Georgia Tech

Lightsey Research Group Overview

Presentation to Space Systems Design Lab
September 6, 2022

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Daniel Guggenheim School of Aerospace Engineering
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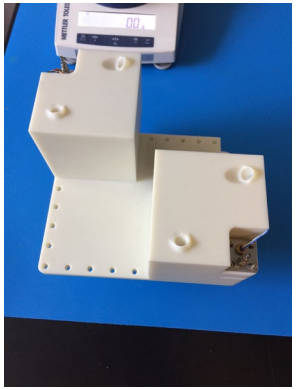
Flashback Update:
Previous CubeSat Cold Gas Propulsion Systems

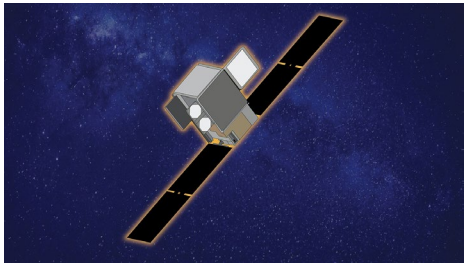
- Additively manufactured tank can be made in many shapes and sizes
- Propellant is R236-fa (refrigerant and fire suppressant)

- AFRL Ascent mission:
  - GEO 12U CubeSat
  - Prop System Delivered in 2019, launched December 2021
  - Successful demonstration, still operational
  - Possible low temperature leak

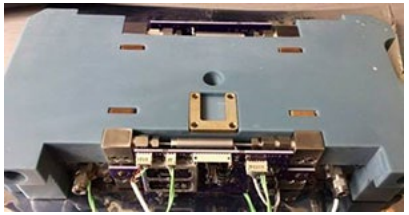
- NASA BioSentinel mission:
  - Deep Space 6U CubeSat
  - Prop System Delivered in 2017, integrated on Artemis I
  - To be used for Moon avoidance maneuver!

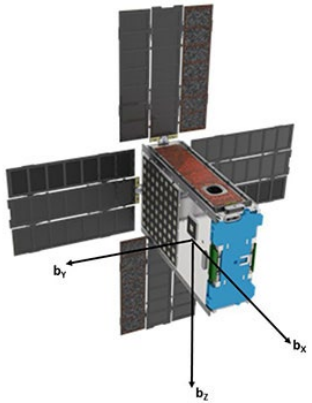


Ascent Prop System



Ascent Spacecraft

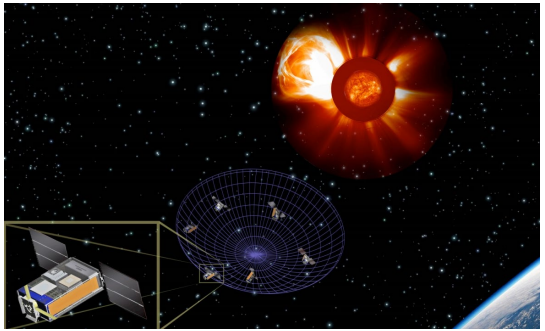




BioSentinel Prop System and Spacecraft

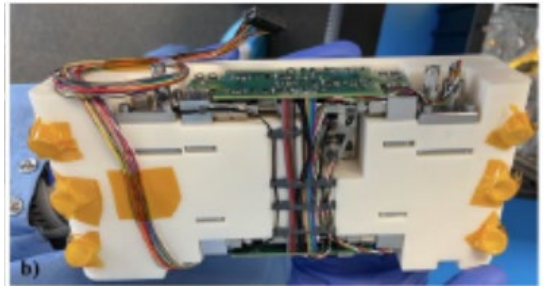
Cold-Gas Propulsion System For CubeSat Formation Flight
SunRISE Heliophysics Mission

- Sun Radio Interferometer Space Experiment
- Six 6U CubeSats flying in formation near Geostationary Orbit
- JPL-managed, Utah State is integrating spacecraft, Georgia Tech is providing cold-gas propulsion system for each spacecraft



SunRISE Mission Concept

- Design, Assembly, and Testing of SunRISE flight units occurring now (2022)
- Design is derived from heritage BioSentinel propulsion system (with modifications*)



SunRISE Prop System

Shirazi, K..; and Lightsey, E.G.; "**Integration and Testing of a 2U Cold-Gas Propulsion System for the SunRISE Mission**," *AE 8900 Masters Report*, August 2022.

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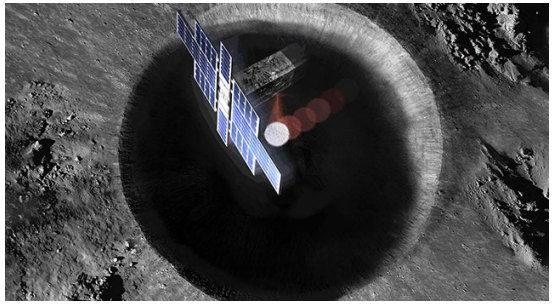
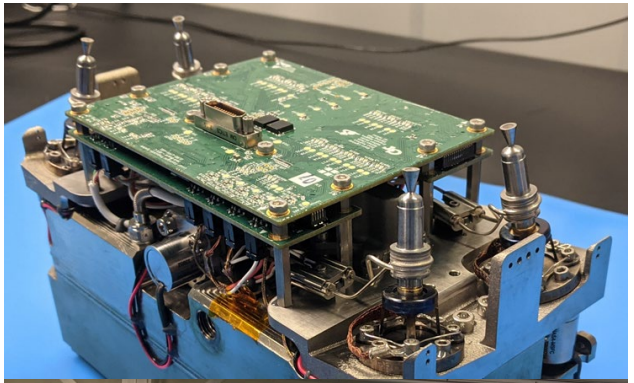
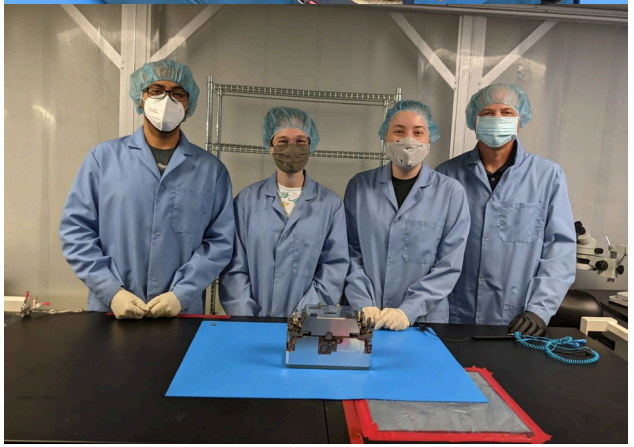
Lunar Flashlight Monopropellant Propulsion System for CubeSat Lunar Orbit Insertion





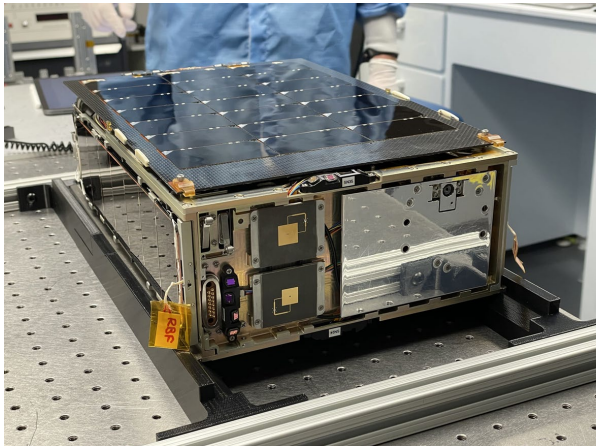


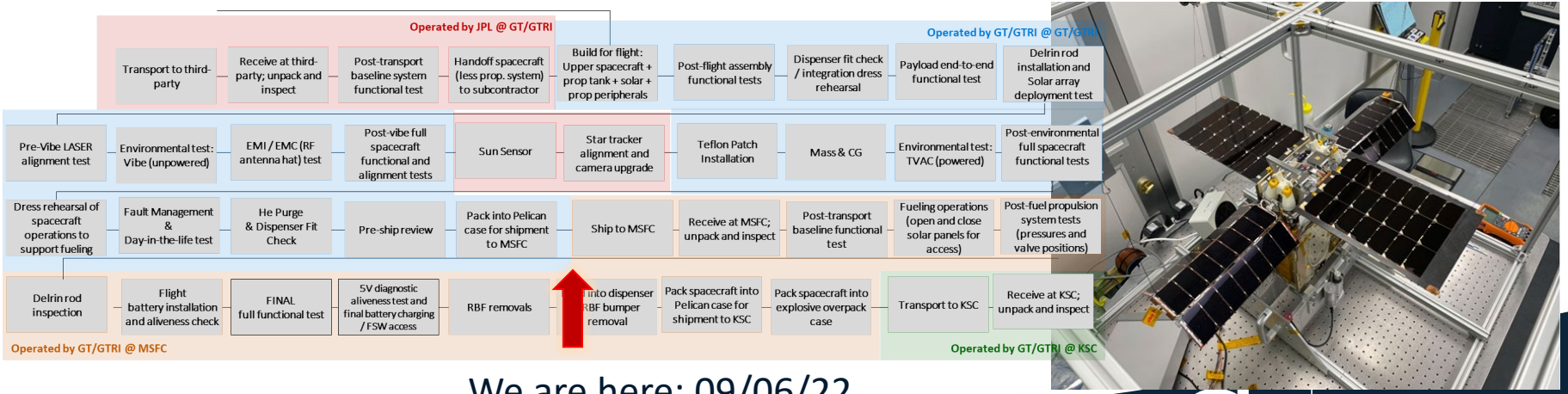
- Lunar Flashlight is a JPL 6U CubeSat mission to look for lunar ice
- GT was tasked to design and deliver the integrated monopropellant system in 24 months
- Delivery was completed in May 2021
- When Lunar Flashlight flies it will be the first CubeSat to use a green monopropellant for an orbit insertion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

Smith, C.; Littleton, L.; Lightsey, E. G.; and Cavender, D.; "**Assembly Integration and Test of the Lunar Flashlight Propulsion System**," *2022 AIAA Science and Technology Conference*, San Diego, CA, January 2022.

Lunar Flashlight
Spacecraft Integration and Testing at Georgia Tech

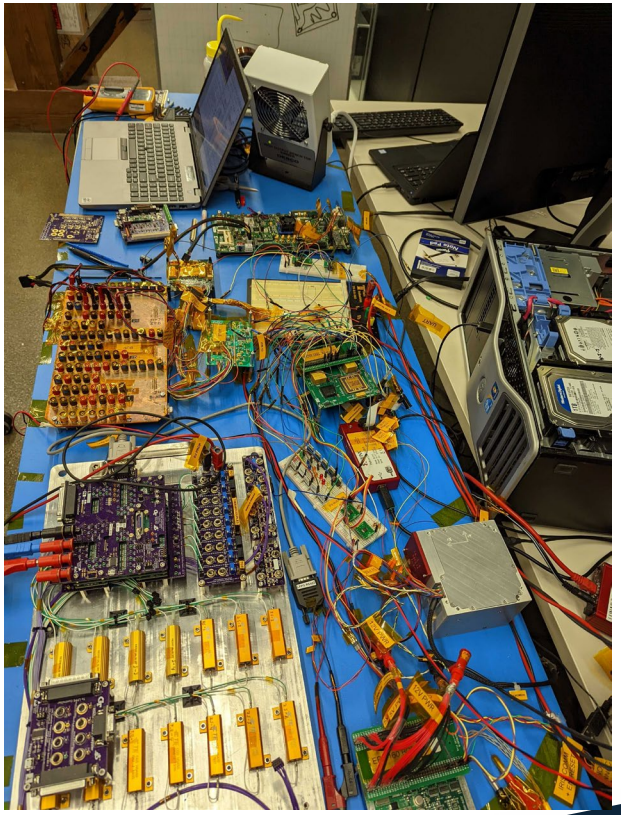
- GTRI and SSDL tasked with completing spacecraft I&T of ~$20M NASA interplanetary spacecraft
- Received spacecraft subsystems Sept. 2021, spacecraft I&T acceptance delivery Feb. 2022
- In SSDL storage until ready to ship to NASA approximately 2 months before launch
- Spacecraft originally scheduled for launch in Jan. 2022, now estimating launch early 2023





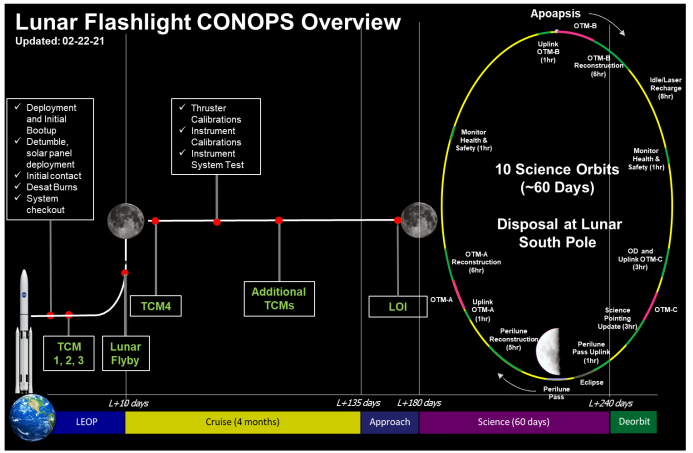
We are here: 09/06/22

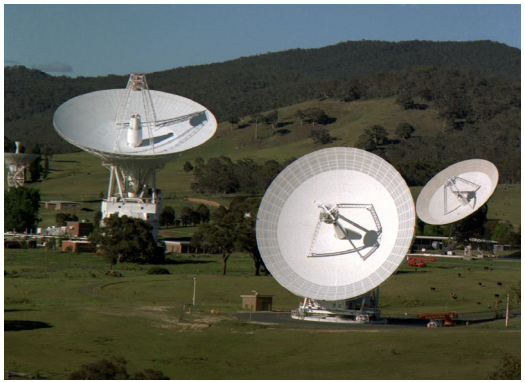
The Engineering Behind the Headlines!

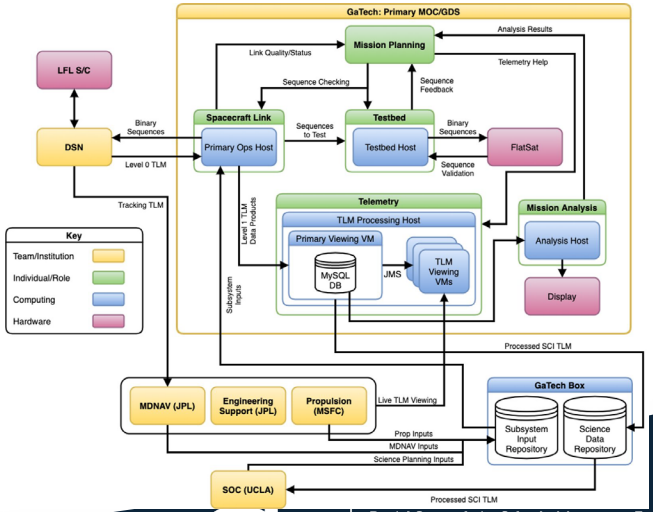


Lunar Flashlight
Mission Operations at Georgia Tech

- Lunar Flashlight will launch in 2023 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
- Currently training ~12 SSDL students as spacecraft operators

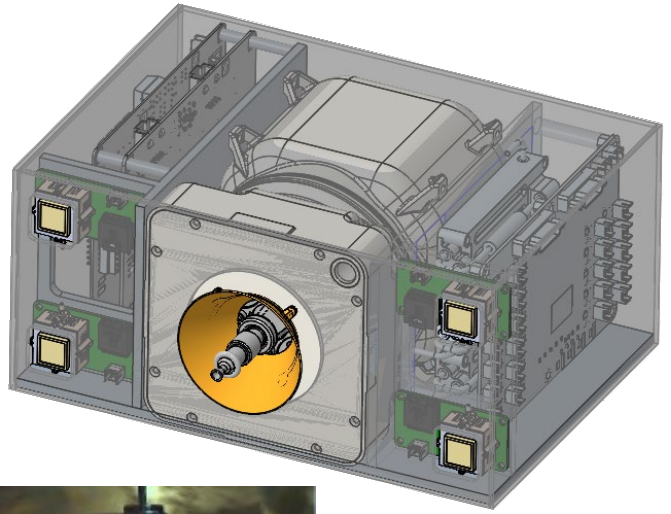


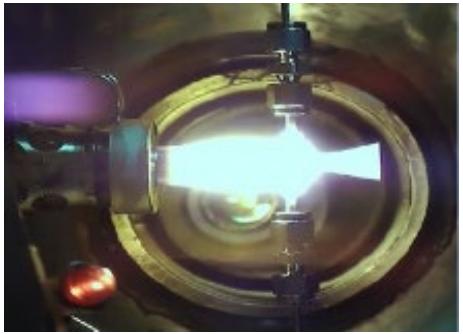




Green Propellant Demonstration Mission (GPDM)

- Partnership Technology Demonstration Mission with NASA Ames and Marshall Space Flight Centers, Georgia Tech, and MIT
- Advanced CubeSat propulsion module will operate in both impulsive and low thrust modes using same propellant
- Will fly on NASA's 6U CubeSat PACE 3 mission in late 2023
- SSDL design and systems integration for overall propulsion system

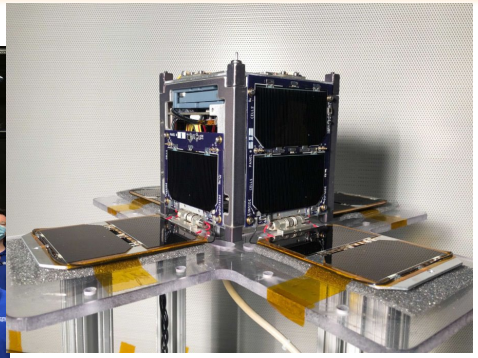




Colón, B.J.; Glaser, M.J.; Lightsey, E.G.; Bruno, A.R.; Cavender, D.P.; and Lozano, P.; "**Spectre: Design of a Dual Mode Green Monopropellant Propulsion System**," *AAS Guidance Navigation and Control Conference*, Breckenridge, CO, February 2022.

GT-1 and GT-2 1U CubeSats

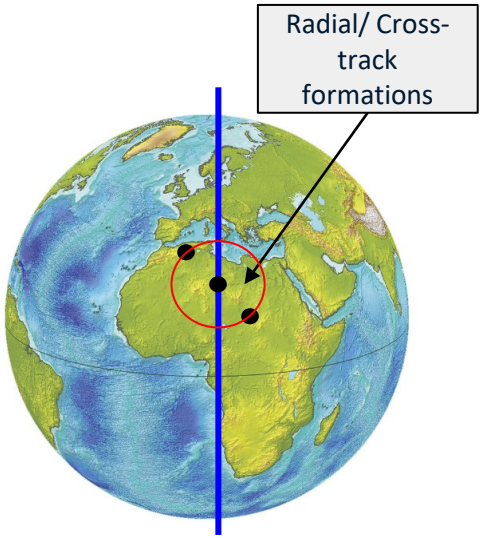
- Internal Research & Development (IR&D) activity
- Develop and demonstrate a flight-proven 1U CubeSat bus for future missions
- Create rapid design-to-operations mission lifecycle of less than 2 years per flight
- Train student workforce on space flight hardware and operations
- Provide value-added space engineering experience beyond traditional classroom and ground-based laboratory
- GT-1 launched from ISS in Feb. 2022, operated successfully for 3 months (radio failure), re-entered after 6 months
- GT-2 being built now, to be delivered and fly sometime in 2023



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

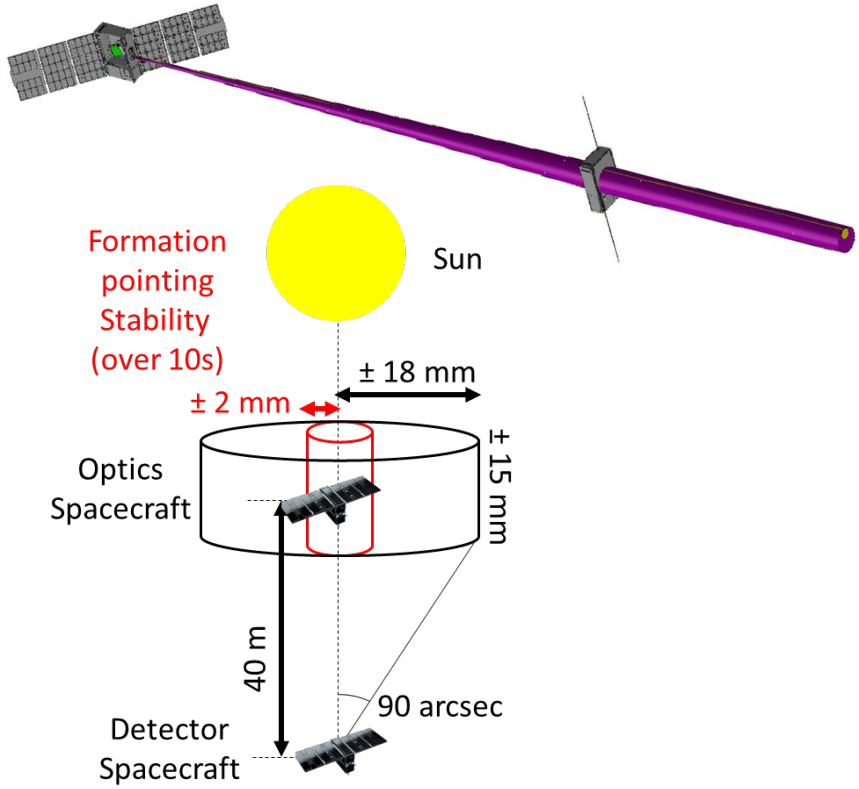
- Space Weather Atmospheric Reconfigurable Multiscale Experiment
- Deploy a reconfigurable swarm of 3x3U CubeSats in near-circular orbits with mean along-track separations of 0.1km - 100km and cross-track separations of up to 10km using differential drag control and low-thrust propulsion.
- Multi-university NSF project led by CU-Boulder
- 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 led by Univ. of Illinois
- GT is providing:
  - Mission systems engineering
  - Cold-gas propulsion system
  - Systems integrator for instrument and spacecraft bus
  - Mission operations
- Planned Launch in 2024



Lightsey, E.G.; Arunkumar, E.; Kimmel, E.; Kolhof, M.; Paletta, A.; Rawson, W.; Selvamurugan, S.; Sample, J.; Guffanti, T.; Bell, T.; Koenig, A.; D'Amico, S.; Park, H.; Rabin, D.; Daw, A.; Chamberlin, P.; and Kamalabadi, F.; "Concept of Operations for the VISORS Mission: A Two Satellite Cubesat Formation Flying Telescope," 2022 AAS Guidance, Navigation and Control Conference, Breckenridge, CO, February 2022.

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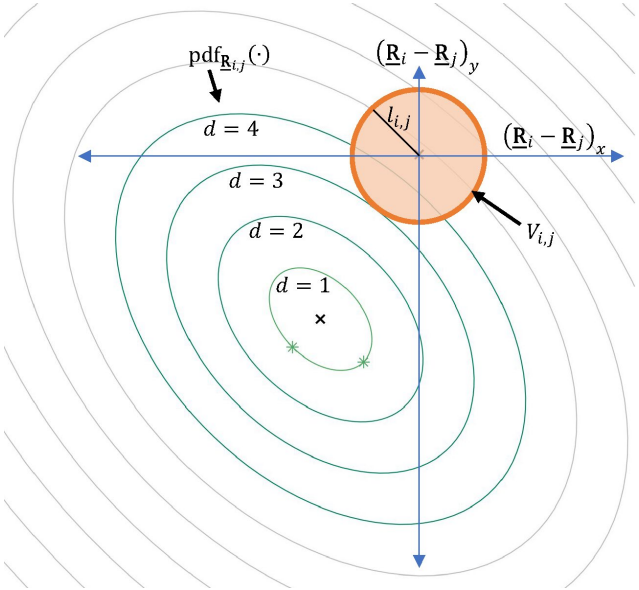
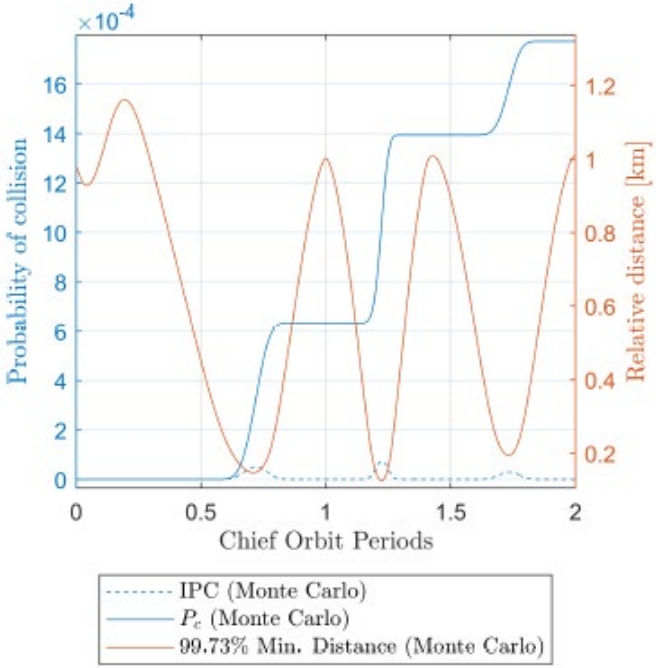
Stochastic Analysis of Spacecraft Collision Risk

- 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

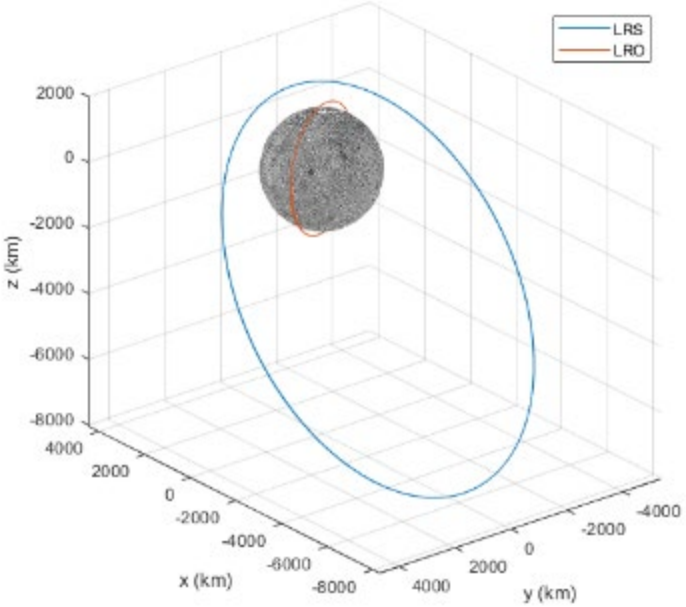


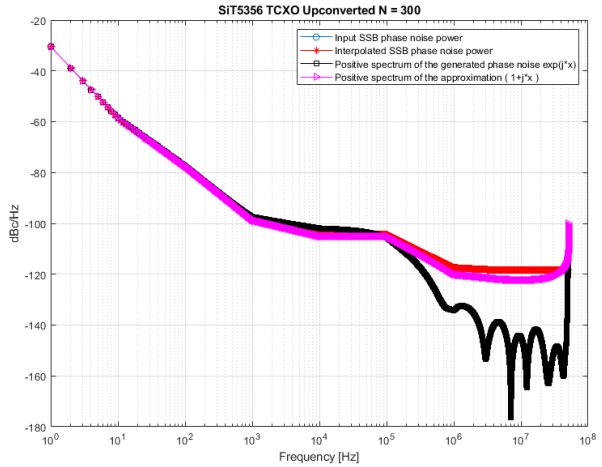


Núñez Garzón, U.E.; and Lightsey, E.G.; "**Sensitivity of Separation Indicators in Spacecraft Formation Collision Risk Analysis**," *2021 AAS/AIAA Astrodynamics Specialist Conference*, Big Sky, MT, August 2021.

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

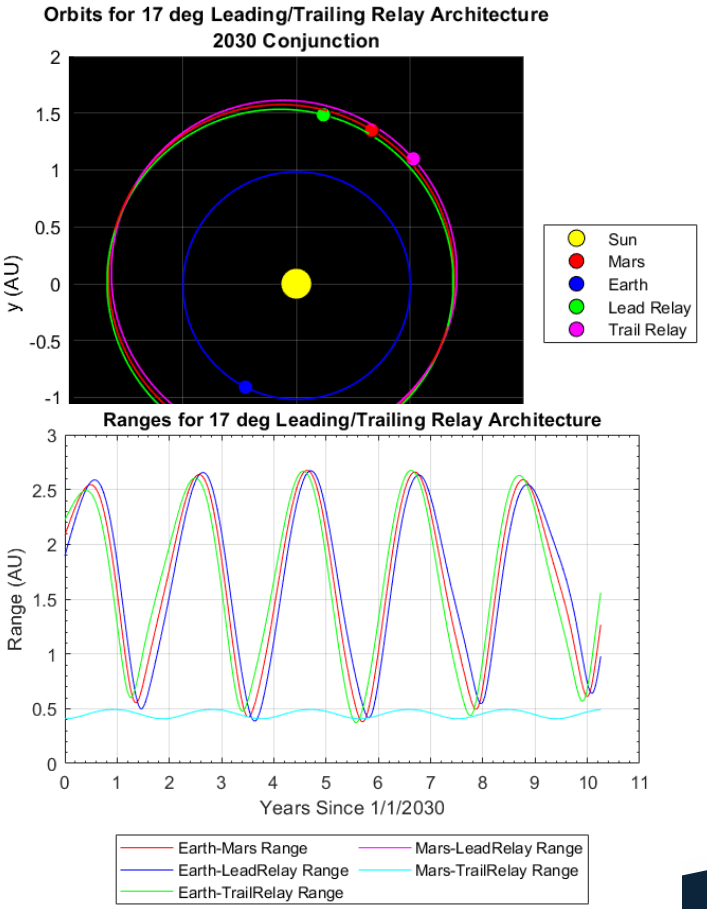


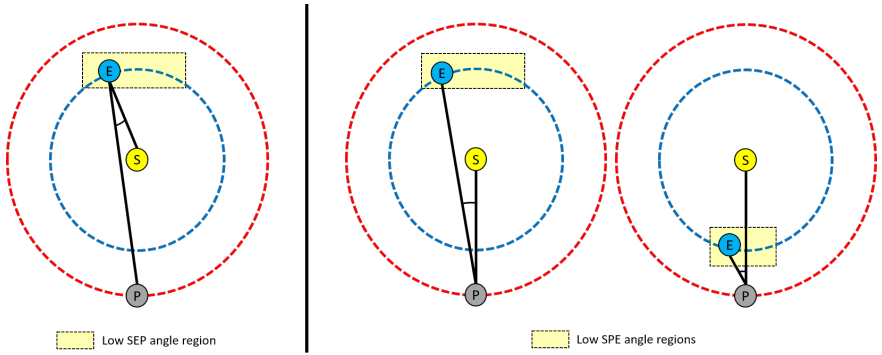


Jun, W.W.; Cheung, K.M.; Lightsey, E.G.; and Lee, C.; "A Minimal Architecture for Real-Time Lunar Surface Positioning Using Joint Doppler and Ranging," *IEEE Transactions on Aerospace and Electronic Systems*, Vol. 58, No. 2, pp. 1367-1376, April 20221.

Deep Space Telecommunications Relay Study For Interplanetary Navigation

- Feasibility study of Mars leading and trailing relay satellites for deep space comms and navigation
- Determine achievable navigation accuracy based on optical link budget
- Determine effect of sun blockage geometries on solution availability
- Input to deep space navigation architecture study

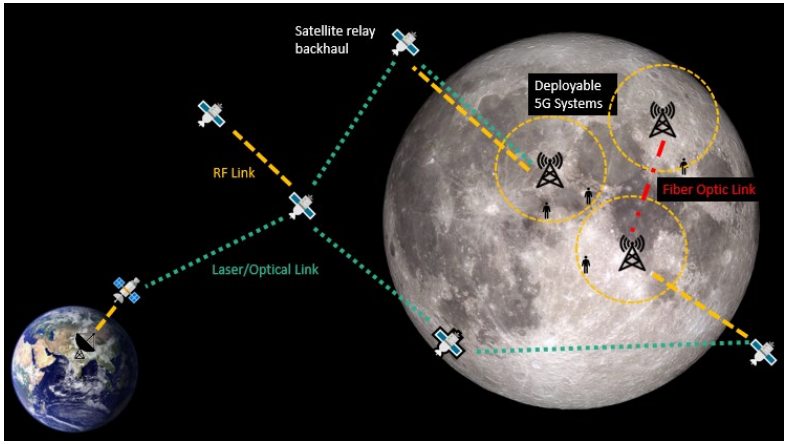


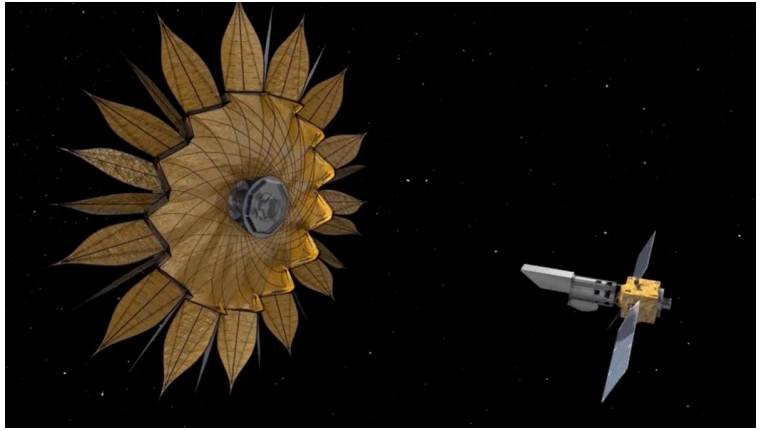


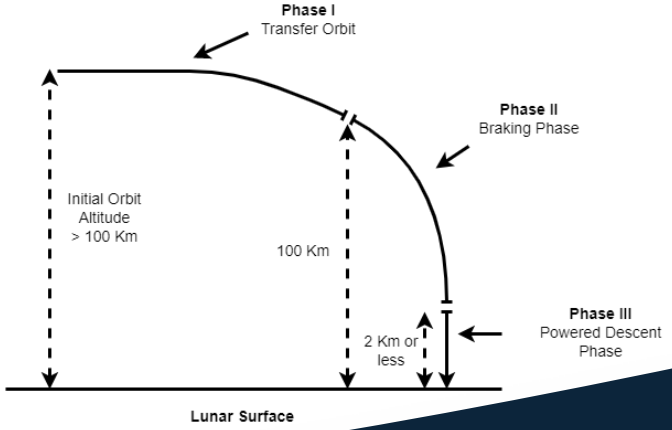
Cheung, K.M.; Carter, P.; Xie, H.; Jun, W.W.; Lee, C.; and Lightsey, E.G.; "Deep Space Relay Architecture for Communications and Navigation," accepted for *2023 IEEE Aerospace*, Big Sky, MT, March 2023.

GTRI Precision Aggregated Space Systems Initiative

- GLRG Contributing to GTRI IRAD Studies:
  - Active Debris Mitigation
  - Cislunar PNTC
  - In Situ Resource Utilization
  - Radio Astronomy Formation Flight







Questions?

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

SSDL Tailgate Party
October 30, 2021

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