Concept of Operations in Small Satellite Functionality

Spectral Ocean Color (SPOC) & Multi-view Onboard Computational Imager Satellite (MOCI)

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Abstract

The University of Georgia Small Satellite Research Laboratory (SSRL) is developing UGA's first Small Satellites. The Spectral Ocean Color satellite (SPOC), developed as part of NASA's Undergraduate Student Instrument Project (USIP), aims to acquire moderate resolution spectral imagery of different coastlines, rivers, and estuaries (namely Sapelo Island) to research ocean productivity, vegetation health, estuarine water quality, and more for the UGA Geography Department. Although SPOC will be deployed first, it is being developed in parallel with the Multi-view Onboard Computational Imager (MOCI) as part of the Air Force University Nanosatellite Program (UNP). The MOCI mission seeks to utilize the Structure from Motion method to map various Earth landscapes from Low Earth Orbit (LEO). In addition, MOCI will map algal blooms and sediment plumes.

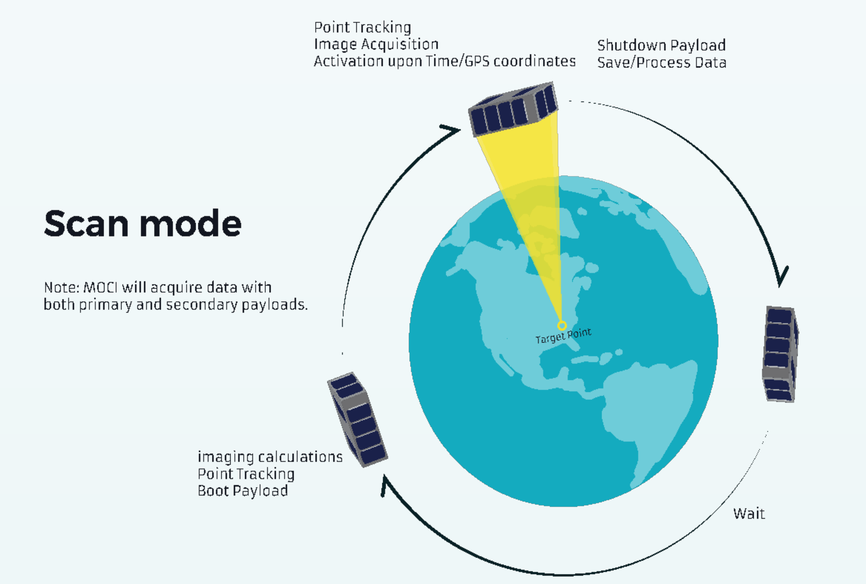
Through this research, the SSRL aims to development efficient satellite operation that can react to the various environments of space, as well any errors that may occur. The satellite should be able to operate completely autonomously, and manually at the broadest level of operation; Modes. Dependent upon its location and current objective, the satellite will operate under a specific Mode that is geared towards this objective. While the satellite should transition between each Mode manually, functionality within the Mode should be autonomous. Satellite operation is defined precisely to the machine component level. By analyzing the anticipated mission life of each satellite, we attempt to develop a foundation of intelligent satellite operation for future missions to come.

Importance

A successful Small Satellite mission requires a practical theory of operation, the Concept of Operations (ConOps), that accounts for all functionality that may occur throughout the lifetime of a satellite. The main purpose of the ConOps is to act as a template for both the satellite operation and the core logic/code that the satellite operates from. The ConOps document should detail how the satellite will function according to a primary objective and its mission criteria. This function is defined by an operation structure that caters to straightforward, sequential, goal-based operation. Although the ConOps is definitive at a broad level of operation, it should also detail satellite operation to a machine component level. As the satellite mission is developed over time, the Concept of Operations is adjusted to satisfy intended satellite operation and feasible Software Architecture. Although the ConOps document is to be fully defined by the time of launch, it should be subject to change upon emergency. A good ConOps document should be one that is both adaptable and easily understood by the user. A poorly defined ConOps can result in major satellite malfunction, or even mission failure.

Functionality Architecture

Satellite operation is defined at the most basic level by the Mode; a general functionality tree that defines which Tasks can be performed at a given point to satisfy logic and command-defined goals. In addition, for each Mode, a Day in the Life visual representation is given. An example of such a Mode would be the Scan Mode, in which the satellite seeks to image a specific target (Figure 1). Mode transitions are manual. A Mode is comprised of many Sub-modes; a unique set of Tasks that further define each individual goal within a Mode (Figure 2). In addition, for every Mode, a table of descriptions for each Sub-mode is given (Figure 3).



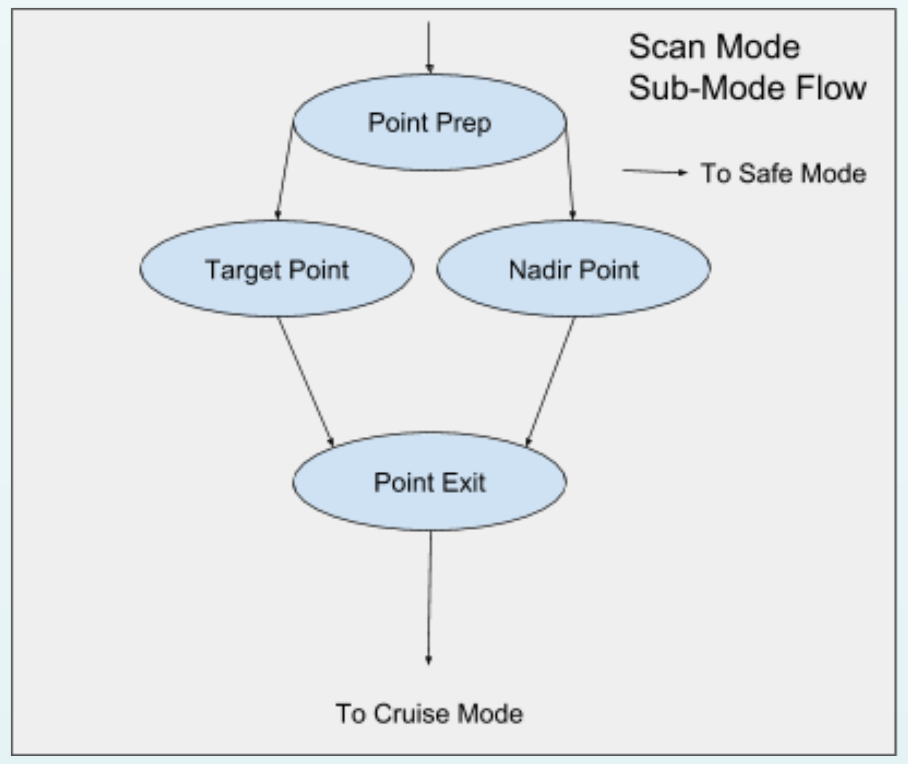


Figure 2

Sub-modes are executed autonomously, and sequentially. Tasks, which comprise Sub-modes, are specific activities that are performed via actions to achieve the purpose of the Sub-mode. In this case, the satellite has a set of 'instructions' to perform autonomously. The satellite performs a function until a specific exit criteria is met, to which a new assignment is given (Figure 2). Operation ceases only upon a forced manual command, of if there is a major error that would put the satellite in an emergency safe state.

Scan Mode Sub-Modes	Description
Point Prep	Orients satellite, boots payload, loads acquisition parameters
Target Point	Slews satellite, executes image acquisitions
Nadir Point	Acquires algal & sediment data, tags data
Point Exit	Returns satellite to nominal attitude, tags data

Figure 3

Operational Description

The MOCI Satellite seeks to utilize Structure from Motion (SfM) in order map various Earth landscapes from Low Earth Orbit (LEO). After an intended launch date of approximately Q4 of 2019, MOCI is deployed from the International Space Station. Following deployment, MOCI stays idle for about 45 minutes, collecting telemetry and health check data. Following this 45 minutes, MOCI detumbles and deploys in antennas. After successful communication with the ground station, MOCI exits Deployment Mode and enters Cruise Mode. MOCI then transitions to Scan Mode where it points toward a ground target and images the target area according to specific imaging criteria. After a set predetermined period of time, MOCI exits Scan Mode and transitions to Cruise, and then to Data Processing Mode where the satellite performs Structure from Motion on the newly acquired imaging data. MOCI then transitions back to Cruise, and then to Data Downlink to communicate with the S-Band ground station to downlink processed data. This nominal operational timeline can be found in Figure 3.

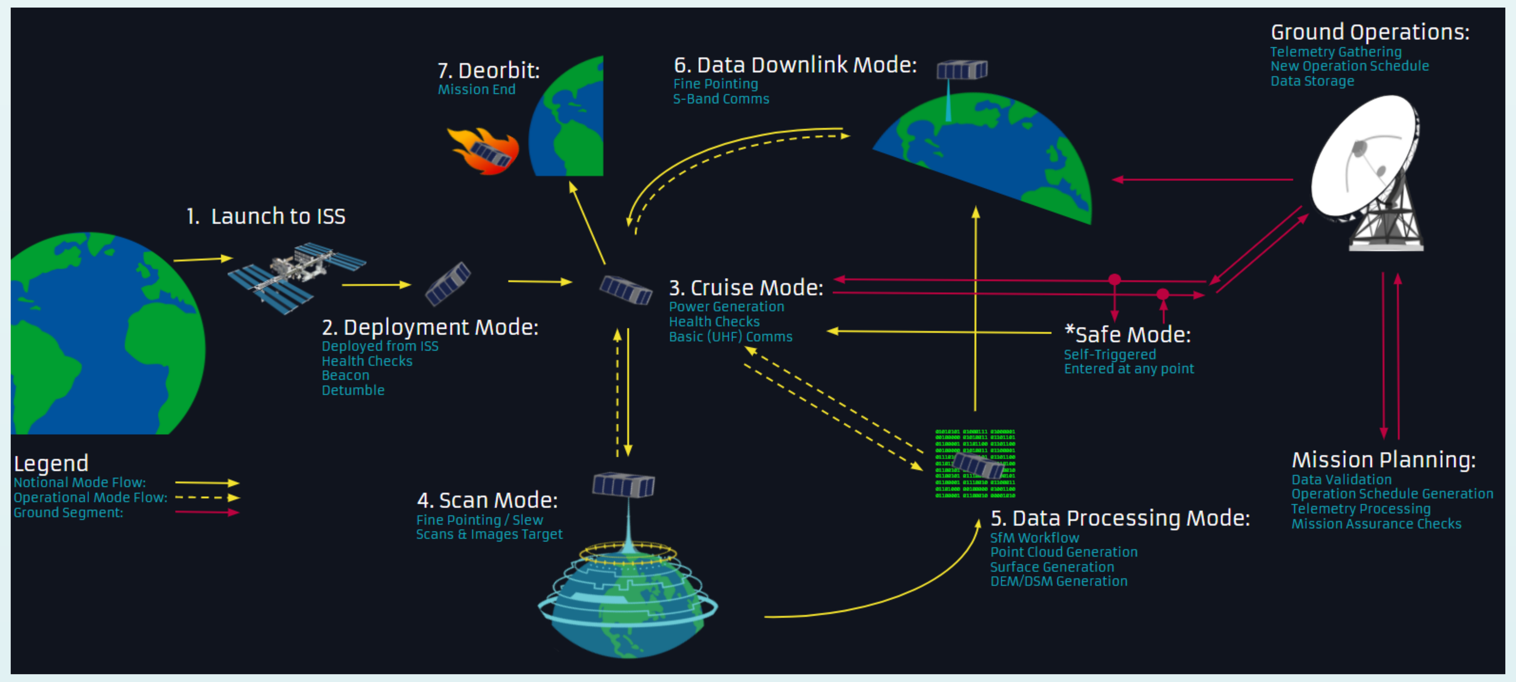


Figure 3

Future Work

The primary focus of this research is to develop efficient satellite operation that can react to the various environments of space. As the SSRL continues to build a permanent presence in Space, the Concept of Operations will be developed as the foundation of all our satellite operation. Satellite functionality will be under constant refinement as more missions are launched. In this, we aim to develop operation structure that is most reliable and efficient for all future satellites.

For more information about CubeSats, the Small Satellite Research Laboratory (SSRL), our missions, visit www.smallsat.uga.edu.

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