Concept of Operations in Small Satellite Functionality

Spectral Ocean Color (SPOC) & Multi-view Onboard Computing Imager Satellite (M

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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 Computing 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.

Concept of Operations Development

As the SSRL has developed since its beginning in mid-2016, the Concept of Operations has moved primarily from automatic-conditional functionality to that of a methodical functionality that is operated manually at the most basic level of functionality. In this automatic-conditional operation the satellite is 'equipped' with many different functions that it is able perform, such as "Detumble" or "Nadir Point". At any given point, the satellite accesses its current state, and decides which function to perform given certain criteria that pertain to its current state and limited available resources. Furthermore, the list of functions that it can perform are prioritized in an "ideal" order. The machine component level of operation is illustrated by a State Table that defines which machine components are on/off in each Task (Figure 1).

	Scan Mode													
	Command		Detumble		Data Acquisition Nadir				Shut-Down			Data Process		
	VH	BT	VH	BT	VH	BT	DA	NP	VH	BT	SP	VH	BT	DP
SPOC-Eye	Off	Off	Off	Off	Off	Off	On	Off	Off	Off	On/Off	Off	Off	On
Interface Board	Off	Off	Off	Off	Off	Off	On	Off	Off	Off	On/Off	Off	Off	On
Clyde OBC	On	On	On	On	On	On	On	On	On	On	On	On	On	On
40 Whr Batt.	On	On	On	On	On	On	On	On	On	On	On	On	On	On
EPS Motherboard	On	On	On	On	On	On	On	On	On	On	On	On	On	On
Solar Panels	On	On	On	On	On	On	On	On	On	On	On	On	On	On
VHF TRX Clyde	On	Off	On	Off	On	Off	Off	Off	On	Off	Off	On	Off	Off
UHF TRX Clyde	Off	On	Off	On	Off	On	Off	Off	Off	On	Off	Off	On	Off
S-Band TX	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
ISIS VHF Antenna	On	Off	On	Off	On	Off	Off	Off	On	Off	Off	On	Off	Off
ISIS UHF Antenna	Off	On	Off	On	Off	On	Off	Off	Off	On	Off	Off	On	Off
S-Band Patch	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
3-axis Reaction Wheels	Off	Off	Off	Off	Off	Off	Off	On	Off	Off	Off	Off	Off	Off
ADCS Motherboard	Off	Off	Off	Off	Off	Off	Off	On	Off	Off	Off	Off	Off	Off
Nanosat Fine Sun Sensor	Off	Off	Off	Off	Off	Off	Off	On	Off	Off	Off	Off	Off	Off
xy MTQ Motherboard	Off	Off	Off	Off	Off	Off	Off	On	Off	Off	Off	Off	Off	Off
z MTQ Motherboard	Off	Off	Off	Off	Off	Off	Off	On	Off	Off	Off	Off	Off	Off
xy MTQs	Off	Off	Off	Off	Off	Off	Off	On	Off	Off	Off	Off	Off	Off
z MTQs	Off	Off	Off	Off	Off	Off	Off	On	Off	Off	Off	Off	Off	Off

Figure 1

After attempting to solidify the ConOps structure we found that such a structure would yield a tremendous amount of operation permutations, and that a new prioritized operation list would be extremely difficult to determine after the initial list is broken, given that satellite operation is not perfect. After a Software Architecture merger, ConOps was redefined to methodical operation.

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.

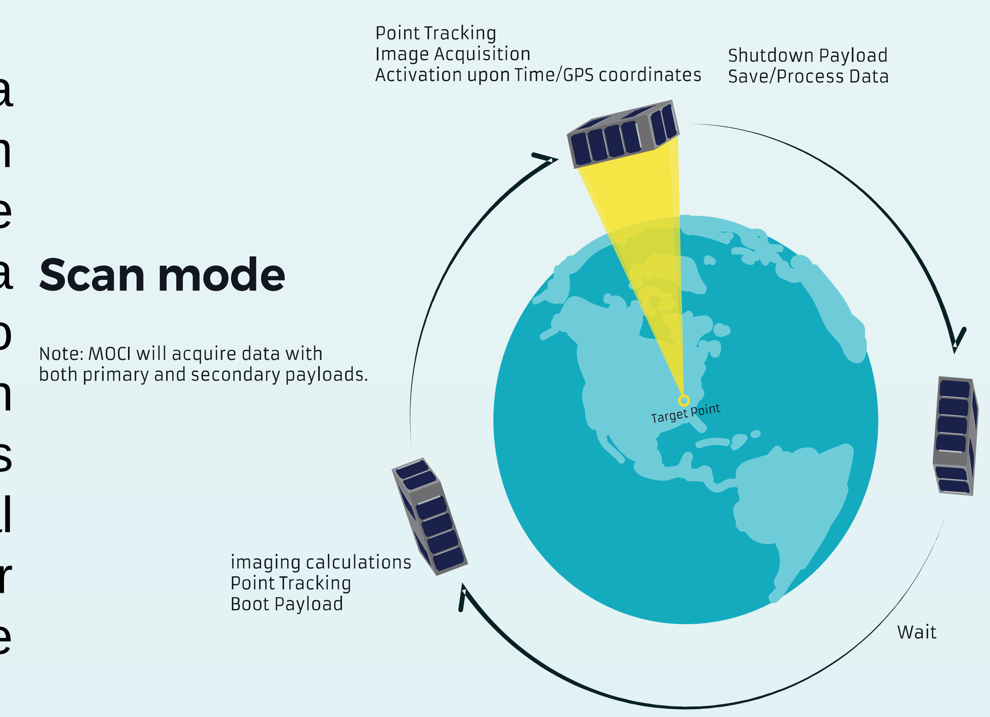

Figure 2

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 (Figure 3). An example of such a Mode would be the Scan Mode, in which the satellite seeks to image a specific target (Figure 4). 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 5). 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. Tasks occur autonomously and sequentially. Satellite operation at a Task level is defined by several Sequences of Sub-tasks. Sub-tasks are defined by 4 Sub-tasks, one for each Sub-system (ADCS, EPS, Payload, Communications). Sub-tasks occur concurrently.

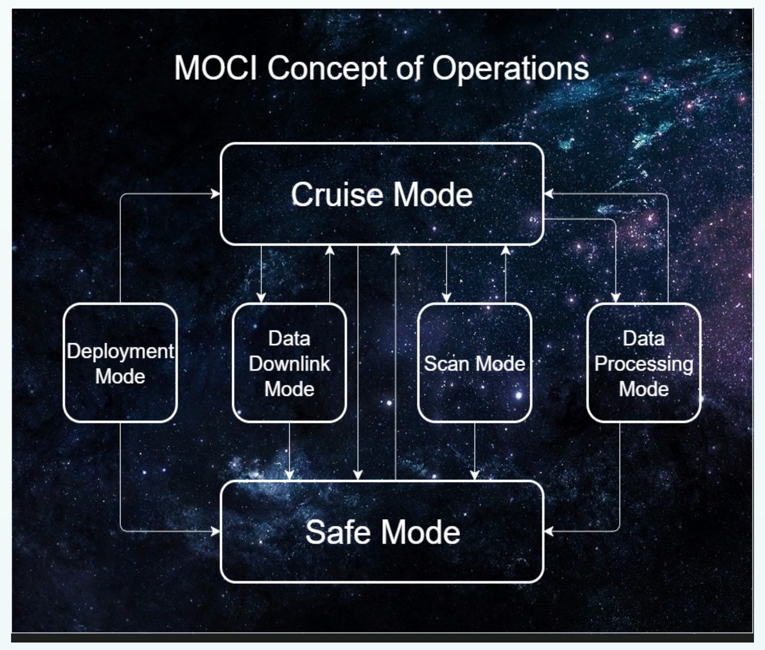

Figure 3

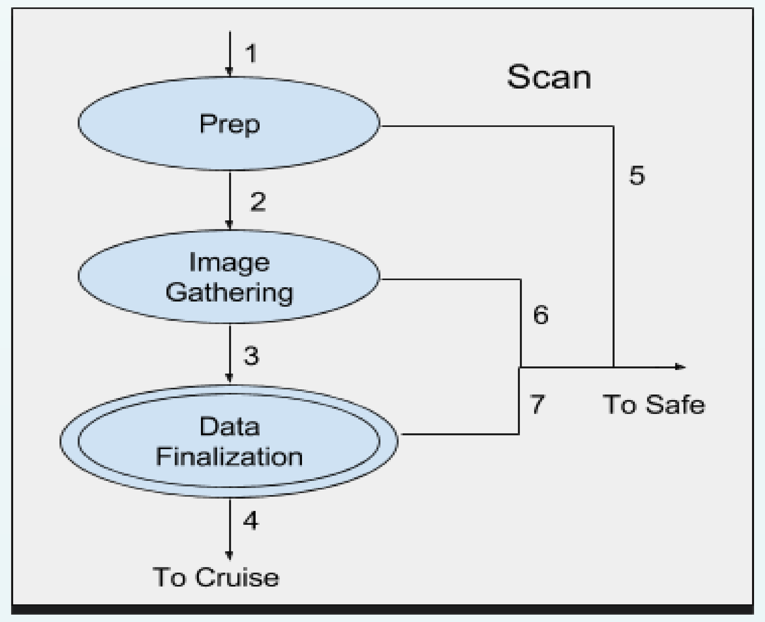

Figure 4

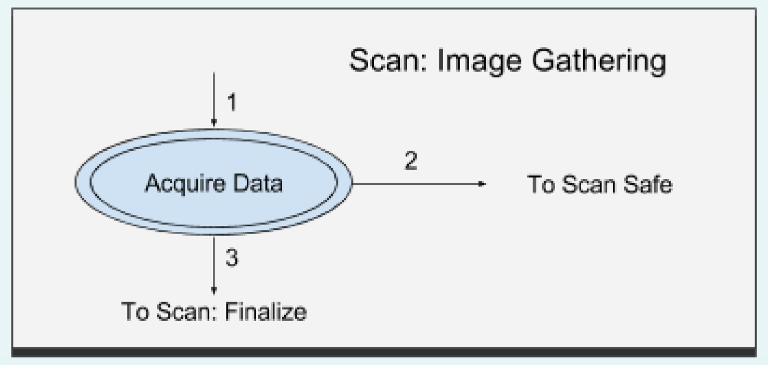

Figure 5

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.