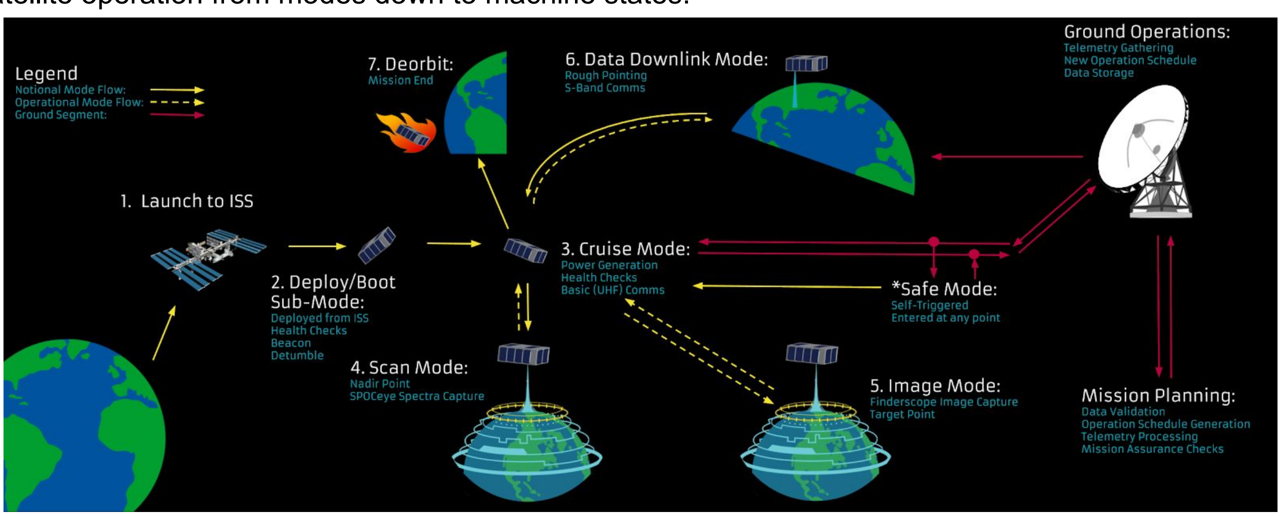


Implementation (Phases C-F)

The Implementation level of system maturity concludes the design phase of the satellite.

Modes

A mode represents the overall operational state of SPOC at any given time. SPOC can only be in any one Mode at a time. All Mode transitions are scheduled, with the exception of an automatic transition to Safe Mode in cases of anomalous behavior. Modes are comprised of several Sub-modes. Sub-mode transitions are also scheduled, but can be manually overridden during ground station passes. It's important to note that sub-modes only operate sequentially. A table of sub-modes is included in each mode description, along with a sub-mode nominal flow diagram. All sub-mode sequences include exit transitions back into Cruise Mode. If a detailed architecture overview is desired, the reader is encouraged to visit the SPOC Software Architecture to understand technical satellite operation from modes down to machine states.



Transitions

Soft Transition

A soft transition is a central command, which is is passed to the core logic of the current operational state. After the soft transition command is received, no new Tasks are assigned. After all activity has ended, the satellite transitions into the desired operational state. All nominal transitions are soft transitions.

Hard Transition

A hard transition is a command to immediately end all processes and transition into Safe Mode, without waiting for completion of any task. Hard transitions are typically used for emergencies; transitions into Safe Mode are hard transitions.

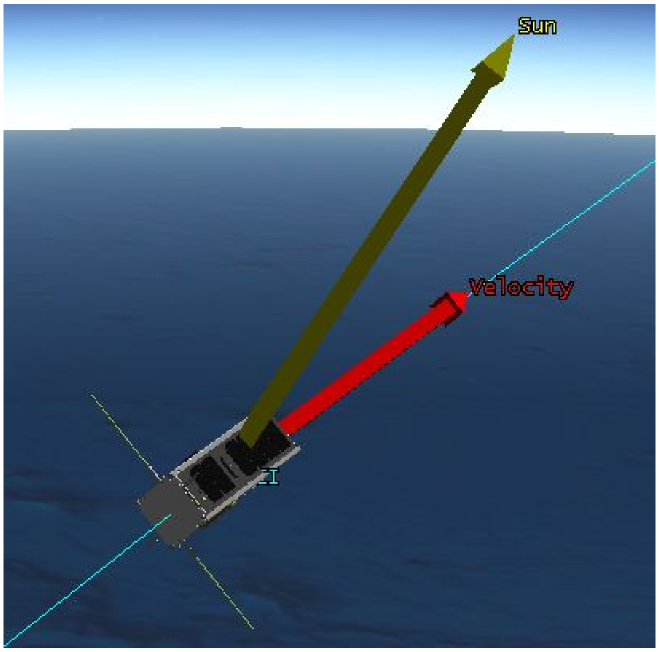
Cruise Mode (CR)

SPOC will enter Cruise Mode immediately upon exit of the Deployment/Boot Mode (See Safe Mode). Cruise Mode is a standard low-power mode when the satellite is operating between Modes. SPOC shall remain in Cruise Mode in nominal operating conditions. At regular intervals of 30 seconds SPOC shall beacon its call sign and telemetry data over UHF. It is important to note that beaconing is not exclusive to Cruise Mode, and the same beaconing characteristics apply to other modes, unless otherwise stated. The telemetry in the beacon is located in the Command & Telemetry List (CTL). Until the CTL is complete this bacon will determine:

1. Battery charge status
2. Data storage
3. Solar panel voltages and currents
4. Thermal state
5. Location of satellite (lat, long, elev)
6. Power draw on 3.3V, 5V, 12V, and VBATT power rails
7. Attitude and rotation rates

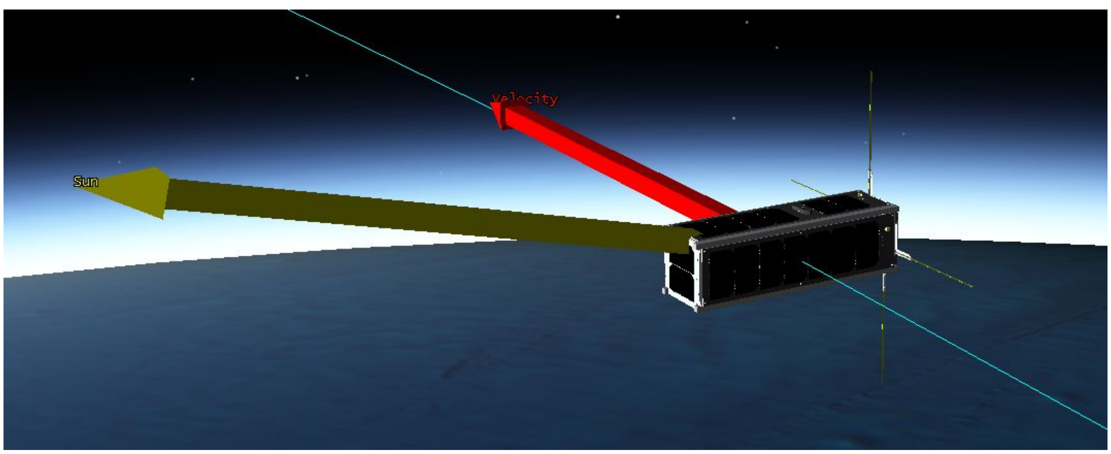
Even neglecting the risk of single-event upsets, cumulative exposure to the comparatively high radiation levels in the SAA could, over time, cause significant hardware damage. To minimize the effects of radiation and ensure continuous nominal operation, the OBC reboots once per week in response to a command received during a pass over the ground station. The OBC’s memory will be regularly scrubbed, as well.

When the beta angle between SPOC’s orbital plane and the Sun is between -5° and 5°, SPOC is in maximum eclipse, significantly hampering power generation. To offset power difficulties, SPOC may rotate 45 degrees around its Z-axis, so that the X+ and Y+ faces will receive nearly equal amounts of sunlight. During such periods, the Power Generation Idle submode will be the priority submode, allowing full transitions to and from all other modes. This sub-mode must be specifically requested by mission control, and a gps trigger or timer must be used to schedule the soft transition.



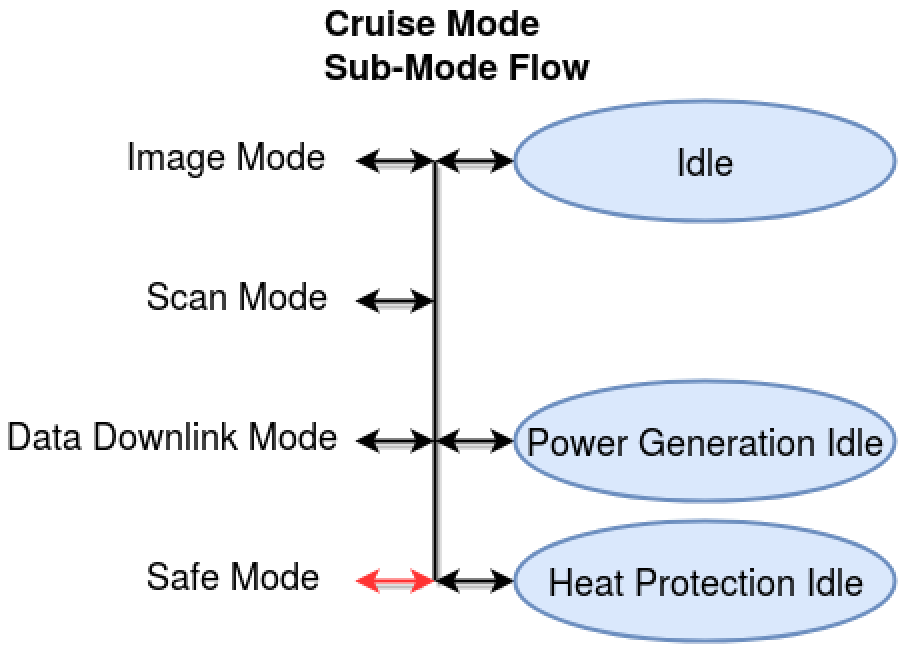
Attitude during Power Generation Idle Sub-Mode

An additional sub-mode is the Heat Protection Idle sub-mode. When the Beta Angle between SPOC's orbital plane and the sun is above 71° or below -71°, SPOC may heat up dangerously. To mitigate this, the attitude of SPOC will be adjusted so that the Z+ face points towards the sun. The special attitude maneuver decreases the power generation for SPOC, thus requiring periodic attitude adjustment to increase power generation before returning to the nominal Heat Protection Idle attitude state. This submode must be scheduled specifically by the ground operator to enter using either a GPS trigger or timer.

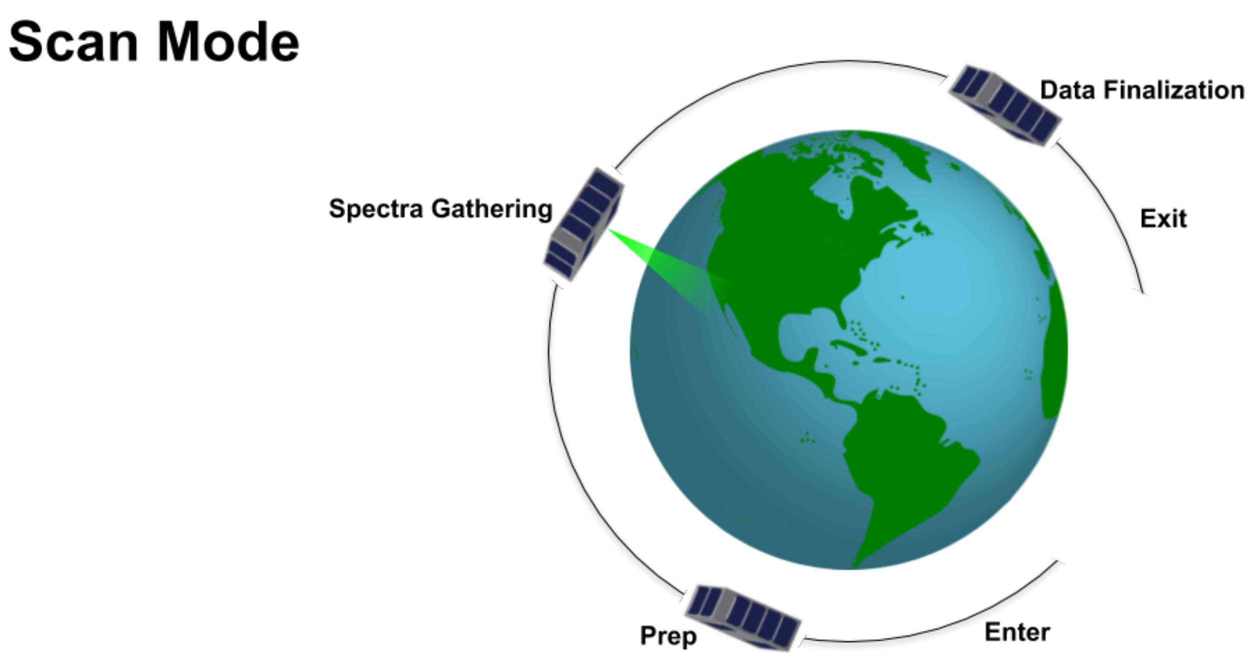


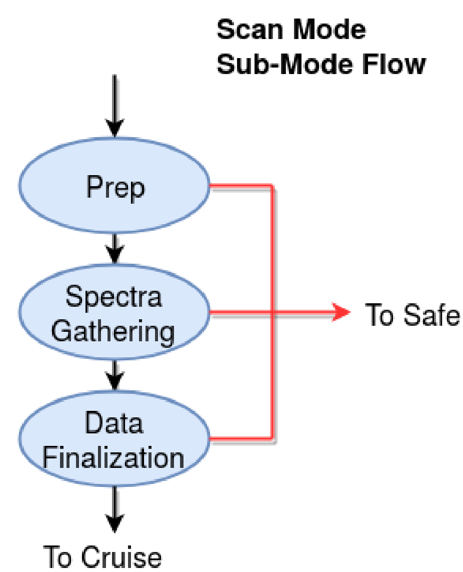
Attitude during Heat Protection Idle Sub-Mode

Cruise Mode Sub-Modes	Description
Idle	Beaconing, awaiting transition or command
Power Generation Idle	Attitude change in low beta angles, maximizes power generation
Heat Protection Idle	Attitude change in high beta angles, minimizes solar heat generation



Scan Mode (SC)





Scan Mode handles data acquisition over the target area. As SPOC nears the target area, the satellite's primary payload, SPOCeye, will boot and make necessary preparations for target imaging. The OBC will make necessary image calculations that determine the frequency and number of images to be taken as a function of orbital velocity and time spent over the target area.

Data acquisition over the target area is dependent upon usable passes. A usable pass over is defined by criteria that needs to be met in order for SPOCeye to scan the target area. If ground control determines that a usable pass over the target area is approaching based on orbital propagation models and weather forecasts, ground control will schedule a transition from Cruise Mode into Scan Mode during the next acquisition of signal of the satellite.

This transition should occur long enough before SPOC passes over the target area so that it has sufficient time to make all necessary preparations. These preparations include calculating the imaging parameters (number of images, frequency, imaging time, etc.), point track, and boot payload. Data acquisition will be triggered via a GPS coordinate and will end when SPOC has completed data acquisition.During the pass, three images will be taken with the finderscope. The first image is captured at the beginning of the SPOCeye scan. The second is when the center of the target is nadir. The final image is taken directly after the last scan is completed. Upon completion, SPOC will process the acquired data, shut down the payload, and return to Cruise Mode.

Cruise Mode Sub-Modes	Description
Prep	Power on SPOCeye, set SPOCeye parameters, nadir point
Spectra Gathering	Acquire scans; acquire 3 images once start, once normal to target center, once done
Data Finalization	Move data to OBC memory, power off SPOCeye

Image Mode (IM)

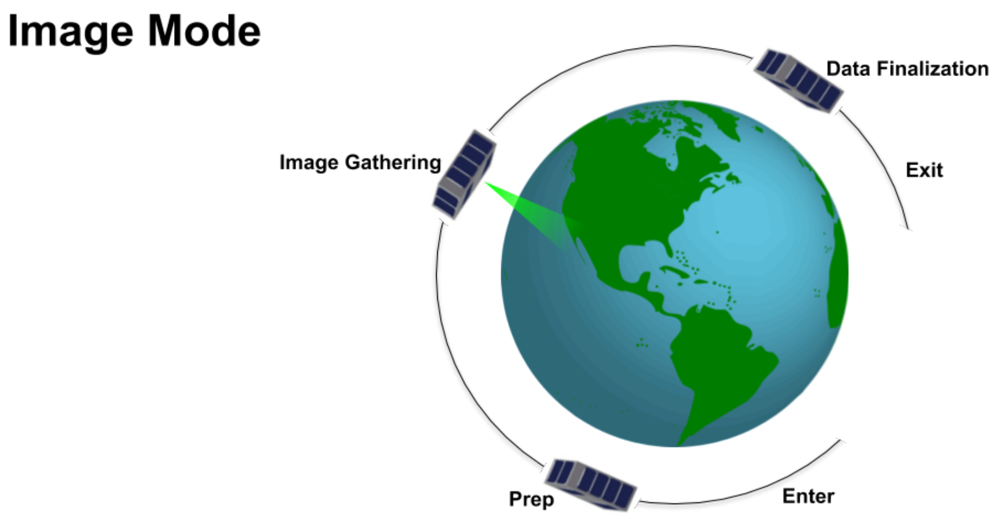
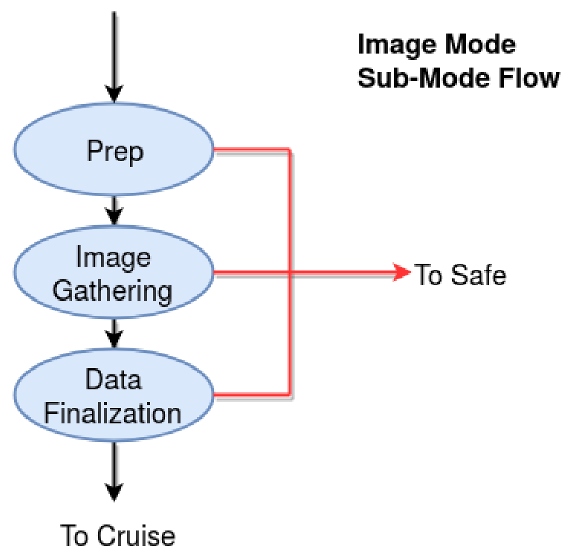


Image Mode performs much like Scan Mode. A high resolution image is taken via the secondary payload, the Finderscope. Though entered upon manual command, image acquisition will occur when a trigger, a timer or GPS trigger set by the ground control, is activated.



SPOC will receive an list of requested images from ground control. SPOC will then prepare for the first element in the list to image. After the image is taken, SPOC will finalize and store the data in the OBC. After this happens, the image request will be removed. This will continue until all requested images are completed.

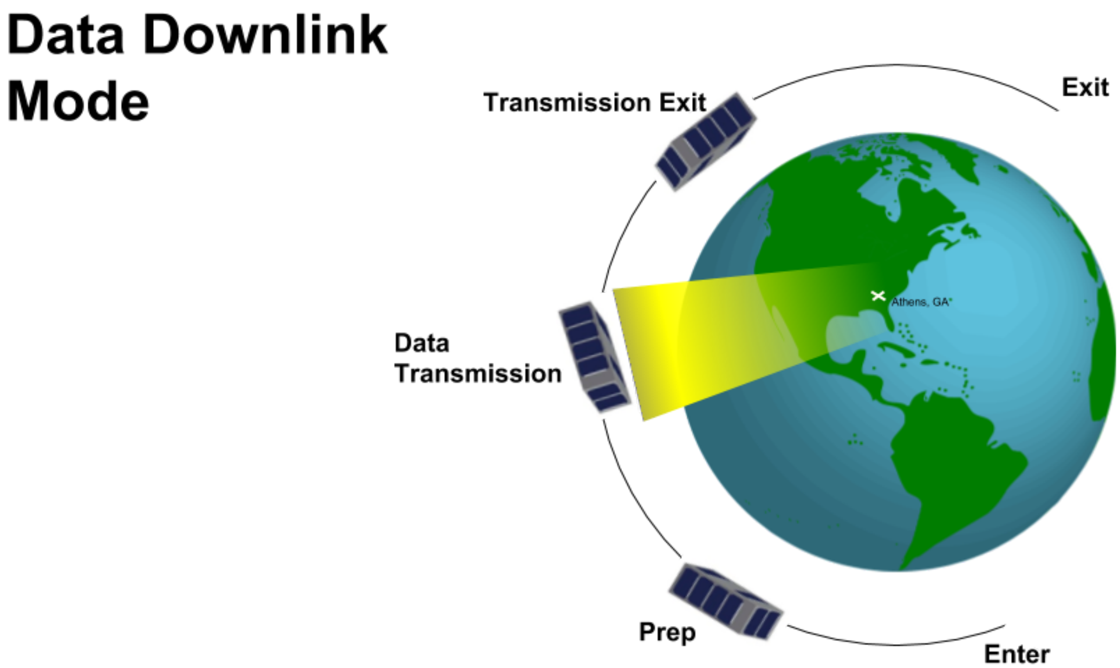
The information sent to the satellite for the completion of this mode is as follows :

- Commanded trigger type
- Commanded trigger value
- Prep Time
- Commanded attitude
- Data Acquisition rate
- number of images

The Prep time is the estimated amount of time to change from one attitude to the desired attitude. Finally, when the capture time is reached the finderscope will gather a specified number of images. Once this is complete, the satellite will return to a nadir orientation to avoid accidental sun exposure.

Cruise Mode Sub-Modes	Description
Prep	Power on Finderscope, set Finderscope parameters, ADCS point
Image Gathering	Acquire images
Data Finalization	Power off Finderscope, nadir point

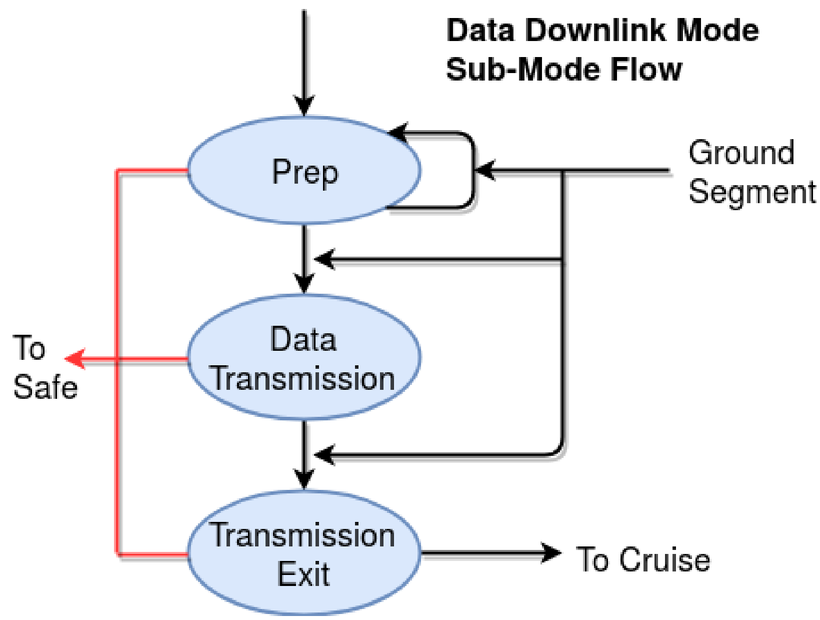
Data Downlink Mode (DD)



In Data Downlink Mode, SPOC nominally downlinks processed data and telemetry. In certain cases, raw gathered data and intermediate data products may be downlinked as well. Because of SPOC's orbital velocity and orbit from an ISS deployment, it is estimated the SPOC will only have about 7 minutes of line-of-sight communication with the ground station. Because it is unlikely that all requested data is downlinked in one pass, it will be important for mission operation scheduling to plan for multiple passes. The S-Band transmitter will output 24 dBm at a data rate of 1 Mb/s.

In the Data Downlink Prep sub-mode, SPOC uses the ADCS reaction wheels to rotate the satellite 70 degrees from nadir towards the SSRL ground station. This slew angle is based off of the 20 degree operational elevation mask. This prepares the satellite to perform its slew maneuver to downlink to the S-Band ground station. Additionally, the Data Prep sub-mode will prepare the scheduled data to be downlinked, including encrypted data. SPOC will also increase the rate of beaconing to every 15 seconds during Data Prep sub-mode to increase visibility to the ground station. A unique feature of the Data Downlink Prep sub-mode is that it will be commanded manually into the Data Transmission sub-mode through successful communication with the ground station.

Upon successful communication with the ground station, the Data Prep sub-mode will have two options: 1. Transition sub-modes and transmit prepared data or 2. Re-prepare new data as specified by the ground station. Acknowledgments on the amount of data received from prior passes from particular datasets will also be passed through. The acknowledgments will allow SPOC to resume data transmission operations in the case of incomplete data downlinks. The ability for the mission operations to have intervention on data to be downlinked early in the pass allows for an agile communication method with SPOC. Additionally, SPOC will begin its slew maneuver with the first initial contact.



After transitioning into the Data Transmission sub-mode, the prepared data will be downlinked. The slew maneuver will continue to be maintained, targeting the UGA ground station with the S-Band patch antenna. The S-Band transmitter handles packetization and modulation as the data is injected into its buffer. Rapid UHF beaconing every 15 seconds continues to occur. Housekeeping can also occur in parallel with Data Transmission, allowing the mission operations team to downlink any large batch telemetry files over S-Band, uplink new operational schedules, and ensuring SPOC operates safely for the next leg of radio silence through telemetry monitoring during the pass. Ultimately, it is at the discretion of the mission operations team the level of housekeeping to be performed. SPOC will remain in the Data Transmission sub-mode sending data to the ground station. If a manual transition command to the Transmission Exit sub-mode is not received, the operational schedule onboard will transition into the Transmission Exit sub-mode after 11 minute from first contact.

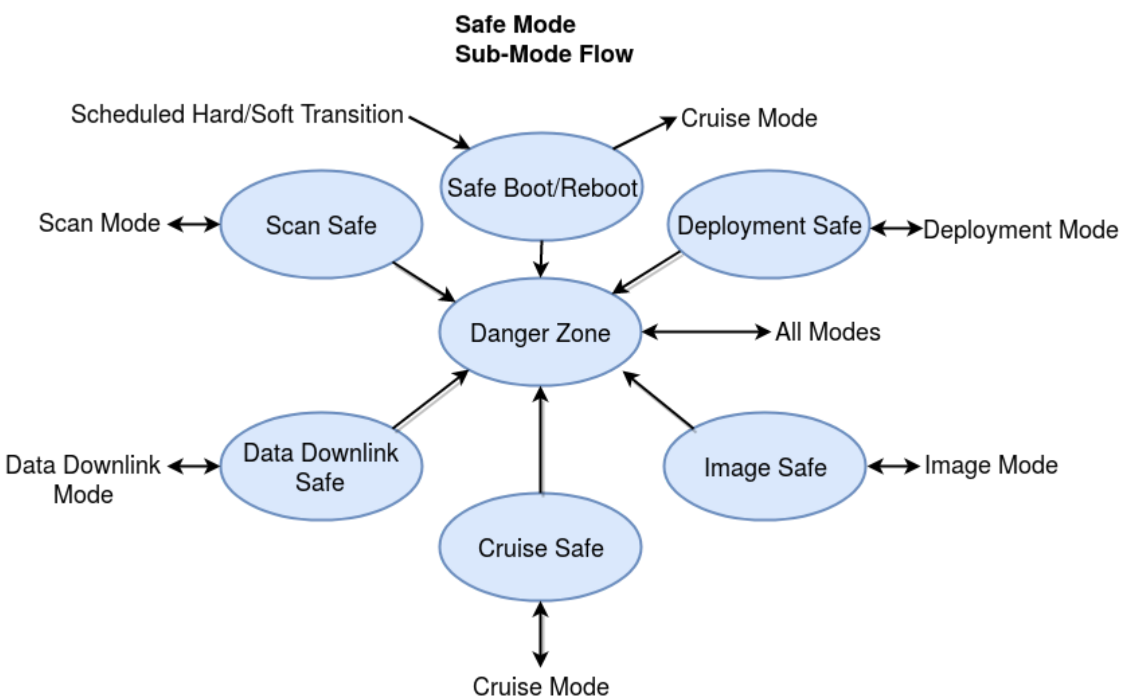
The Transmission Exit sub-mode is a scheduled operation which allows for the maximum usable communication time between the ground station and SPOC. Once SPOC slews for a total of 140 degrees, the ADCS will re-orient the satellite into its nominal nadir pointing state. Upon successful re-orienting, SPOC will transition into Cruise Mode to resume operations.

Data Downlink Mode Sub-Modes	**Description**
Data Prep	Increased rate of beacon, data is prepared to be downlinked, slew preparations and execution
Data Transmission	Transmission of data, ground station targeted slew
Transmission Exit	Re-orient satellite, transition to Cruise Mode.

Safe Mode (SF)

Safe Mode addresses all emergency and extreme events that SPOC may experience during its mission timeline. Safe Mode can be transitioned into at any point and serves as a very low-power survival mode of the satellite until the mission operations team is able to perform diagnoses. Anomalies causing the OBC to reboot is considered a “hard transition” into safe mode and a software trip transition into Safe Mode is considered a “soft transition.” Safe Mode can also be manually transitioned into if hardware degradation dictates such a transition is necessary. If the OBC is forced to reboot, SPOC will reboot into its Failsafe image. The Failsafe image provides absolutely minimal functionality with no access to transition into other modes. SPOC is considered to be in Safe Mode still. A “soft transition” into Safe Mode keeps the satellite in the current software image. Both scenarios require the ground segment to command the satellite out of Safe Mode.

If SPOC automatically transitions into Safe Mode, an error has occurred somewhere. The



mission operations team will utilize rehearsals, training, and the satellite user’s guide to deal with the situation and bring SPOC back into an operational state. This entails using the UHF transceiver to have constant contact with SPOC, as well as using the GPS to have accurate positional tracking data. A transition out of Safe Mode into Cruise Mode must be made by the mission operations team either during a pass or with a short-term schedule. GPS data for beaconing is polled every other beacon in order to remain power positive.

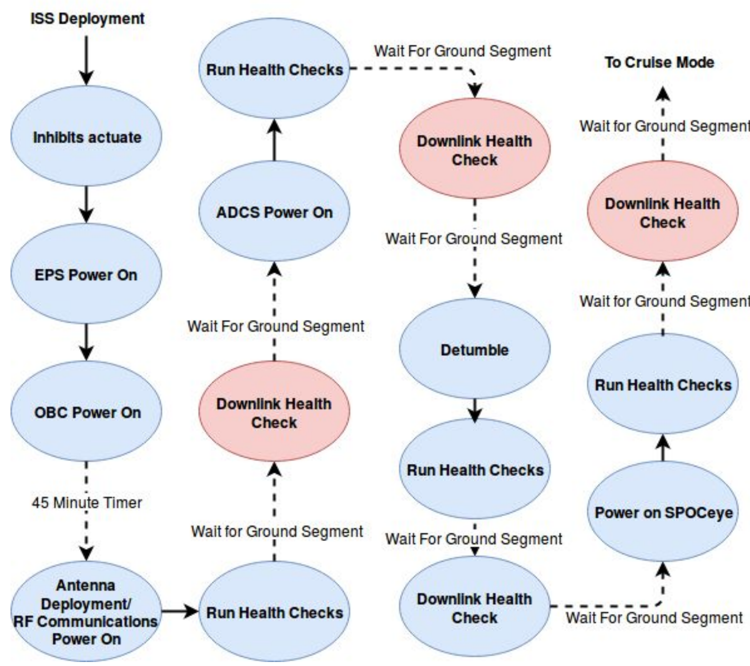
The most significant and nominal use of Safe Mode is for the Safe Boot/Reboot Sub-mode. This Sub-Mode is utilized in two situations. The first is when the satellite is first deployed, and the other is when a scheduled reboot occurs. SPOC shall have two flags to determine if it is a deployment scenario or a reboot scenario. The first flag is the deployable antenna responding whether it is deployed or not and the other is a software flag in the OBC. If either flag is activated, the satellite will perform a safe boot.

Special Safe Mode Operations

The Safe Boot Sub-mode assumes power just began to flow through the EPS. The OBC will boot and realize it is in Safe Boot Submode with the deployment flags activated. The OBC will then wait for 45 minutes and then it will deploy the antenna and ensure that the RF comms are functional. At this point, the satellite will begin to beacon every 15 seconds and listen between beacons. SPOC will remain in a tumbed state. When the Ground Segment hears SPOC's beacon, it will transmit instructions to spoc to transmit health and safety data to the ground. Once this is finished, the ground segment will tell SPOC to power the ADCS and run safety checks. Then those results are downlinked, SPOC will be allowed to detumble to a nadir orientation. After this, the ground segment will tell SPOC to power on and test SPOCeye. Once all that is downlinked to the ground segment, SPOC will be commanded to go to Cruise Mode.

If both flags are deactivated, SPOC will perform a reboot. With this, all above operations happen automatically. The satellite will power cycle the OBC and perform all of the above health checks in the order listed in the previous paragraph without downlinking health data or waiting on the ground segment.

Boot
Sub-Mode Flow
Deployment Scenerio



Frequency Utilization

SPOC will utilize S-Band and UHF spectrums to facilitate mission success. S-Band spectrum will be prioritized for raw data, intermediate end-products, and end-products. SPOC's S-Band will operate downlink-only. On the UHF spectrum, SPOC will operate half-duplex, with primary UHF downlinks for station identification and telemetry beaconing. The UHF spectrum will also serve as the sole method of housekeeping on SPOC.

The mission operations team will be developing a SPOC Beacon Portal, where amateur radio operators can download the provided software to decode received SPOC beacons. Amateur radio operators will be able to upload the raw beacon data to the portal, to ensure valid telemetry data. This will allow the mission operations team to have a more in-depth understanding of the health and activities of SPOC while not in line of sight. Although many prior missions have had good success with using amateur radio operators around the world, completing the mission is not jeopardized if amateur radio operator activity is low. Mission operations, scheduling, and executions are all designed so that the University of Georgia can act as the sole ground authority as necessary.

The SPOC mission licensure will be completed through the FCC, NOAA, and IARU. We require IARU coordination to operate on ameature bands. Then we will coordinate with NOAA to obtain a remote sensing license. Finally, we will obtain an FCC experimental license. After this occurs SPOC will be fully licensed to fly. Currently, we are working on the IARU coordination letter for permission to operate on ameature bands.

The licensing process is considered to be in progress. Additional information can be found in the SPOC Proof of Licensing.

CURRENT STATUS:

- IARU Coordination : In progress; Document finalization
- NOAA CRSRA License : In progress; Edits received
- FCC Experimental License : Not started

Mission Operations

SPOC is one of the first satellite missions for the University of Georgia and is a critical university and state resource which requires a high level of mission operations support. Mission operations best practices, thorough planning and rehearsal of nominal and anomalous operations, and stringent configuration management are all part of strong mission operations support. All operational schedules must be approved by the Mission Director prior to consideration for uplink. Flight Directors give direction and execution to mission console operators during pass operations. Flight Director 1 assumes Mission Director responsibilities when the Mission Director is not present.

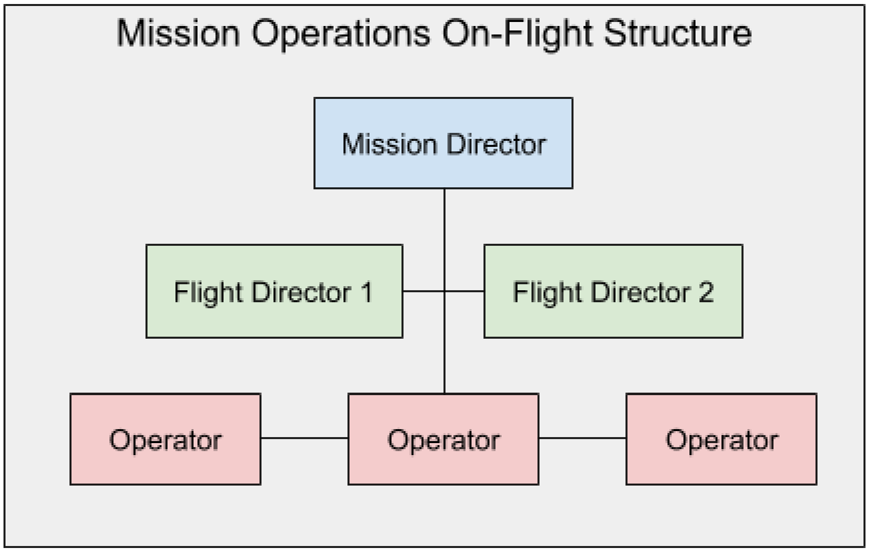


Figure In-Orbit Mission Operations Chain of Command

Because SPOC is a mission which is primarily led by students, mission operations consoles will not be staffed 24/7. However, mission operators will be scheduled to be on-call 24/7 to respond to any anomalous behavior. During regular operation hours (8 am - 10 pm), operators will execute any necessary spacecraft commands for housekeeping, monitor telemetry data for health performance, and respond to any real-time needs. Telemetry data will be made available to non-console mission operators for historical health trend analysis.

Engineering support on the mission operations team will ensure that spacecraft health data indicates continued safe operation. Maneuver planning, spacecraft and payload anomaly investigation, and payload calibration are among the advising responsibilities of the engineering support segment of the mission operations team.

The following are key points in the mission operations methodology applied to SPOC, along with appropriate flight rules:

Commanding

- All operational schedules require the approval of the Mission Director.
- Operational schedules are validated through the spacecraft simulator.
- Initial approval and validation of common operational sequences.
- Definition of critical command sets requiring additional special approval prior to transmission.
- Entry and exit criteria verification during operational schedule planning.
- Command procedures include documentation to the operator for execution and interpreting execution errors.
- Operational schedules accomplished using predefined time sequence for automatic scheduled transitions.
- Encrypted uplink and downlink in all cases.

Telemetry Monitoring and Trending

- Clear textual and graphical representation of telemetry and event messages.
- Ground system performance display for real-time monitoring.
- Analysis system permitting quick and simple access to near real-time and historical telemetry data.
- System permits data retrieval from web interface.

Routine Operations

Routine operations are those performed continuously by mission operators at consoles. These operations are supervised by Flight Directors.

- Monitor satellite telemetry for successful execution of commands.
- Monitor satellite telemetry for precursors to anomalous behavior.
- Take appropriate action to ensure continued operational safety in case of anomalous behavior.
- Ensure operational schedule continuity in case of ground system errors.
- Monitor the performance of ground systems.
- Creating and testing satellite schedules

Housekeeping Operations

Housekeeping operations are those which occur on a regular basis for maintenance of SPOC's basic functionality. Attitude management, clock maintenance, OBC management, or subsystem reconfigurations outside the scope of regular transitions are examples of housekeeping operations. Periodic payload calibration or maintenance is included in housekeeping operations. Mission scheduling will schedule periodic "outage" times where housekeeping operations will be performed with line-of-sight. It is estimated that monthly "outage" times will be required for payload adjustments.

Housekeeping operations are included in the notional flow of Data Downlink Mode. Scheduled housekeeping will occur within the auspices of this mode, as it allows for full use of the S-Band transmitter for high bandwidth operations. The Data Prep sub-mode during scheduled housekeeping will involve detailed batch telemetry, as requested in the onboard operational schedule. Basic housekeeping operations, such as uplinking new operational schedules, occurs near the end of end-data downlink passes.

Special Operations

Special operations are those that do not occur on a daily basis and are considered to be higher risk operations than other routine operations. These special operations will be supported by an engineering support team of appropriate disciplines. Operations like long-term attitude changes or complex maneuvers. Some known special operations are outlined below:

High Beta-Angle Operations

As discussed in the Deployment Mode section, SPOC will enter phases of its orbit where it will the sun for about a month. This is dangerous for the COTS parts in the payload, as they could overheat easily. When the orbital beta angle is either above 71° or below -71°, SPOC will re-orient so the Z+ faces the sun.

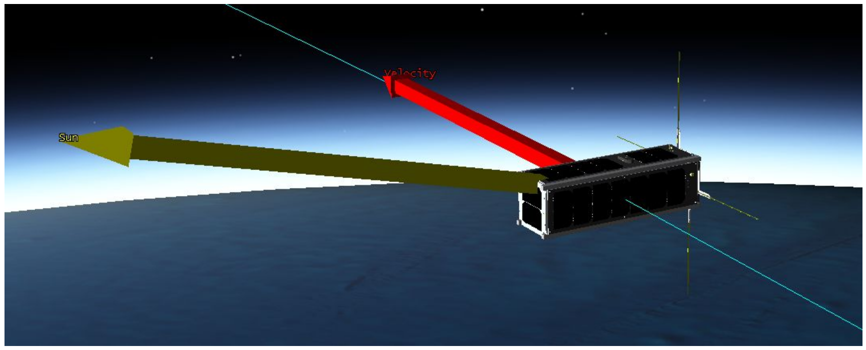


Figure 19: High Beta Angle Attitude

The above figure reiterates the required attitude. Power generation is extremely hampered and has repercussions across the operations of the satellite. First, periodic attitude adjustments to reveal the Y+ face to the sun will be required to maintain power levels. Second, on-board operations must be kept to a minimum, in order to minimize heat generation inside the satellite. Third, because the track of SPOC during this operation will have long shadows, the only data gathering to perform is with algal bloom/sediment plume tracking.

Although this operation has its own sub-mode, the higher risk nature and low occurrence warrants it as a special operation.

Low Beta-Angle Operations

Low orbital beta angles cause a deficiency in power generation when passing through the range of -5° to 5° in orbital beta angles. During these times, SPOC will rotate itself 45° around the Z-axis to reveal the X+ and Y+ solar panels to the sun. There are no operational restrictions, with the exception that SPOC will require additional time to slew into initial positions.

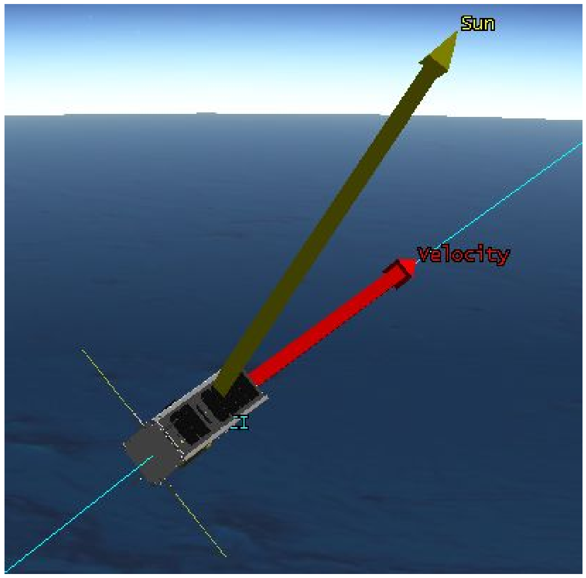


Figure 20: Low Beta Angle Attitude

Fine Sun Sensor Visibility Operations

Due to the nature of SPOC's orbit, the primary "Y-axis" which sees the sun changes every time SPOC travels through an orbital beta angle of 0°. Because our hardware architecture only uses 2 orthogonal fine sun sensors, the Z-face which faces prograde will change at the crossing of 0°. When the beta angle is positive the Z- face will face prograde. When the beta angle is negative, the Z+ face will face prograde.

Weekly OBC Reboot

To meet radiation mitigation requirements, the OBC will be rebooted weekly. This will be performed during regular housekeeping to ensure safe operations after the reboot operation. Contact with the ground station will need to be maintained during the operation in order to switch the operating system image from the Failsafe image to the primary image.

Anomaly Operations

Anomaly operations occur when SPOC experiences a failure or degradation which affects system performance and nominal operations. Anomalies can be sudden, causing the OBC to reboot, or they can be gradual and noticed with engineering telemetry trend analysis. Onboard error detection from Bright Ascension software will rectify most small anomalies automatically. These kind of anomalies are considered Level 1 anomalies. Any error which Bright Ascension safely ignores are considered Level 0 anomalies. Anomaly reports will be generated onboard the satellite as needed and will be downlinked during housekeeping and analyzed by the mission operations engineering support team. Generating anomaly trend data is an important aspect of this. Extensive documentation in anomaly investigations will be generated.

For cases where the Bright Ascension software is unable to rectify an issue on its own and or SPOC requires mission operations intervention, SPOC will safely transition into Safe Mode. Safe Mode allows for long-term attitude control in a power-positive state, all while maintaining ground communication. The mission operations team will respond as rehearsed to the anomaly. Recovery into Cruise Mode requires a significant amount of checkouts and simulation on the ground. This is considered a Level 2 anomaly.

In cases where a critical and rapid hardware error has occurred, where the OBC has been forced to reboot, SPOC will enter Safe Mode, but will boot into a Failsafe image. With the Failsafe image booted, SPOC will maintain ground communication and power-positive state. This is considered a Level 3 anomaly, and mission operators will respond accordingly. A recovery from a Level 3 anomaly into Cruise Mode requires much more work than a Level 2, and involves deep hardware diagnoses.

Anomaly Level	Description
Level 0	Bright Ascension recognizes error, does not fix, logged
Level 1	Bright Ascension recognizes error, attempts fix, logged
Level 2	Satellite in Safe Mode and Primary Boot Image
Level 3	Satellite in Safe Mode and Failsafe Boot Image

Eclipse

SPOC's operations are limited when in eclipse because SPOC will lose its ability to point-track. SPOC only has sun sensors for fine attitude knowledge and with no knowledge comes no pointing ability. Data Transmission over S-Band cannot occur when in eclipse. Scan Mode is unable to occur in eclipse, as sunlight is required.

Flight Software

Flight software can be periodically updated through uplink of either a new software image or re-configuration of configurable value onboard. Before transmitting any software adjustments, rigorous testing on the ground will be performed.

Flight Rules

SPOC Flight Rules	
SFR-1	Spacecraft cannot downlink data when in eclipse.

SFR-2	Payload cannot look directly at sun.
SFR-3	Permission from Mission Director is required for manual transition into Safe Mode.
SFR-4	Software updates will only occur if another pass occurs within 100 minutes.
SFR-5	Weekly “outage” housekeeping passes need to be open-ended and controlled by ground operations.
SFR-6	Batteries shall not exceed 20% depth of discharge during operations.

End-Of-Life Decommissioning

FCC rules dictate that satellite missions be deorbited within 25 years of termination of the primary mission. Although SPOC’s orbital lifetime is projected to be around 1.5 years, proper disposal ope rations need to occur. If SPOC needs to be decommissioned prior to natural decay, the decommissioning process will aim to increase the rate of orbital decay by placing the Y- face in the prograde direction.

Scheduling/Mission Planning

Routine and special operations planning of SPOC will use an operational schedule process. Using a relative time counter onboard, time-based triggers will start the transition in and out of different modes and sub-modes. The operational schedules may be planned a month in advance of their respective start date. However, creating operation schedules occurs on a weekly basis, with SPOC having a new operational schedule uplinked every week. Thus, the schedule uplinked for any given week may have entered development as early as a month prior. Mission planning and scheduling will use spacecraft simulators, like STK, to predict out the operation of SPOC.

To support mission agility and “just-in-time” operations, operational schedules can be changed at any time when there is line-of-sight with the ground station. This will also add support for rapid changing conditions for algal bloom/sediment plume tracking.

Schedules onboard SPOC will have 7-day nominal operational schedule, with a 14-day contingency operational schedule. The contingency schedule enables SPOC to continue acquiring data despite any possible ground station anomalies.

The mission operations team will be cognizant of scheduling concerns using the VirtualSat software suite developed by UGA SSRL. Although primarily a development tool during software development and debugging, the VirtualSat software suite will be able to be used for operational scheduling, giving mission planners an overview of spacecraft systems, dependent on certain schedules. The VirtualSat software suite is currently being planned.