Georgia Tech

Lightsey Research Group Overview

Presentation to Space Systems Design Lab
September 21, 2021

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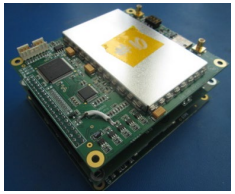
Georgia Tech Space Systems Design Laboratory

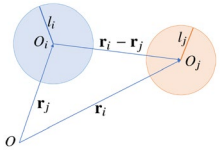
Getting From Here to There in a Small Form Factor …and All That Enables

Navigation:
Where Am I?



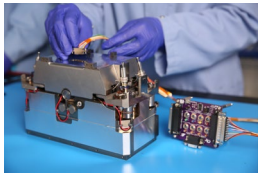
Software Defined Radionavigation
Reduced Infrastructure Navigation

Autonomous Formations
Proximity Operations



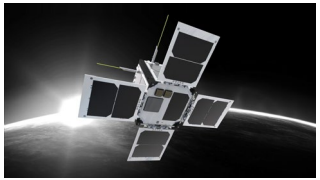
Guidance:
Where Do I Want to Be?

Control/Actuation:
How Can I Get There?



Small Satellite Propulsion
Attitude Determination & Control

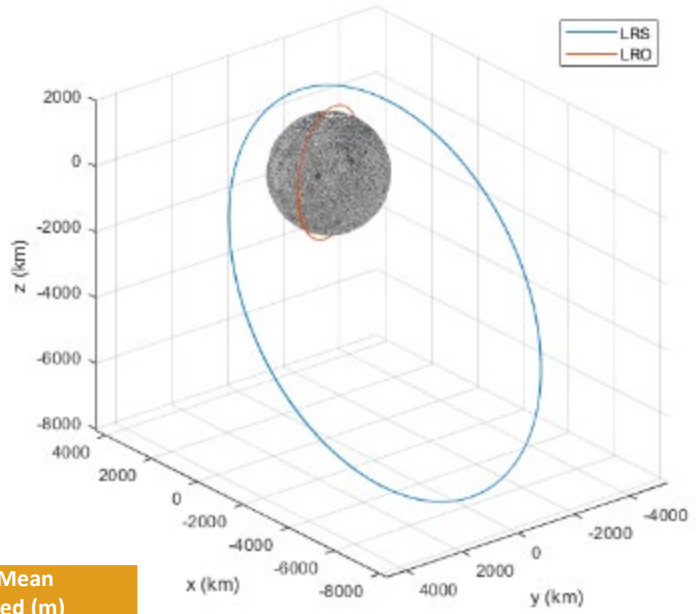
Spacecraft Formations
Interplanetary Missions



Systems Engineering:
Flight Projects

Reduced Infrastructure Radionavigation

- Use pseudorange and doppler measurements from just one or two satellites for navigation
- Nearby reference station for relative position fixes
- Prototype design for lunar and Martian surface navigation

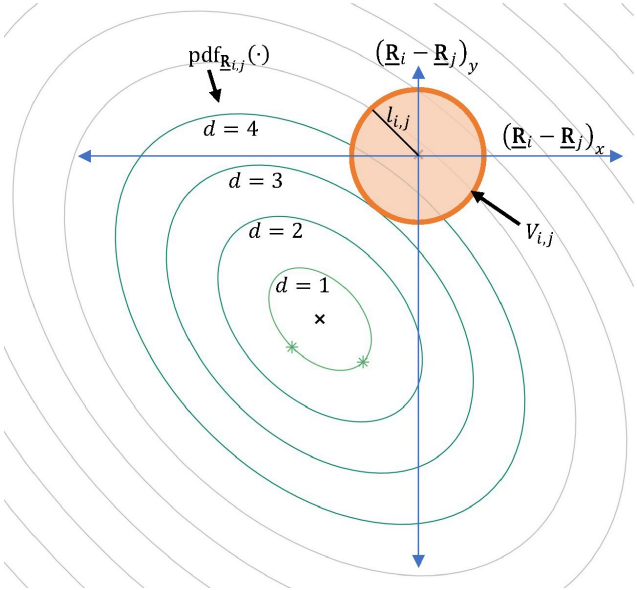


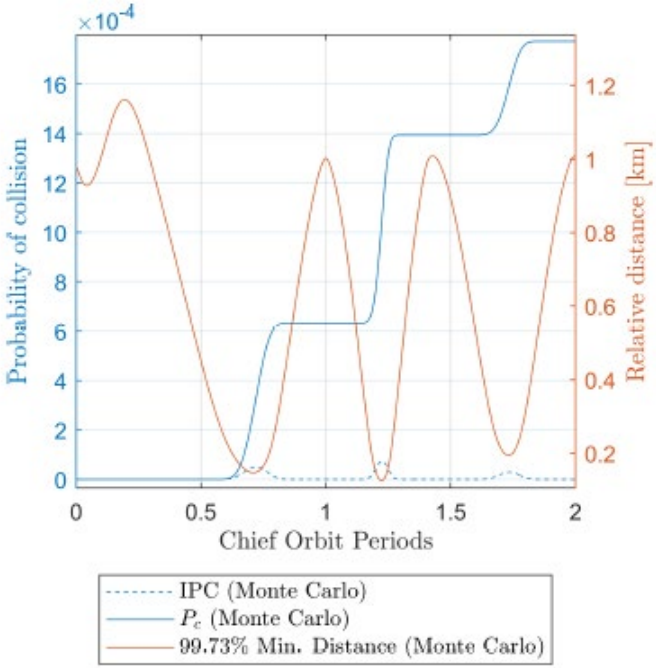
Number of Satellites in Scheme	Known altitude	Gaussian Error Type	Mean (m)	Standard Deviation (m)	Root Mean Squared (m)
1	Yes	Nominal	19.9222	13.0868	23.8361
		Optimistic	6.6321	3.9542	7.7214
2	No	Nominal	14.7187	9.6877	17.6207
		Optimistic	7.5728	5.4586	9.3351

Jun, W.; Cheung, K.M.; Lightsey, E.G.; and Lee, C.; "Time Position Determination on the Mars Surface Using Relative Joint Doppler and Ranging Measurements," *The Interplanetary Network Progress Report*, Vol. 42-224, pp. 1-14, February, 2021.

Stochastic Analysis of Spacecraft Collision Risk

- Examine alternate indicators of collision risk for spacecraft operations (e.g. IPC, Pc, 99.73% distance)
- Develop risk informed spacecraft guidance laws
- Stochastically safe formation flight in a constrained form factor

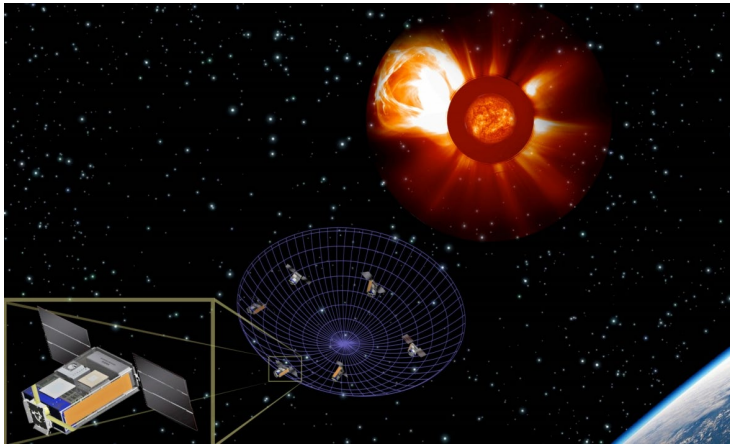


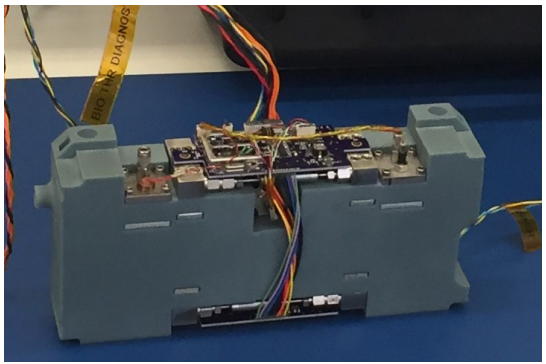


Núñez Garzón, U.E.; and Lightsey, E.G.; "**Sensitivity of Separation Indicators in Spacecraft Formation Collision Risk Analysis**," *2021 AAS/AIAA Astrodynamics Specialist Conference*, Big Sky, MT, August 2021.

Cold-Gas Propulsion System For CubeSat Formation Flight SunRISE Heliophysics Mission

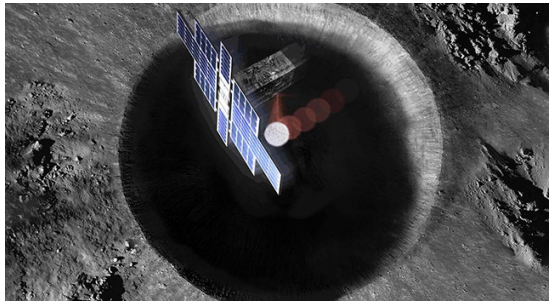
- Sun Radio Interferometer Space Experiment
- Six 6U CubeSats flying in formation near Geostationary Orbit
- JPL managed, Georgia Tech is providing cold-gas propulsion systems for each spacecraft
- Design, Assembly, and Testing of seven flight unit thrusters occurring this academic year
- Design is derived from heritage BioSentinel propulsion system (with modifications*)

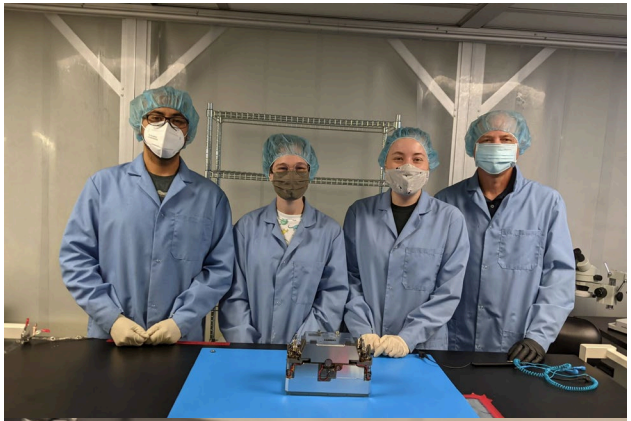


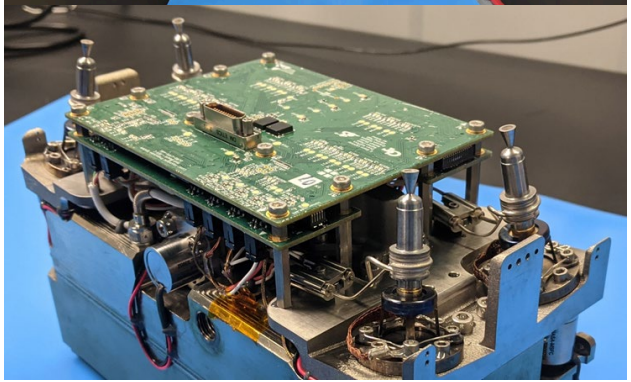


Skidmore, L.; and Lightsey, E.G.; "**Design of a Cold Gas Propulsion System for the SunRISE Mission**," *AE 8900 Masters Report*, August 2021.

Lunar Flashlight Monopropellant Propulsion System for CubeSat Lunar Orbit Insertion





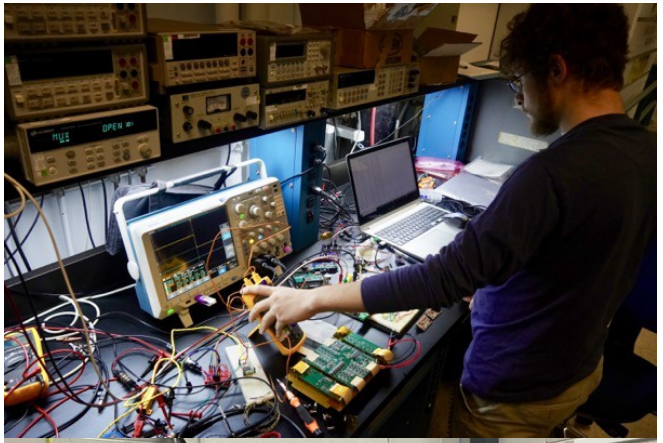


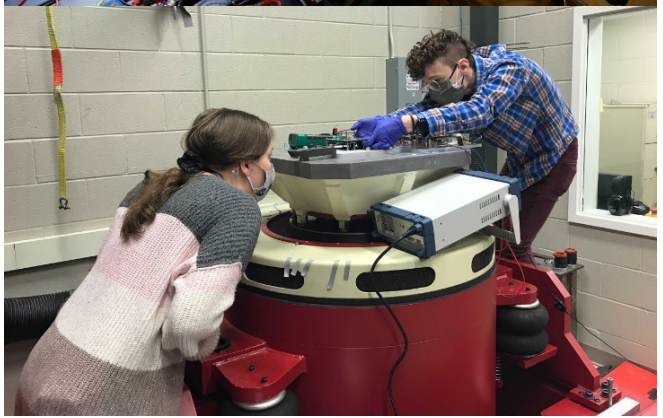
- Lunar Flashlight is a JPL 6U CubeSat mission to look for lunar ice
- GT was tasked to design and deliver the integrated monopropellant system in 24 months
- Delivery was completed in May 2021!
- When Lunar Flashlight flies it will be the first CubeSat to perform an orbit insertion maneuver beyond Earth orbit

Andrews, D.; Huggins, G.; Lightsey, E.G.; Cheek, N.; Lee, N.D.; Talaksi, A.; Peet, S.; Littleton, L.; Patel, S.; Skidmore, L.; Glaser, M.; Cavender, D.; Williams, H.; McQueen, D.; Baker, J.; and Kowalkowski, M.; "Design of a Green Monopropellant Propulsion System from the Lunar Flashlight CubeSat Mission," *34th AIAA Small Satellite Conference*, Logan, UT, August 2020.

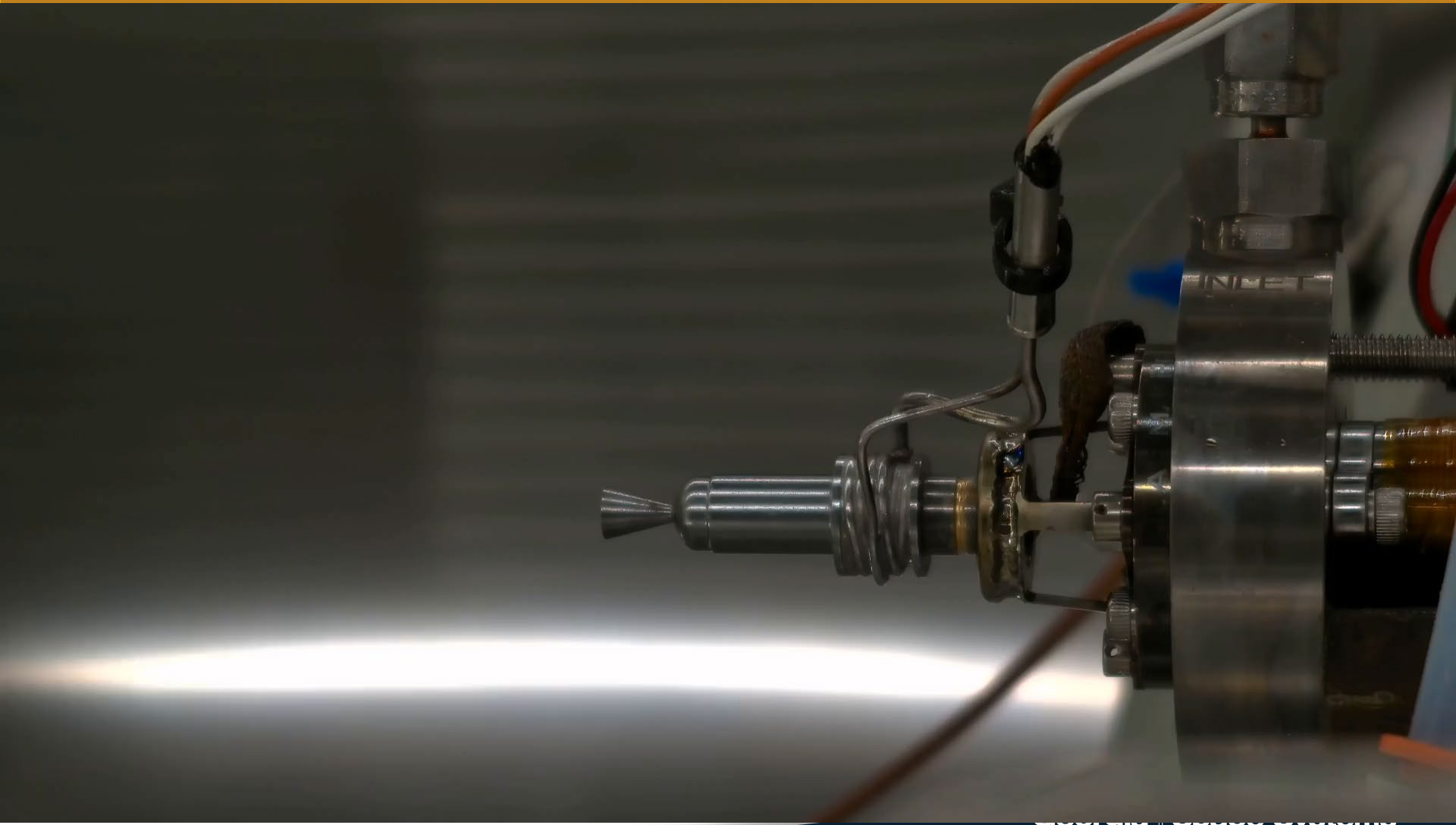
Lunar Flashlight Propulsion System Controller

- Responsible for operation of the system's thruster valves, heaters, and pump
- Firmware development using F Prime framework used on JPL rovers and CubeSats
- Multiple techniques implemented for radiation tolerance using COTS electronics
- System was environmentally tested for radiation, vibration, and thermal vacuum
- It works!



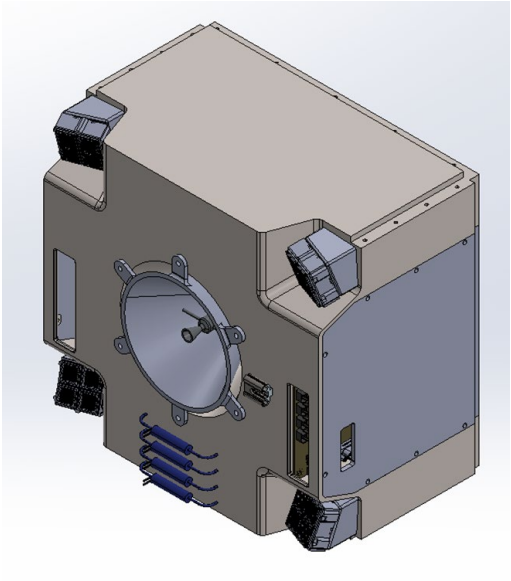


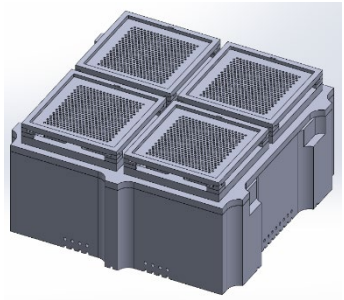
Cheek, N.; Daniel, N.; Lightsey, E.G.; Peet, S.; Smith, C.; and Cavender, D.; "**Development of a COTS-Based Propulsion System Controller for NASA's Lunar Flashlight CubeSat Mission**," *35th AIAA Small Satellite Conference*, Logan, UT, August 2021.



Spectre: Bimodal CubeSat Propulsion System

- Combines green-prop, high impulse thruster with high efficiency electrospray system
- Both systems are fed from same tank for volume efficiency
- Selected for Phase II product development over next 2 years
- Possible NASA Pathfinder Technology Demonstration Mission in 2024

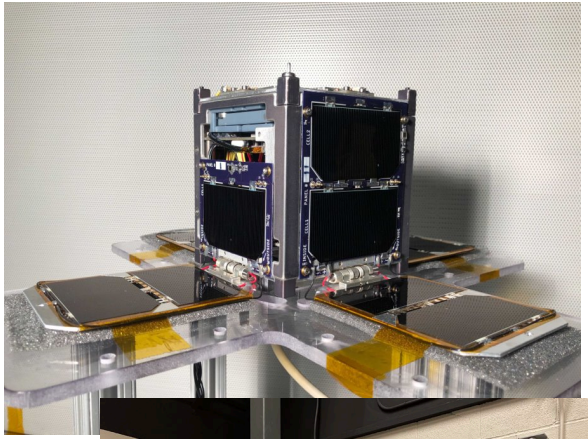


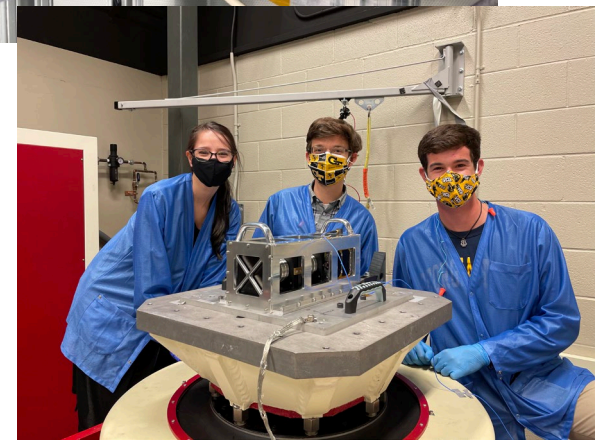


Colón, B.J.; Lightsey, E.G.; Bruno, A.R.; Cavender, D.P.; and Lozano, P.; "**Spectre: Design of a Dual Mode Green Monopropellant Propulsion System**," submitted to *AAS Guidance Navigation and Control Conference*, Breckenridge, CO, February 2022.

GT-1 and GT-2 1U CubeSats

- Sponsored as an Internal Research & Development (IR&D) activity
- Develop and demonstrate a flight-proven 1U CubeSat bus for future missions
- Create rapid design-to-operations mission lifecycle of less than 2 years per flight
- Train student workforce on space flight hardware and operations
- Provide value-added space engineering experience beyond traditional classroom and ground-based laboratory
- GT-1 delivered September 2021 and will launch on ISS reservicing mission in December (with TARGIT and Dr. Carr's biology experiment!)

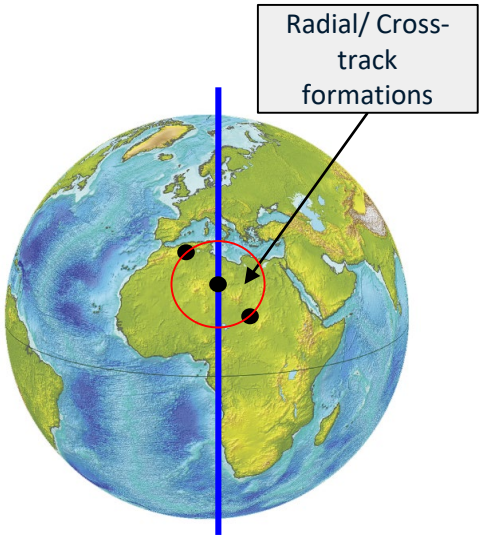




Kolhof, M.; Rawson, W.; Yanakieva, R.; Loomis, A.; Lightsey, E.G.; and Peet, S.; "Lessons Learned from the GT-1 1U CubeSat Mission," *35th AIAA Small Satellite Conference*, Logan, UT, August 2021.

SWARM-EX: Extensible CubeSat Swarms

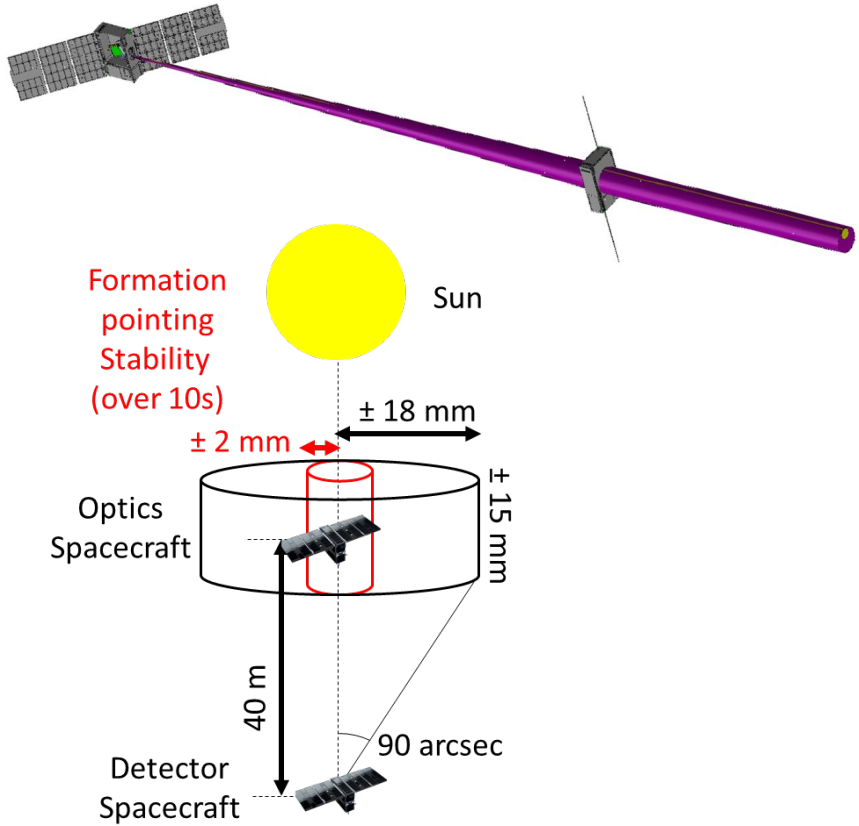
- Space Weather Atmospheric Reconfigurable Multiscale Experiment
- Deploy a reconfigurable swarm of 3x3U CubeSats in near-circular orbits with mean along-track separations of 0.1km - 100km and cross-track separations of up to 10km using differential drag control and low-thrust propulsion.
- Multi-university NSF project
- GT is responsible for the attitude determination and control system (procured) and the cold-gas propulsion system (produced)
- Planned launch in 2024



Gundamraj, A.; and Lightsey, E.G.; "**Attitude Guidance and Control Law Design for the Science Phases of the SWARM-EX Mission**," *AE 8900 Masters* Report, May 2021.

VISORS: Distributed CubeSat Space Telescope

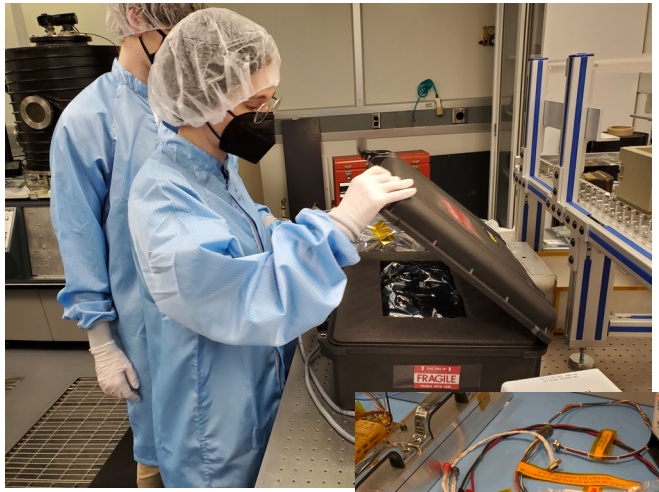
- VIrtual Super-resolution Optics using Reconfigurable Swarms
- Employing CubeSat formations to create a virtual telescope with unprecedented resolution
- Multi-university NSF project
- GT is providing:
  - Mission systems engineer
  - Cold-gas propulsion system
  - Systems integrator for instrument and spacecraft bus
  - Mission operations
- Planned Launch in 2024

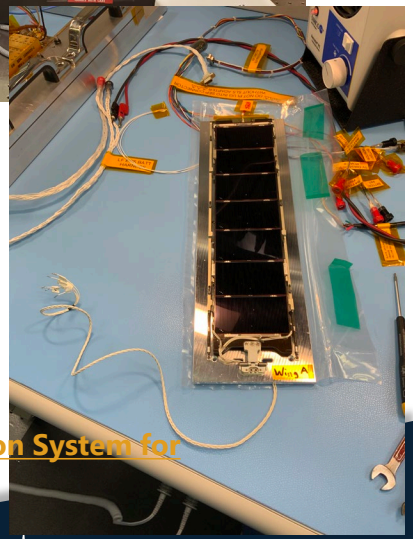


Thatavarthi, R.; Gundamraj, A.R.; Carter, C.A.; and Lightsey, E.G.; "**Systems Architecture and Conceptual Design of a CubeSat Formation Serving as a Distributed Telescope**," *2020 AIAA ASCEND*, November 2020.

Lunar Flashlight Spacecraft Integration and Testing

- JPL has contracted with GT and GTRI to conduct full spacecraft I&T and mission operations for Lunar Flashlight
- Spacecraft bus, solar panels, and GT's propulsion system have been delivered to GTRI's Center for Spacecraft Handling Assembly Fabrication and Testing facility
- Spacecraft I&T to happen Fall 2021
- Expected launch on Artemis I in 2022

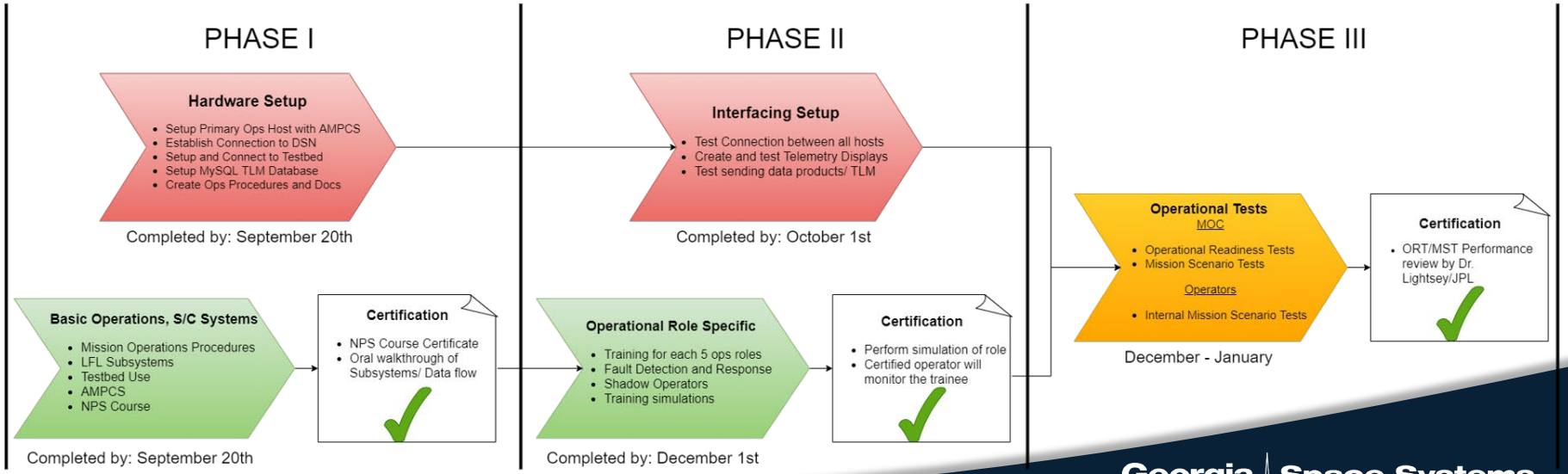




Littleton, L.M.; and Lightsey, E.G.; "**Assembly, Integration, and Testing of a Green Monopropellant Propulsion System for NASA's Lunar Flashlight Mission**," *AE 8900 Masters Report*, August 2021.

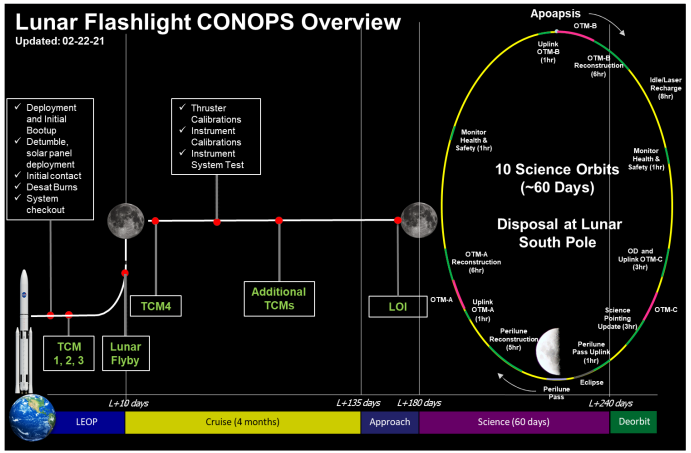
Georgia Tech Mission Operations Center (GT MOC)

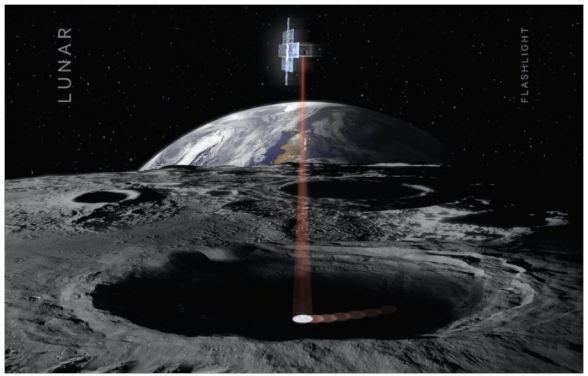
- GT MOC will be integrated with Georgia Tech and other ground stations
- GT missions will be operated and controlled at the GT MOC
- GT MOC must be ready to operate by December 2021 for GT-1, TARGIT, and LF

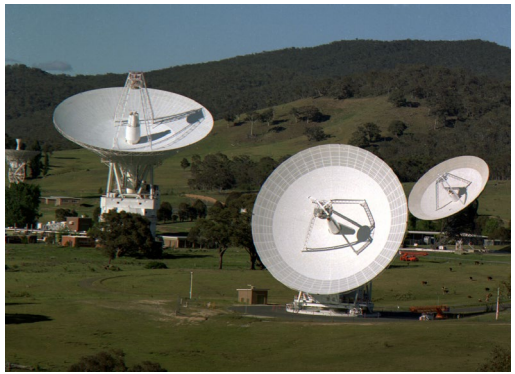


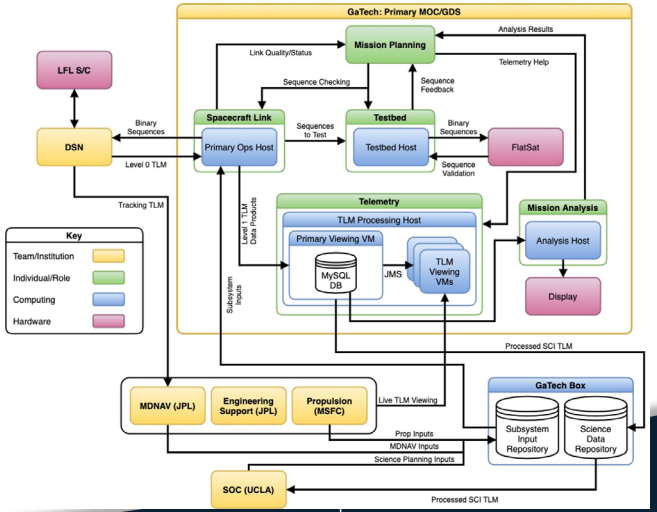
Lunar Flashlight Mission Operations

- Lunar Flashlight will launch in 2022 for lunar flyby with 9-month mission
- GT propulsion system will be used for lunar orbit insertion
- Communication with satellite will be conducted through GT MOC via NASA's Deep Space Network
- Lots to do to prepare for this









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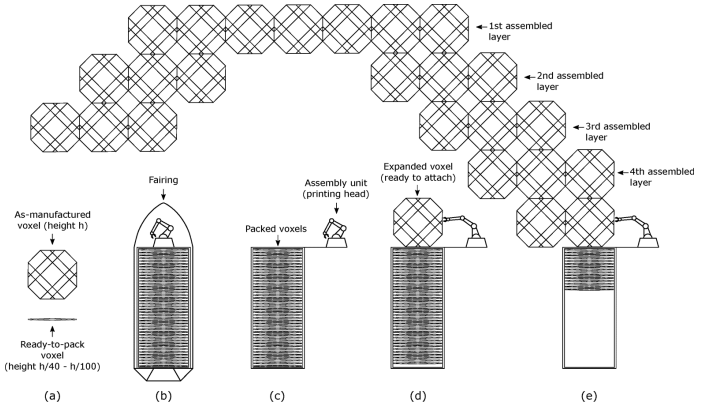
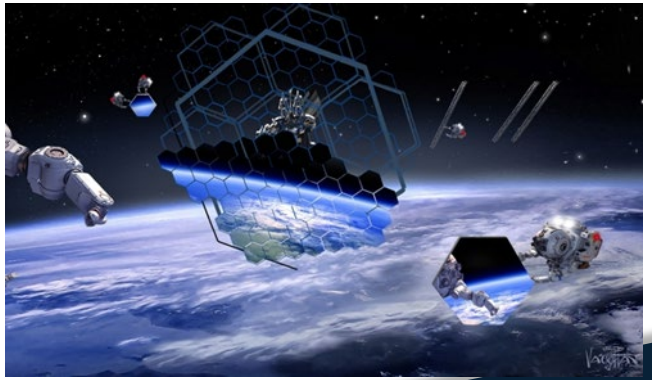
GTRI Precision Aggregated Space Systems Initiative

- A unifying grand challenge collaboration between GTRI and the academic colleges at Georgia Tech
- GT will create a decadal goal in space technology of relevance to US space policy and national interest
- Coordinated multi-vehicle space missions require an interdisciplinary team of thought leaders
- Example missions:
  - Reconfigurable Space Sensor Arrays
  - In-Space Assembly and Manufacturing
  - Large Space Structures





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Questions?

NASA Administrator Bridenstine's
Visit to SSDL on July 31, 2019

NASA Administrator Bolden's
Visit to SSDL on November 17, 2019