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**Aerospace Engineering**

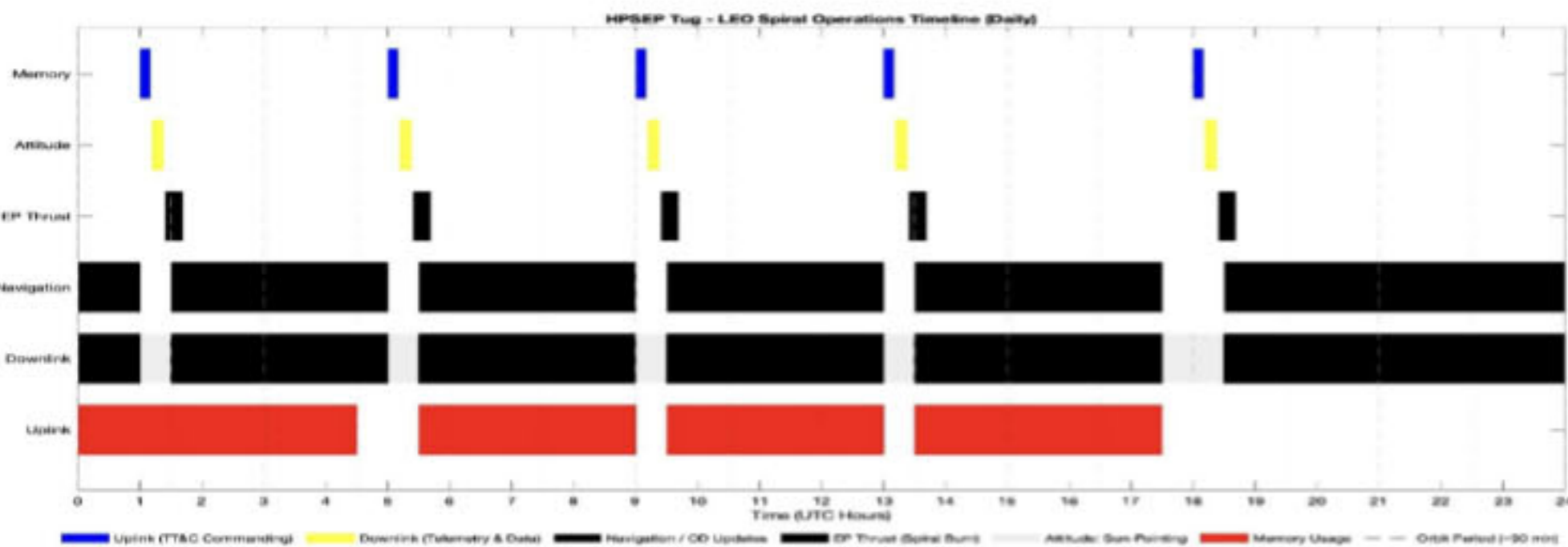
## Abstract

Andromeda Space Work's mission is to develop a modular, reusable high-powered solar electric propulsion (HPSEP) space tug for better efficient and cost-effective lunar payload transport. The goal of this project is to create a sustainable, on-orbit refueling system that can support NASA's Artemis program and long-term infrastructure for Lunar exploration. Using Hall-effect thrusters that are powered on by 84 kW solar electric propulsion system that will allow it to fly from (LEO) lower Earth orbit to Lunar orbit. The refueling methods for HPSEP are pressurized xenon transfer and replaceable tank modules. HPSEP Space Tug proposal will advance electric propulsion technology and foster further expansion of transportation throughout our solar system.

## Mission Objectives

- Provide high efficiency solar-electric capable orbital transfer capabilities
- Deliver payloads from LEO to Lunar Orbit with solar electric propulsion
- Demonstrate reusable in space transportation
- Multi-mission using replacement Xenon tanks
- Generate high onboard power for electric propulsion
- Produce +90 kW using deployable ROSA to operate the thruster cluster

## Mission Schedule



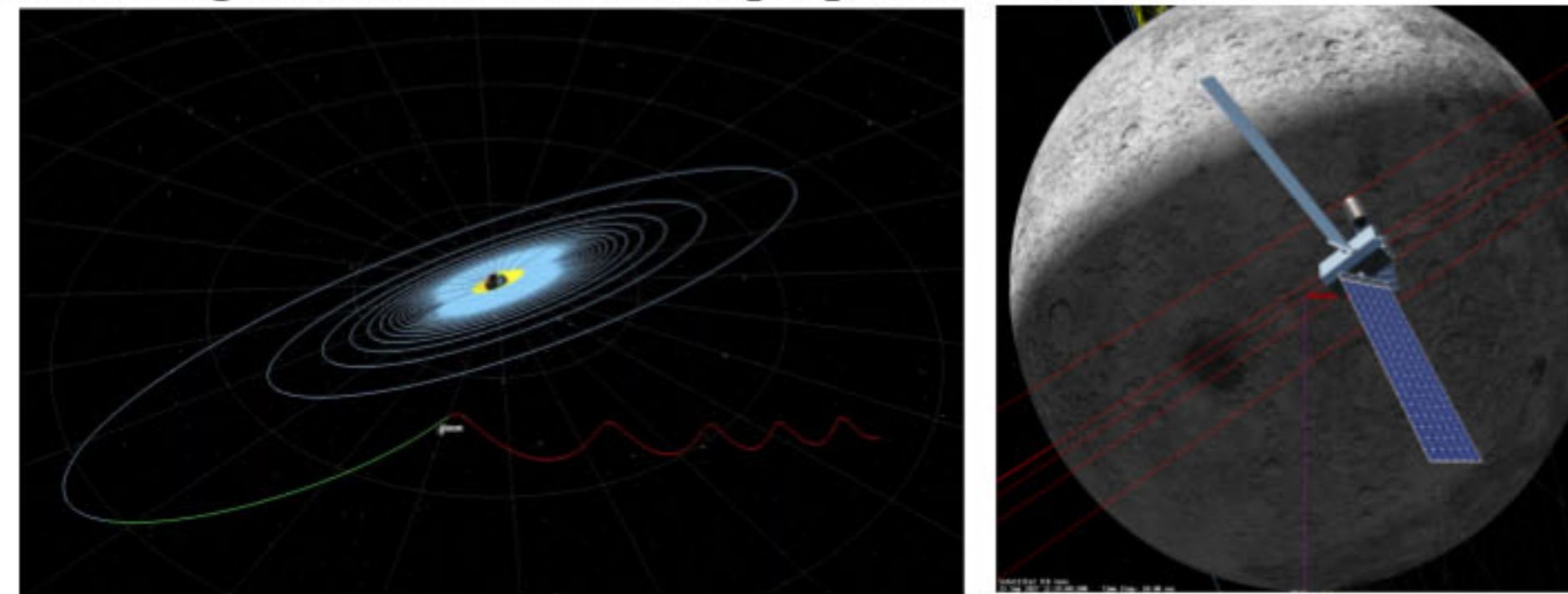
Our mission timeline is structured as a command sequence that prioritizes continuous long burns of the propulsion system and accommodates ground station interactions and mission constraints. Propulsion is a priority for the HPSEP tug due to the limited communications windows; the tug must reach the next commanding window with ample time to receive and analyze them from the ground station. As the tug moves through cislunar space, these windows are less frequent but last longer, and the tug will operate more autonomously during this period. All activities are planned in universal coordinated time (UTC) and cross-referenced with ground station local time.

## Acknowledgements

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## Orbital Transfer

The mission sequence begins with launch from Cape Canaveral into a 900 km circular low earth orbit, after which the spacecraft performs a continuous low-thrust spiral to gradually raise its orbit. The craft utilizes Hall-effect propulsion, following a low-thrust spiral transfer towards the moon and accumulating  $\Delta V$  over extended periods of time, rather than utilizing impulsive maneuvers. Upon lunar arrival, the spacecraft is captured into an elliptical orbit where the HPSEP space tug recircularizes its trajectory into a near-circular orbit at approximately 250 km altitude. Throughout the trajectory, coasting phases and load shedding leverage natural orbital mechanics, thus balancing mission duration and propellant conservation.



The HPSEP space tug is capable of transferring loads of ~6500 kg between Earth and cislunar space. Based on the available xenon propellant capacity, the system can support 2 round-trip transfers from lunar orbit to LEO before refueling, achieving a total operational lifetime of 10 years. The current mission design enables sustained multi-mission support for cislunar logistical and infrastructural development.

Phase	Orbit Type	Altitude (km)	e	i (deg)	Period	$\Delta V$ (km/s)	Duration
Initial Orbit	LEO	900	~0	28.5	1.75 hr	—	—
Earth Escape Spiral	Expanding Spiral	900 → SOI Esc.	Variable (increasing)	~const	—	2.496	90 days
Lunar Transfer	Elliptical Spiral	—	Variable (increasing)	—	—	3.3489	109 days
Lunar Capture	Elliptical	Variable → 200 (0.30)	decreasing (0.72 → 0)	74.9348	—	0.661	20 days
Final Orbit	Circular Lunar (approx.)	200	0.17	75.6251	2 hr	—	—

## Payload Subsystem

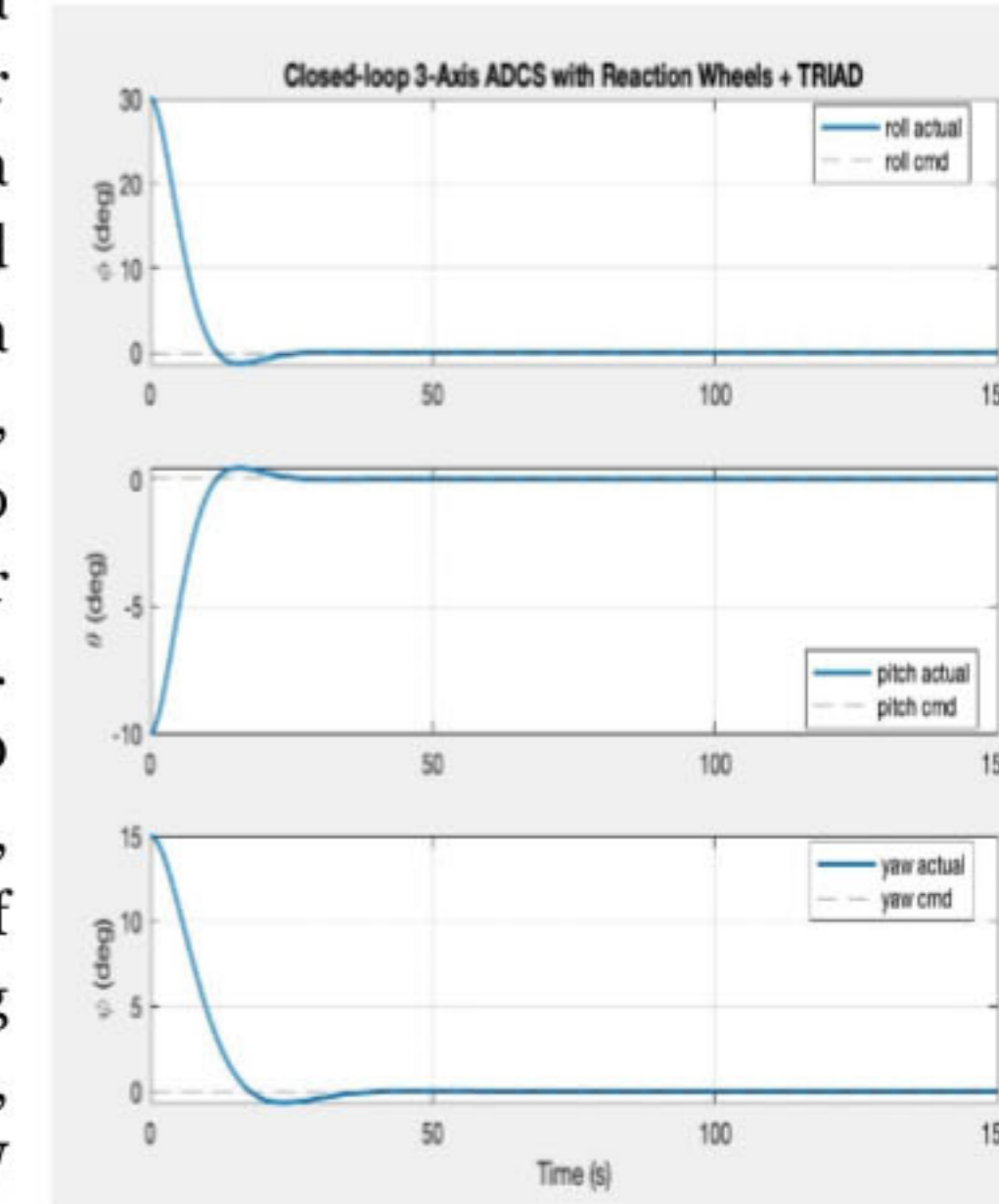
**NASA Active Docking System (NDS):** Provides the mechanical and structural interface for autonomous docking between the HPSEP tug and client spacecraft or payload modules. The system supports capture, alignment, load transfer, and repeated docking operations for reusable mission architecture. **Relative Navigation Sensor Suite (RNSS):** Measures relative position and orientation using LiDAR, stereo cameras, and radar during proximity operations. **Proximity Communications and Ranging (PC&R):** Supports short-range tug-to-client communications and ranging during rendezvous and docking. **Payload Interface Pallet (PIP):** Provides structural, electrical, thermal, and data connections between the payload hardware and the spacecraft bus.

## Budget

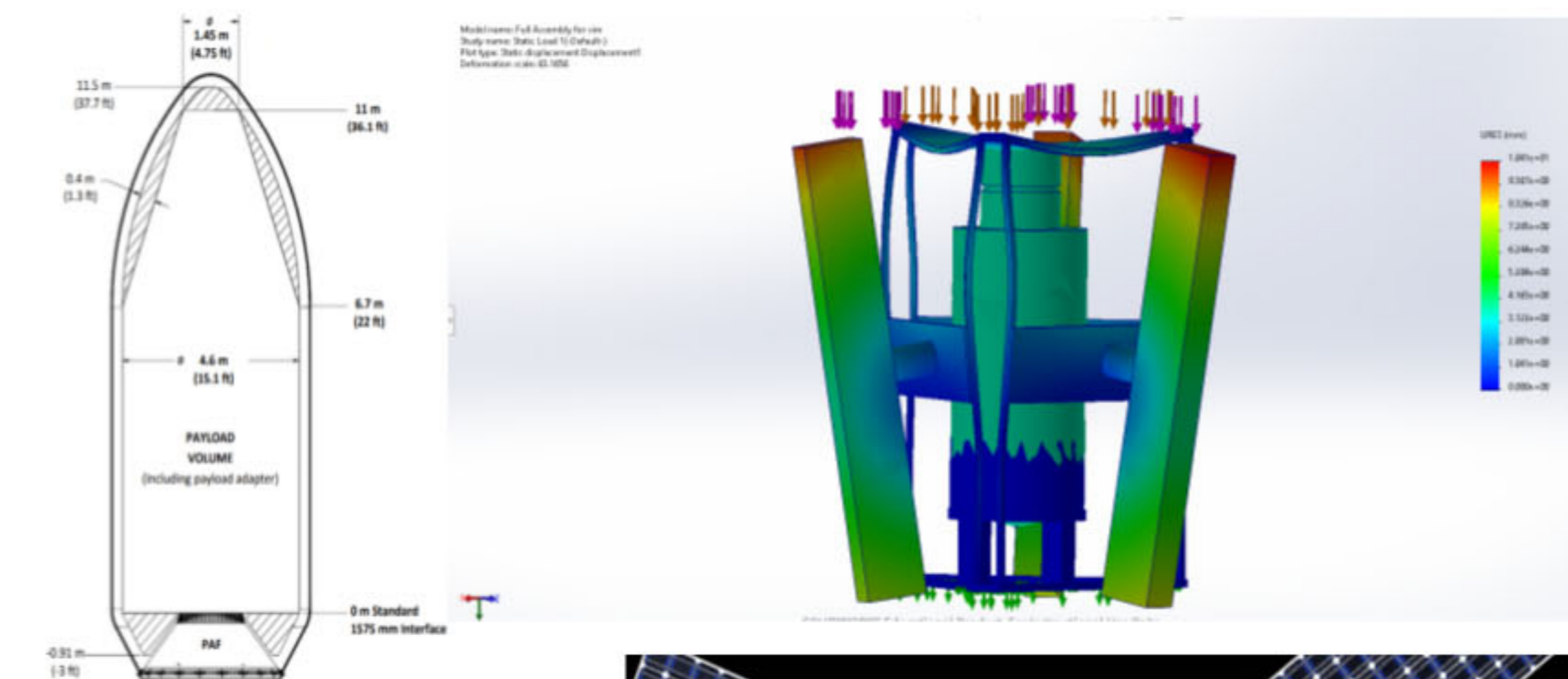
Work Package / Subsystem	Estimated Cost (USD)
Electric Propulsion (AEPS Strings x4)	\$45-60M
Power Generation & PMAD	\$70-110M
Additional BHT-6000 Strings	\$20-40M
Propellant & Tankage (Xenon + Plumbing)	\$6-20M
GNC & Avionics (includes FR and RNSS)	\$10-25M
Structures & Mechanisms (includes NDS + PIP)	\$15-30M
Thermal & High-Voltage Harness	\$6-14M
Systems Eng., Integration & Qualification	\$25-40M
Launch & Operations Reserve	\$120-150M
<b>Total Program Cost</b>	<b>\$400-470M</b>

## ADCS Subsystem

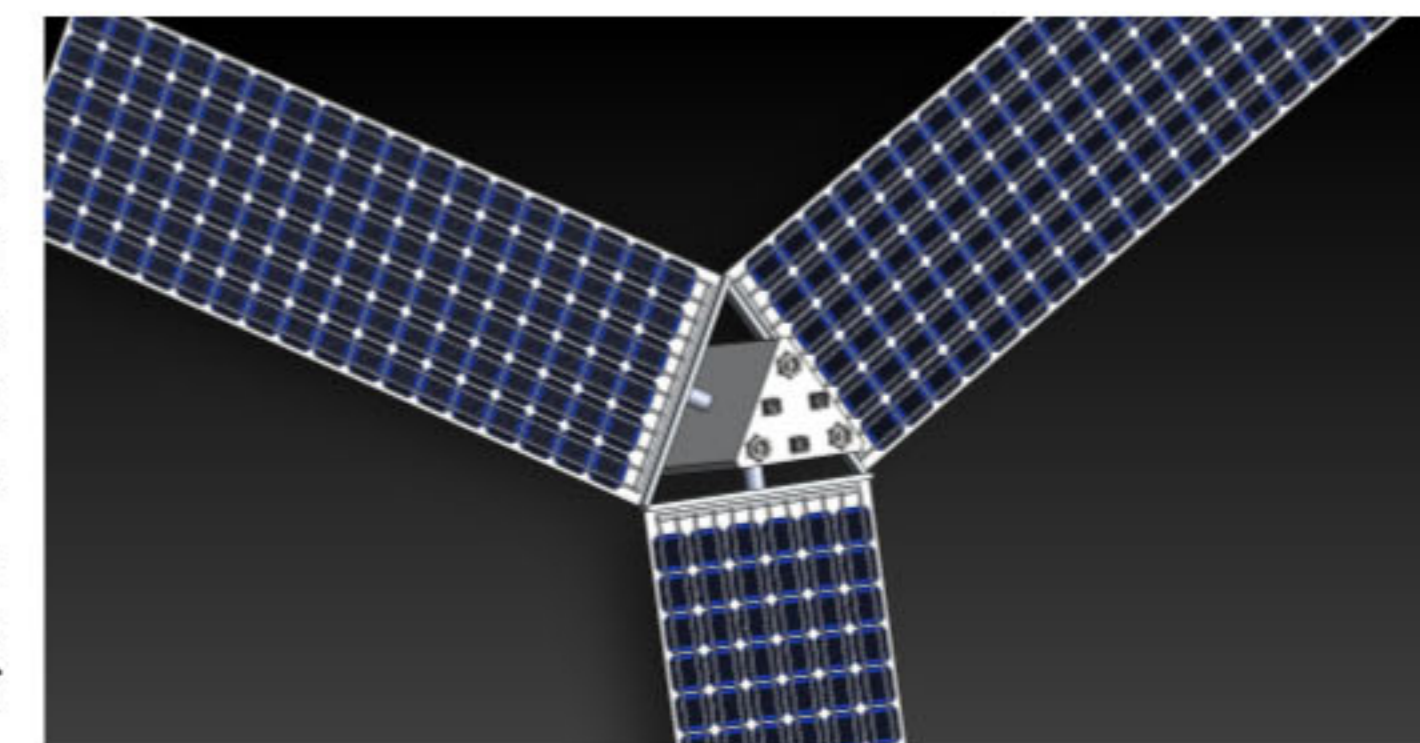
ADCS provides precise three-axis stabilization for HPSEP, utilizing a high-reliability hardware suite of two star trackers, three sun sensors, two IMUs, and a GNSS receiver. Fine pointing control and disturbance rejection are managed by a four-wheel tetrahedral reaction wheel array, a configuration specifically selected to ensure full mission capability and 10-year durability through 3+1 active redundancy. Operating at a deterministic frequency of 10 Hz within the Sirius On-Board Computer, the system maintains a pointing accuracy of  $\pm 0.5^\circ$ . This precision is critical for aligning high-power 54 kW Hall thruster burns, maximizing solar incidence on the 84 kW ROSA arrays, and protecting the 22.9 dB link margin for X-band communications during cislunar transit.



## Design/ Structural Analysis



Finite element analysis of the structure with a 15000N distributed load on the central structure, with a 3000N distributed load on each of the 3 solar arrays. Diagram to scaled by 63x to show directions of displacement.



## References

[1] "BHT-600 Hall Thruster." Busek Co. Inc., <https://www.busek.com>. Accessed 10 Nov. 2025.  
 [2] "Advanced Electric Propulsion System (AEPS)." Aerojet Rocketdyne, L3Harris Technologies, <https://www.l3harris.com>. Accessed 10 Nov. 2025.  
 [3] Blue Canyon Technologies. "Reaction Wheels and Nano Star Tracker." Blue Canyon Technologies, <https://bluecanyontech.com>. Accessed 10 Nov. 2025.  
 [4] Professor Bani Younes, of the SDSU Department of Aerospace Engineering.