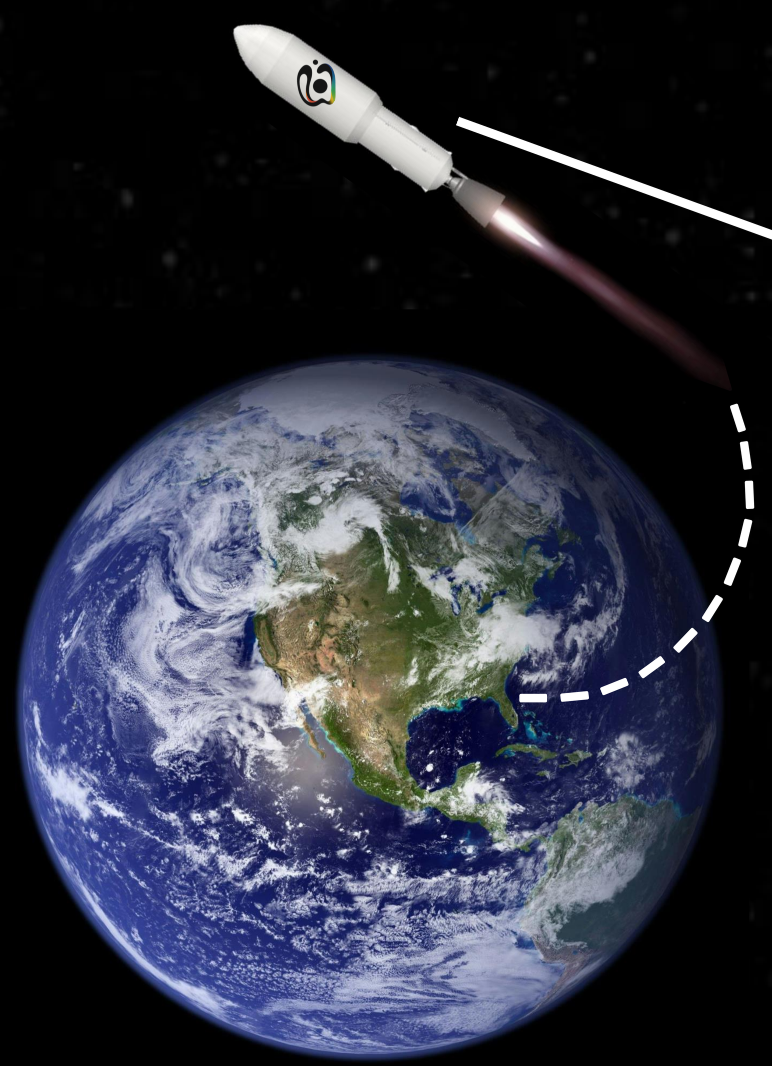
NASA 2025 HuLC Forum | June 2025

THERMOS

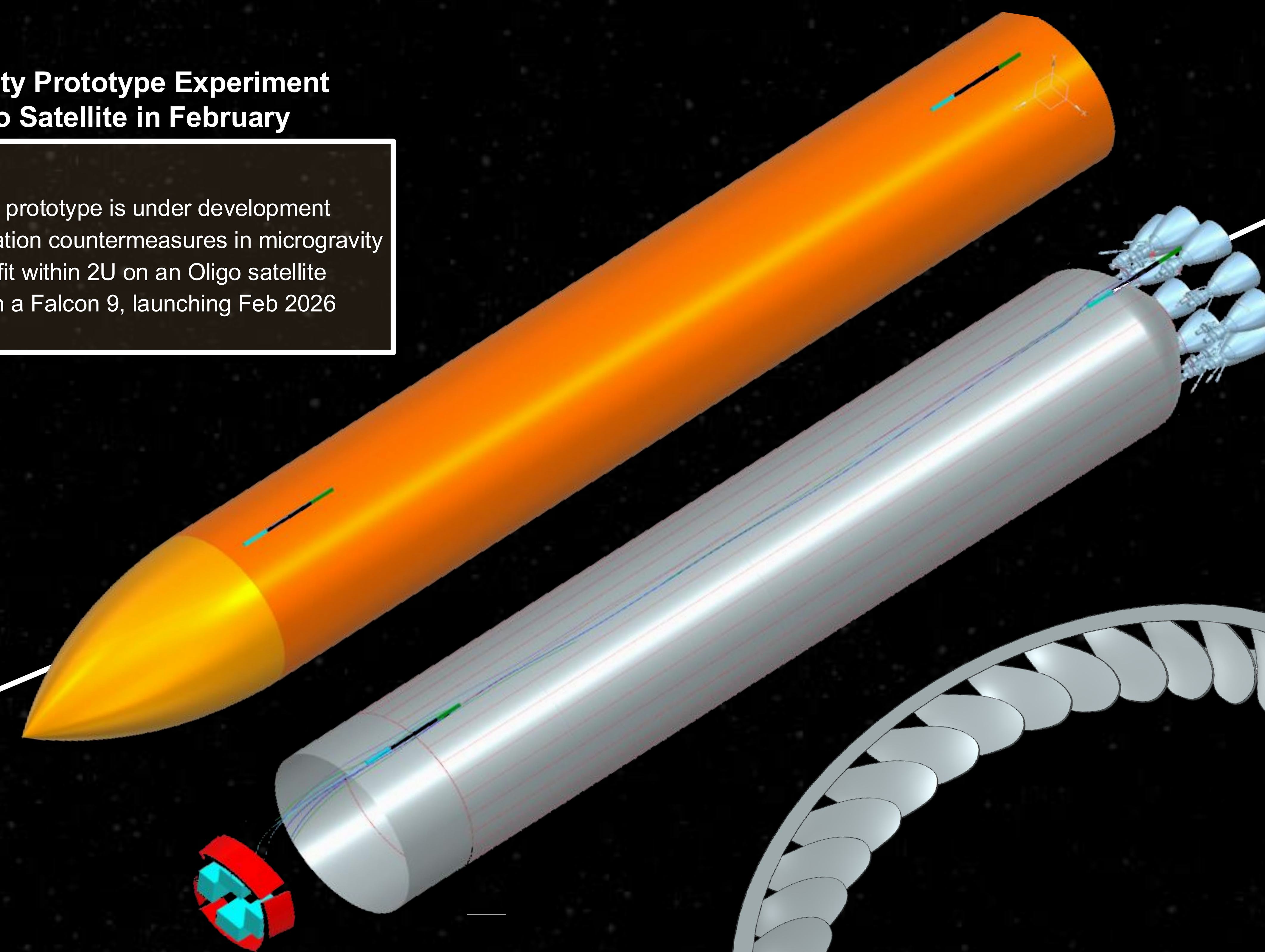
Translunar **HE**at **R**ejection and **M**ixing for **O**rbital **S**ustainability

Massachusetts Institute of Technology



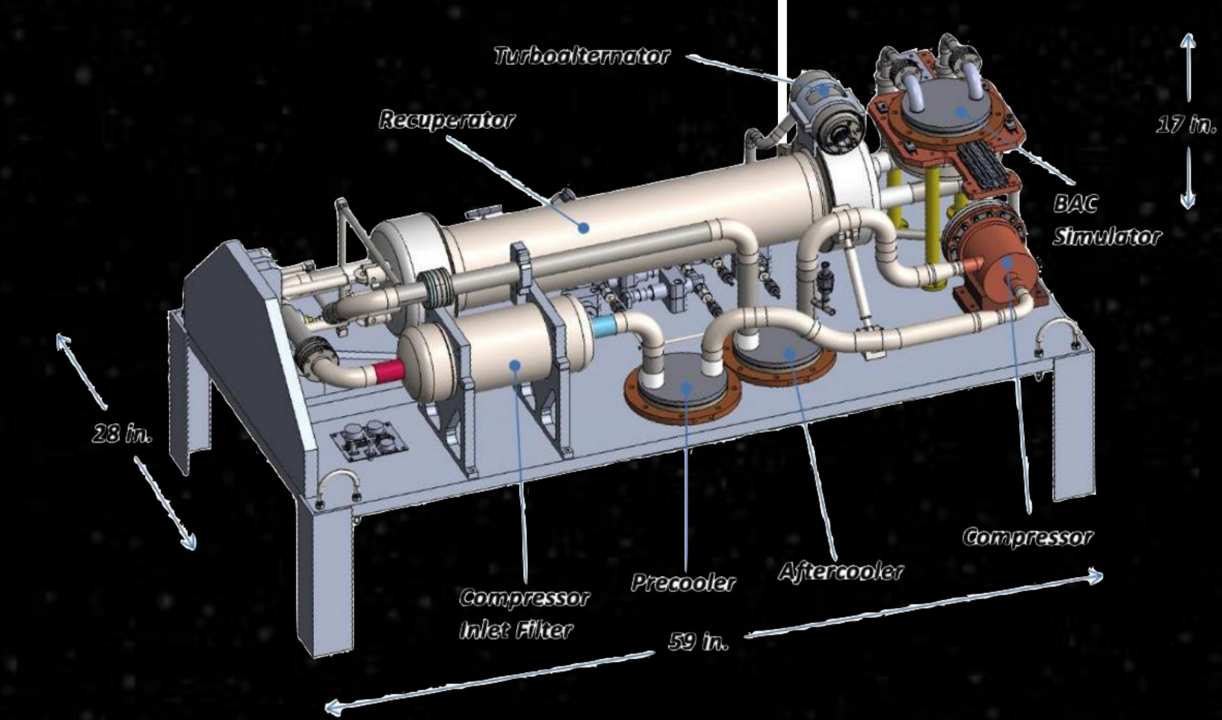
Microgravity Prototype Experiment on Oligo Satellite in February

- Small baffles prototype is under development
- Test stratification countermeasures in microgravity
- Designed to fit within 2U on an Oligo satellite
- Rideshare on a Falcon 9, launching Feb 2026



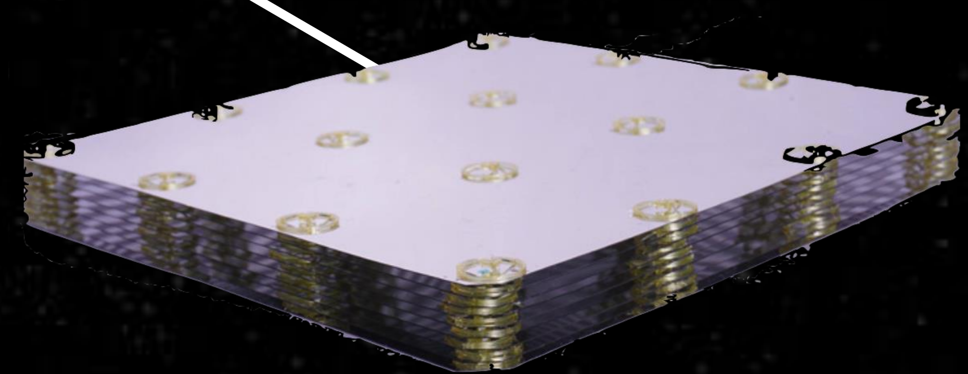
Broad Area Cooling

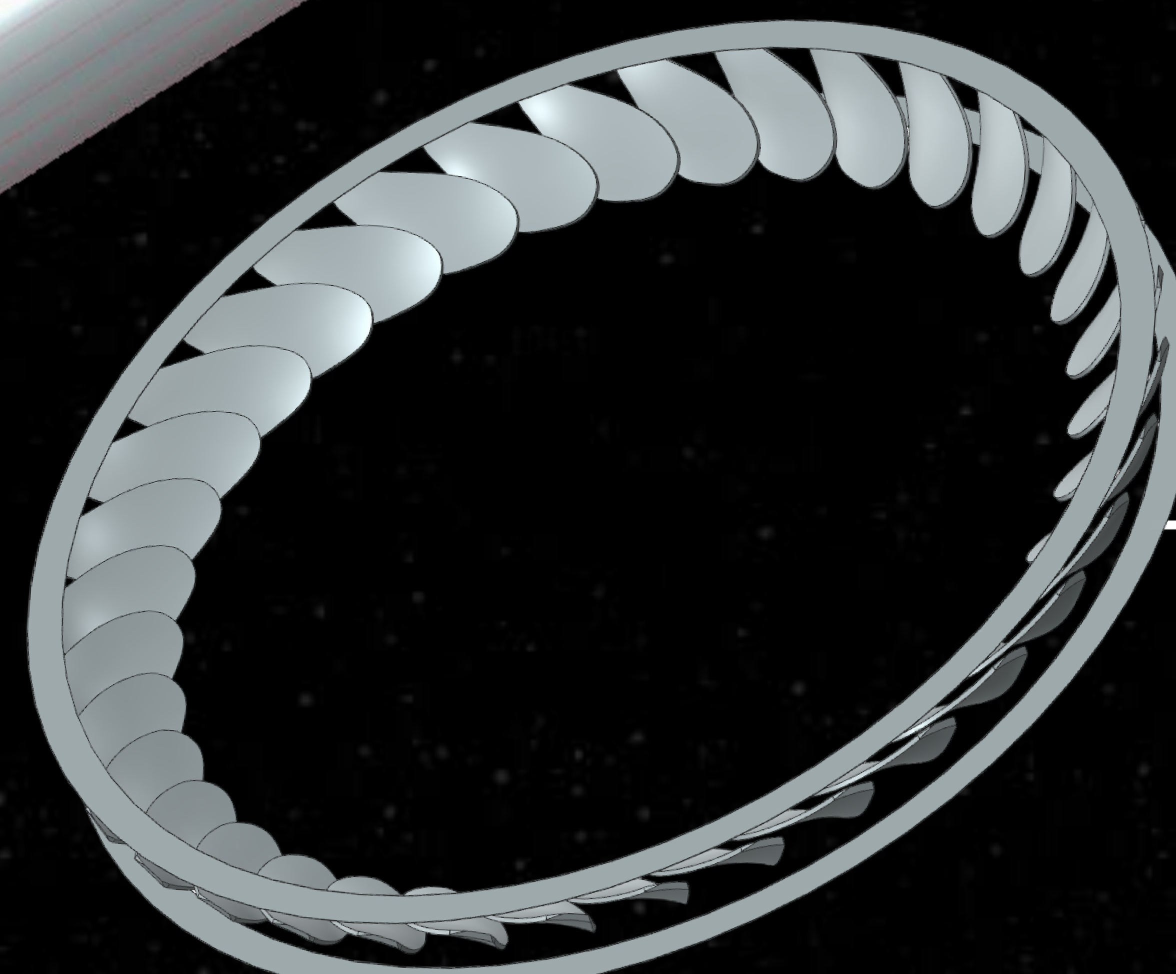
- 7 Creare 150 W @ 90 K Reverse Turbo-Brayton cryocoolers
- 28 evenly spaced coolant tubes around tank
- Coolant tubes act as foundational support for MLI to rest upon
- Mass: 3.4 t / Power required: 8.4 kW



Structural Multi-Layer Insulation (MLI)

- 60 layers result in only 1,400 W of heat leak at NRHO
- Alternating layers of aluminized polymer film and spacer meshes
- Overall effective emissivity from 0.016 to 0.019, with a conservative MLI degradation factor of 4x
- Outermost MLI layer also functions as a Whipple shield and electrostatic charge diffuser
- Thermal, structural and mass synergies with Broad Area Cooling system
- Mass: 12.8 t





Modified Baffles and Cryopump

- Existing slosh baffles twisted and extended into hydrodynamic geometries
- Baffles induce mixing from centrifugal forces from changes in axial rotation for slew correction
- Additional small axial cryopump cycles total volume every 24 hours
- RPM of 2-3 result in radial forces of 0.02g – 0.05g
- Estimated additional mass: 0.6 t

CONCEPT: A SYSTEMS ENGINEERING SOLUTION FOR BOILOFF MANAGEMENT

THERMOS is an innovative, systems-level solution to mitigate boiloff during long-term storage of cryogenic liquids in the space environment, carefully designed for implementation on Artemis missions within 3-5 years.

Key Information:

- Combination of MLI and broad area cooling (BAC) systems enables near-zero boiloff in NRHO (75% of time)
- Novel internal baffle design with internal axial pump reduces temperature stratification within propellant tanks
- Innovative combination of proven and well-known technologies allows for a realistic path to flight by 2029

ROBUST, EFFICIENT, AND EASILY IMPLEMENTABLE ARCHITECTURE

Combination of MLI and BAC lead to high levels of redundancy:

- THERMOS yields Lunar Accent Propellant Margin (LAPM) of 25.5%
- Failures in one subsystem are mitigated by other systems:
  - LAPM is only reduced to 22.5% with total cryocooler failure
  - With MLI degradation factor of 9x, LAPM only falls to 14.3%
- Combination of both passive MLI and active cryocoolers maximize THERMOS overall redundancy

Synergy between active and passive systems:

- Passive systems (MLI, baffles) use no power and are low risk
- Active systems (BAC, cryopump) enhance performance, optimize heat rejection, and complement passive systems
- Mission mode decision (HEO departure) with mix of well-known technologies improves robustness and probability of mission success

System design leads to easy implementaion:

- THERMOS is mainly additive, avoids excessive HLS vehicle changes

DESIGNED FOR SHORT PATH TO FLIGHT FOR ARTEMIS III

Reliable proven technology allows for rapid integration:

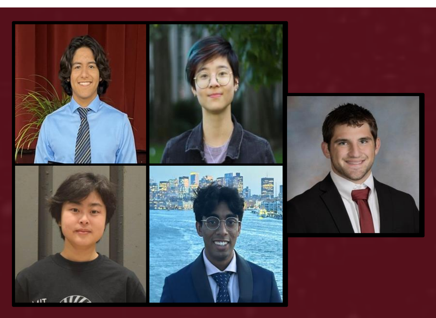
- Novelty of THERMOS is in system design, not subsystem design
- MLI, Broad Area Cooling are relatively well-known technologies
- MLI TRL in relevant use cases is 9; BAC and baffle TRL are 4
- Implementation into Starship tanks could lead to flight tests as early as 2026
- Based on our TRL maturity analysis, THERMOS will be fully capable of a crewed Artemis III mission in 2029
- THERMOS is designed for use on Starship V3, but can also be implemented on Starship V2 and still have a viable LAPM

Beyond Artemis III:

- THERMOS concepts are readily scalable and easily applied to cryogenic storage in cislunar and lunar environments
- Cryogenic storage is a necessary technological development to allow for Lunar Gateway and human expeditions to Mars

TEAM

Students:



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(Photos from left to right)

Acknowledgements:
Jules Penot, Lorenzo Nardi, Soki Sakurai, Yuki Murota; MIT course 16.89, MIT Space Resources Workshop, Oligo, *NASA ESDMD, Mass Space Grant, and HLS program office*

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