Development of UCLA ELFIN CubeSat Mission Operations Software

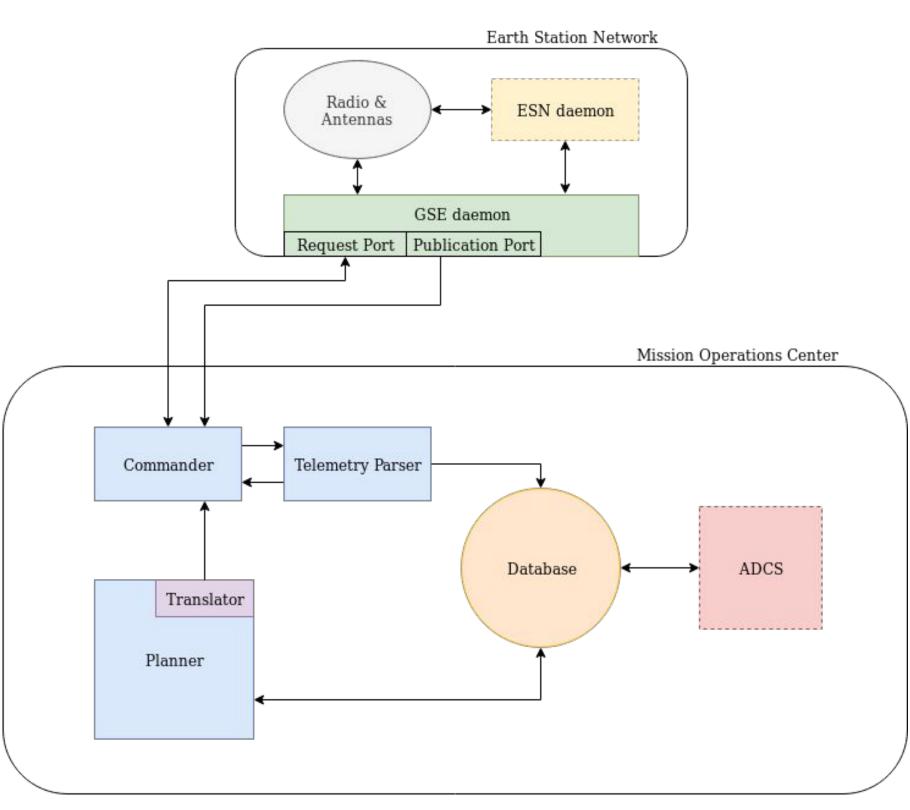
Jason Mao (jmmp8@ucla.edu), Vassilis Angelopoulos, Ethan Tsai, Akhil Palla, Daniel Schwartz, Chanel Young, Sharvani Jha, Austin Norris, Andrew Evans, Koji Kusumi

Abstract

The Electron Losses and Fields Investigation (ELFIN) is a student run cubesat project at UCLA with a pair of spin stabilized 3U+ cubesat currently in LEO, each using three custom scientific instruments to study precipitating electrons and correlating them with EMIC waves. Due to heavy constraints on instrument commanding and power consumption, most of the flight software is necessarily custom made and low in computational power; prebuilt control systems are incapable or ineffective at interfacing with the low level procedures of the flight computer, so most of the ground software is analogously custom.

ELFIN ground control software is a suite of python modules working in tandem to assist satellite operators by turning logical commands into radio messages for the flight computer as well as receive, parse, and store satellite responses. A high degree of automation is also included to accommodate for the varying availability of student operators. We present the design, methodology, and lessons learned for future CubeSat applications.

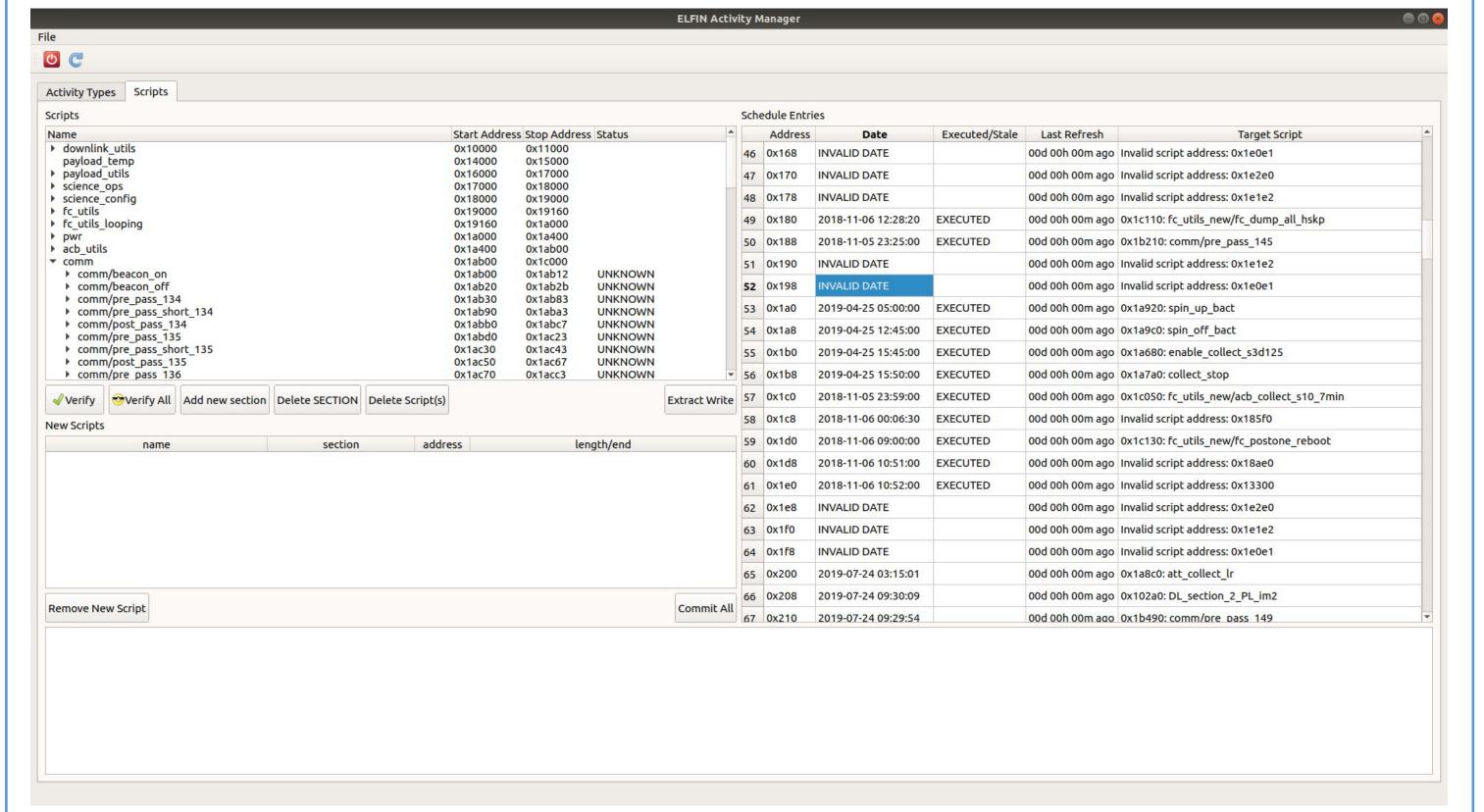
At a Glance

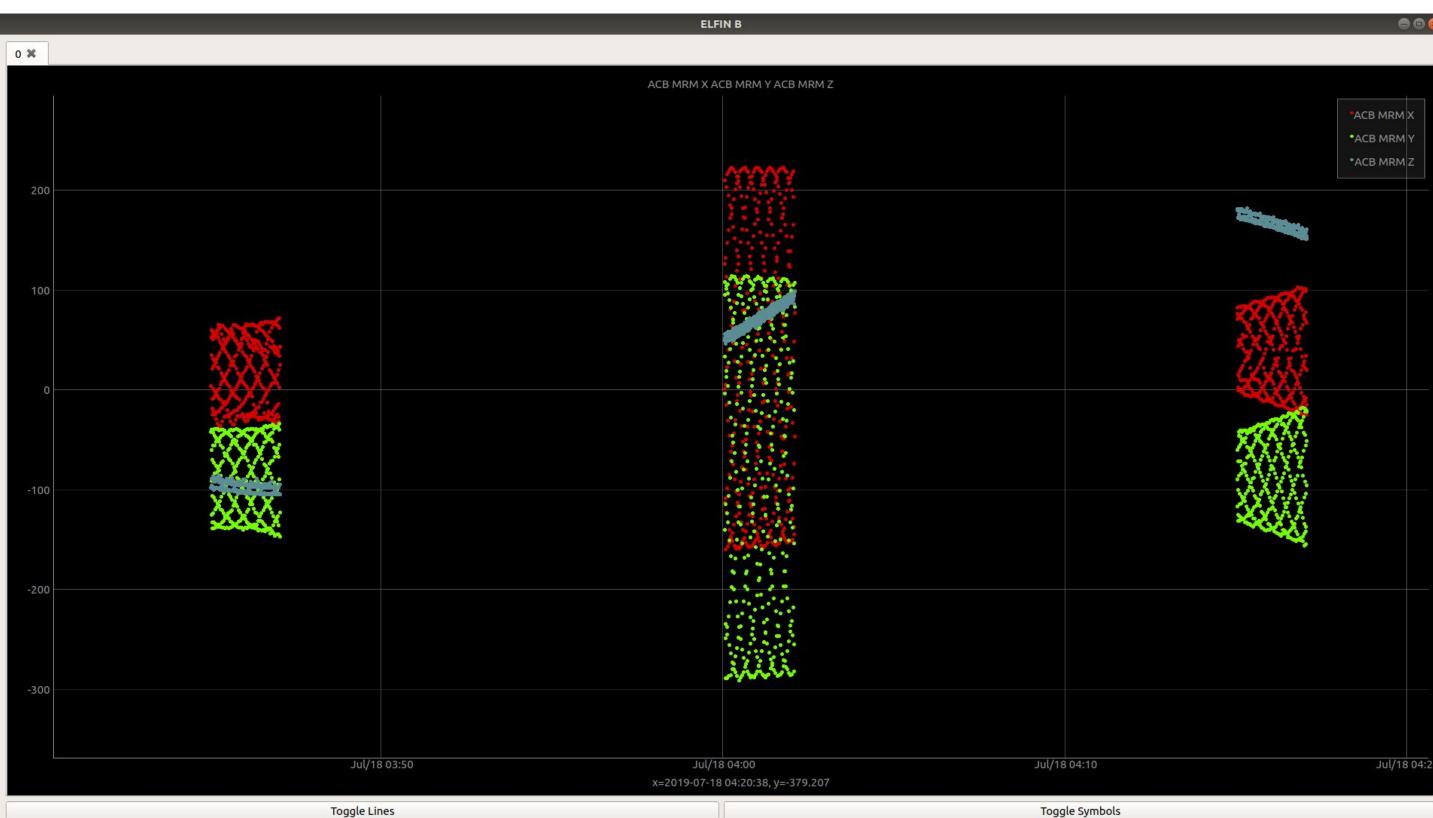


ELFIN software diagram. ADCS and ESN segments are condensed to blackbox representations. Two instances of the Commander, Telemetry Parser and Planner are used concurrently - one for each of the two ELFIN satellites.

- User Interface for commanding and planning
- Server-side command automation
- Real-time telemetry parser and graphing
- Central database for storing state and planning information
- Interconnection with ADCS and ESN segments for automation and maneuvers
- Server published state information to ensure consistent operations across multiple modules

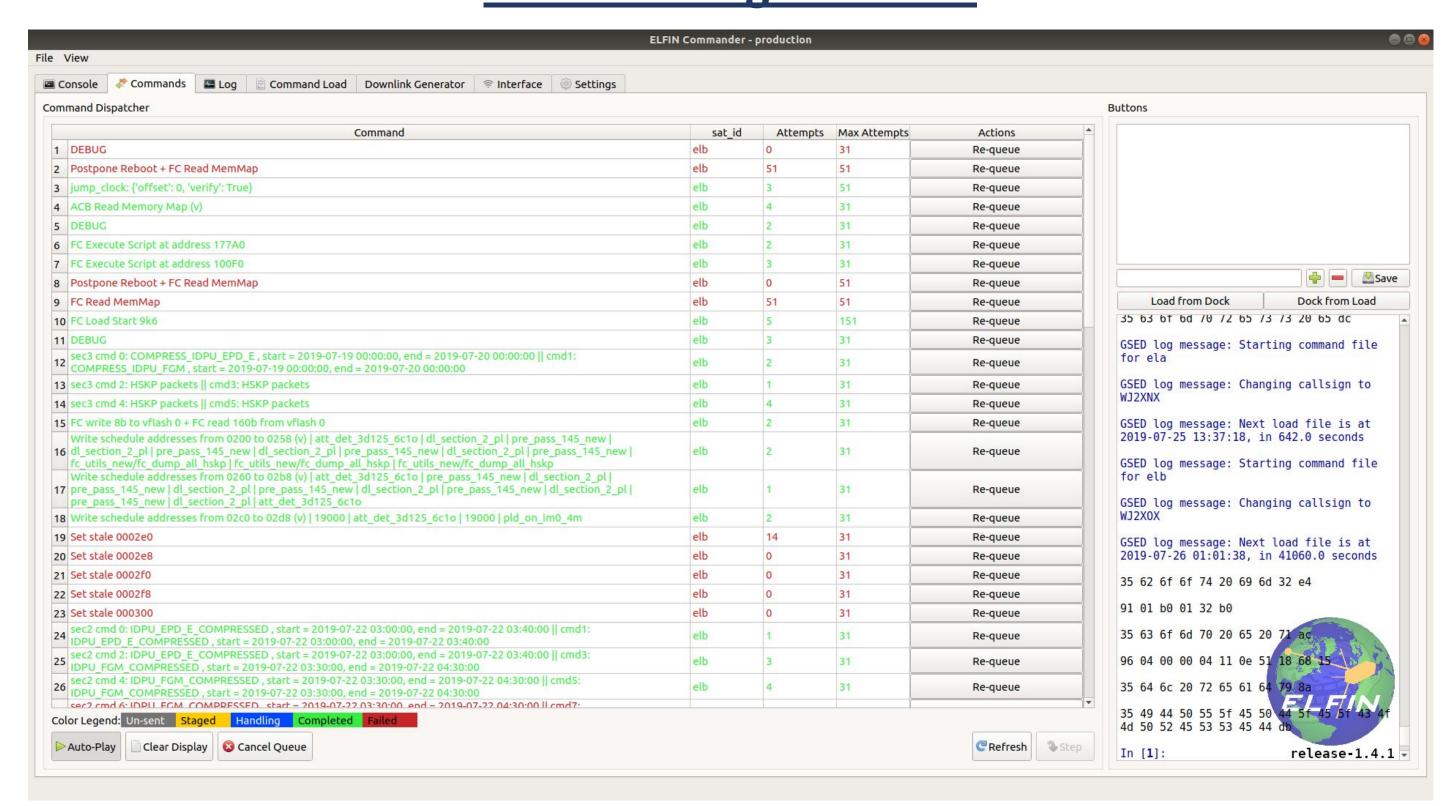
Telemetry Information





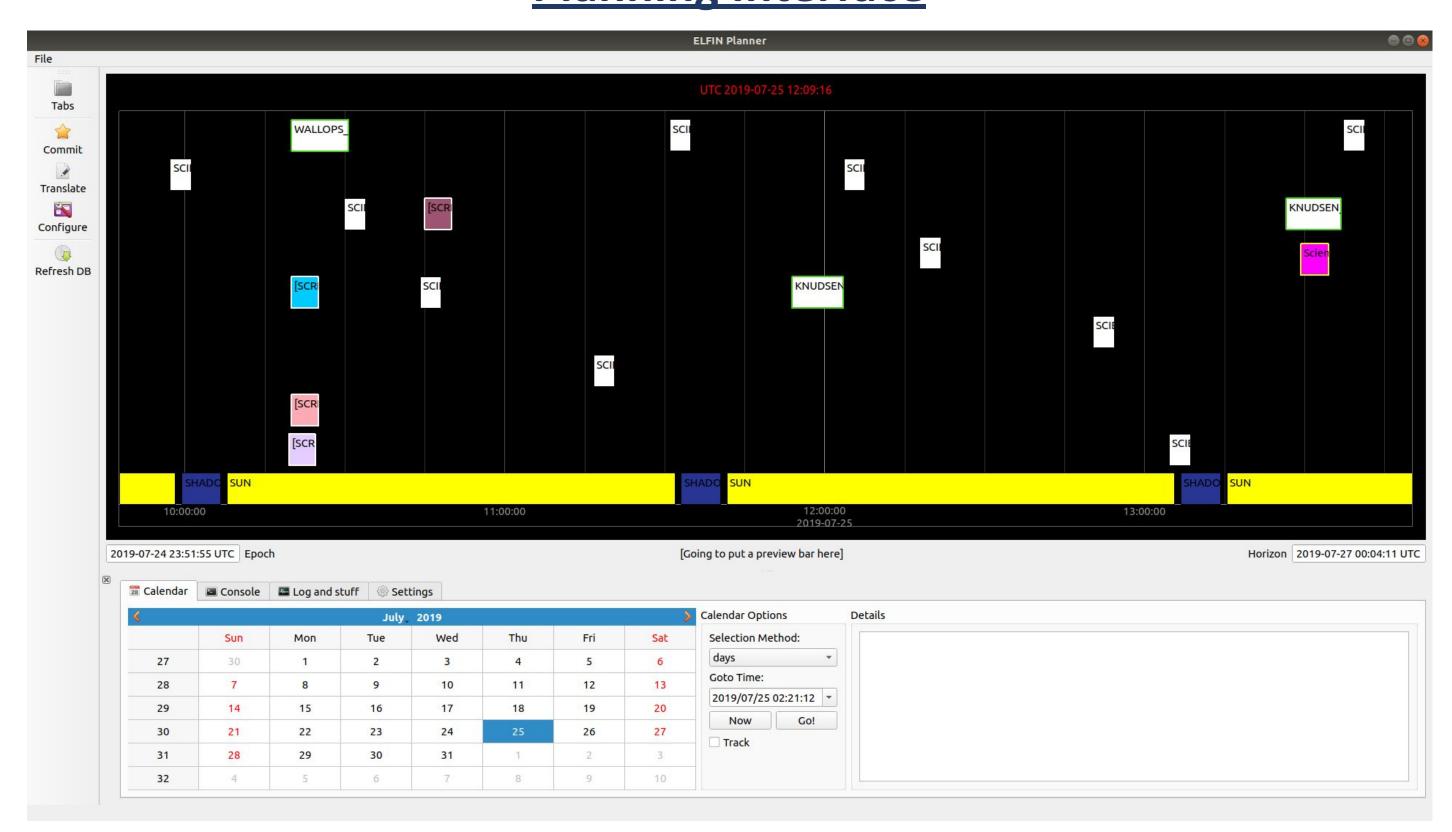
Above: State information displaying state on on-board scripts and scheduled executions. Updated in real-time. Below: Plotted magnetometer data from the Attitude Control Board (ACB) MagnetoResistiveMagnetometers (MRM).

Commanding Interface



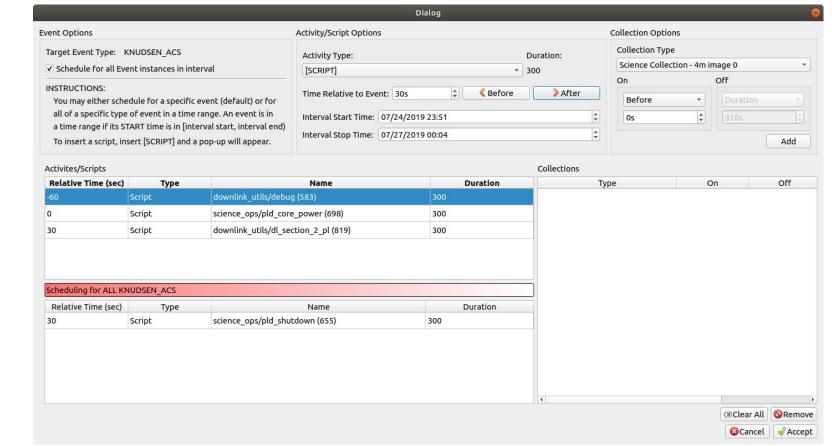
List of currently and previously sent commands. Commands may be constructed and queued for sending via the embedded python terminal. The commanding interface also contains elements to modify ESN/GSE daemon server settings

Planning Interface



Long term planning via inserting downlinks, data collection, script executions, or ADCS maneuvers into the interactive timeline displayed above. Multiple planned activities may be added relative to specific orbital events.

A translation module turns these logical activities into direct satellite commands.



Automation

Command automation is achieved by pre-uploading a timestamped list of commands to the GSE daemon server.

The commands will be parsed and executed reaching the timestamp, corresponding the start of a communication pass.

				cerngs										
Reload Passes	timestamp			descri	iption			bytes	delay after	retries	timeout	A	Load	
Upcoming Passes (Orbit Number)	1 None	Postpone Reboot + FC Read MemMap						N/A, special comman	d 5000	50	3500		Scriptif	
▶ 4800: Thu 2019-07-25 00:03:49	2 None	jump_clock: {'offset': 0, 'verify': True}					N/A, special command	d 5000	50	3500		◎ Delete		
▼ 4801: Thu 2019-07-25 01:36:29 duration: 10min 8sec	3 None	ACB Read Memory Map (v)						N/A, special comman	d 5000	30	5000		Extract Comi	
elevation: 24.242 4807: Thu 2019-07-25 12:03:49	4 None	DEBUG						b'\x06\x01\x00\x00'	10000	30	3500		ttract com	
 4808: Thu 2019-07-25 13:37:18 4815: Thu 2019-07-25 23:30:55 	5 None	FC Execute Scri	FC Execute Script at address 177A0 b'\x06\x01w\xa0' 30000 30 3500											
▶ 4816: Fri 2019-07-26 01:01:38	6 None	Echo comp fgm q + IDPU 2 packet count from @2019-07-25 18:00:00 to @2019-07-25 20:00:00 N/A, special command 5000								30	3500			
 4817: Fri 2019-07-26 02:37:28 4822: Fri 2019-07-26 11:30:34 	7 None	FC Dump UART1 (v) N/A, special comisect cmd 0: IDPU_FGM_COMPRESSED , start = 2019-07-25 18:00:00, end = 2019-07-25 20:00:00 cmd1: N/A, special comisect cmd 0: IDPU_FGM_COMPRESSED , start = 2019-07-25 18:00:00, end = 2019-07-25 20:00:00 cmd1: N/A, special comisect cmd 0: IDPU_FGM_COMPRESSED , start = 2019-07-25 18:00:00, end = 2019-07-25 20:00:00 cmd1: N/A, special comisect cmd 0: IDPU_FGM_COMPRESSED , start = 2019-07-25 18:00:00, end = 2019-07-25 20:00:00 cmd1: N/A, special comisect cmd 0: IDPU_FGM_COMPRESSED , start = 2019-07-25 18:00:00, end = 2019-07-25 20:00:00 cmd1: N/A, special comisect cmd 0: IDPU_FGM_COMPRESSED , start = 2019-07-25 18:00:00, end = 2019-07-25 20:00:00 cmd1: N/A, special comisect cmd 0: IDPU_FGM_COMPRESSED cmd1: N/A, special cmd 0: IDPU_FGM_COMPRESSED							(2) (1) (2) (3) (3) (4) (4)	30	3500		A	
 4823: Fri 2019-07-26 13:01:55 4831: Sat 2019-07-27 00:27:10 	8 None									30	3500	-11-	×	
▶ 4832: Sat 2019-07-27 02:01:02	9 None	sec1 cmd 2: IDPU FGM COMPRESSED , start = 2019-07-25 18:00:00, end = 2019-07-25 20:00:00 cmd3:									3500			
 4837: Sat 2019-07-27 10:59:36 4838: Sat 2019-07-27 12:27:15 	10 None	7.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0	sec1 cmd 4: IDPU FGM COMPRESSED, start = 2019-07-25 18:00:00, end = 2019-07-25 20:00:00 cmd5:						* Open Register (1997) (Sept. 1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (1997) (3500	-		
 4839: Sat 2019-07-27 14:02:49 4846: Sat 2019-07-27 23:53:14 4847: Sun 2019-07-28 01:25:44 4853: Sun 2019-07-28 11:53:15 4854: Sun 2019-07-28 13:26:28 4861: Sun 2019-07-28 23:20:38 	(C)	11 None sec1 cmd 6: IDPU FGM COMPRESSED , start = 2019-07-25 18:00:00, end = 2019-07-25 20:00:00 cmd7						A LONG TO A STATE OF THE PROPERTY OF THE PROPE		30	3500	-		
		12 None sec1 cmd 8: IDPU FGM COMPRESSED , start = 2019-07-25 18:00:00, end = 2019-07-25 20:00:00 cmd9: N/A, special coi								30	3500		Save	
	13 None								00\xf0' 3500 30 3500				Export	
Timestamp	Fi	lename	Spacecraft	Time Until	Abort	Timestamp		Filename			Status	A		
1 2019-07-26 01:01:38	server/loads/elb_48	16.load	elb	04hr 44min		18 2019-07-20_13:13:03		ela_4731.load			Fin	ished		
					Force	19 2019-07	-20_13:23:18	elb_4	elb_4731.load		Fin	ished	□ □	
						20 2019-07	-21_00:38:24	ela_4	739.load		Fin	ished	■ D	
						21 2019-07	-21_00:48:24	elb_4	379.load		Fin	ished		
						22 2019-07	-21_02:12:06	ela_4	740.load		Fin	ished	€ Re	
						23 2019-07	-21_12:38:26	ela_4	746.load		Fin	ished		
						24 2019-07	-21_12:49:00	elb_4	746.load		Fin	ished		
						25 2019-07	-22_01:36:51	ela_4	755.load		Fin	ished		
						26 2019-07	-22_01:47:10	elb_4	755.load		Fin	ished		
						27 2019-07	-22_12:04:30	ela_4	761.load		Fin	ished		
						28 2019-07	-22_12:14:20	elb_4	761.load		Fin	ished		
						29 2019-07	-22 13:37:29	ela 4	762.load		Fin	ished		
						2, 20., 0.			70211000				_	

Future Considerations

Further improvement to the software include more advanced and automated planning capabilities. Specifically, constraint checks on filesystem space, collection processing to downlink pipelines, and de-conflicting collection times. We hope that developers of mission operations software for future missions may take into considerations the methods we used for automation, planning, and command handling and apply them to their own challenges.

Contact

ELFIN: https://elfin.igpp.ucla.edu/
Author (Jason Mao): jmmp8@ucla.edu/





