UCST

The Cryogenic Complex: Cryogenic Tanks and Storage Systems

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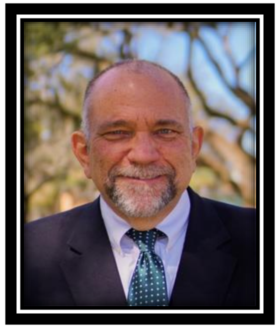

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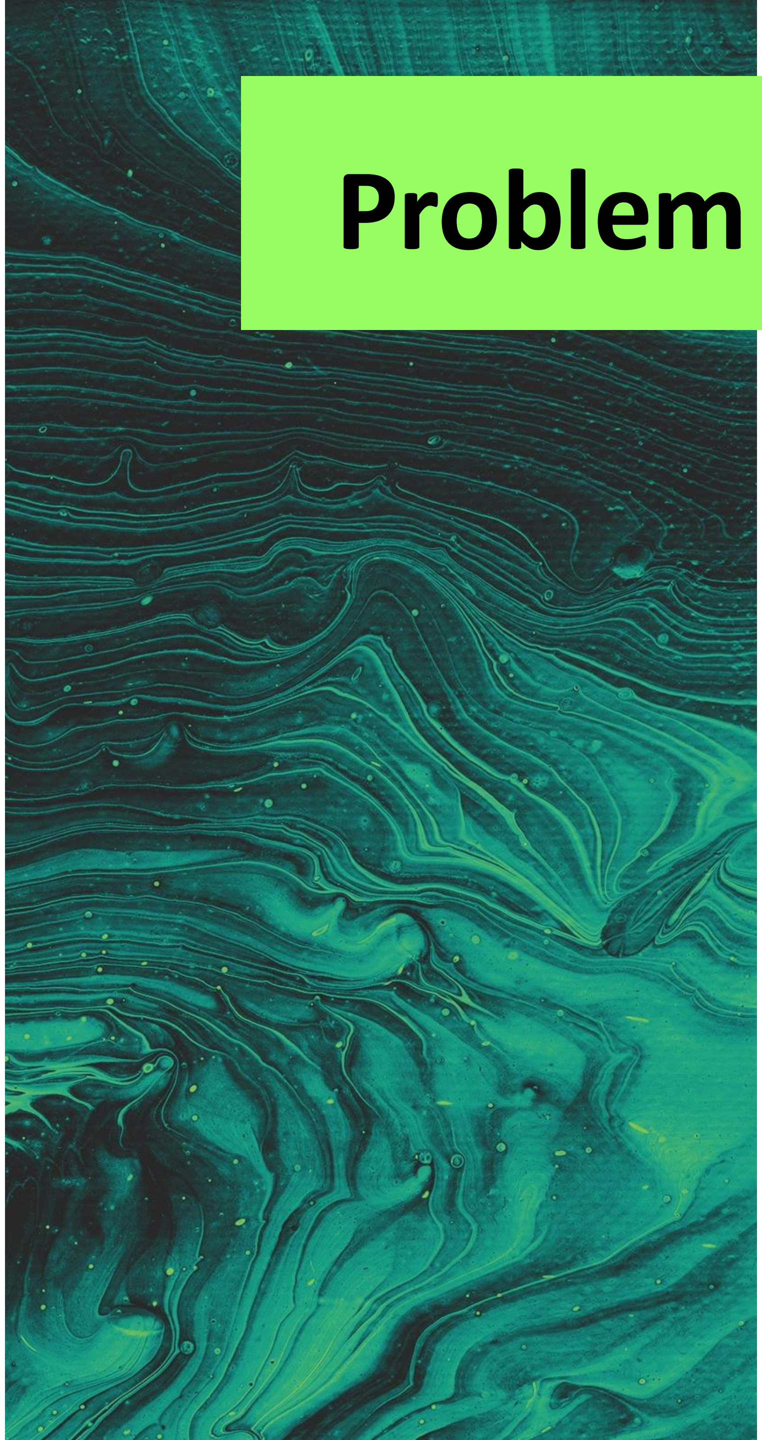
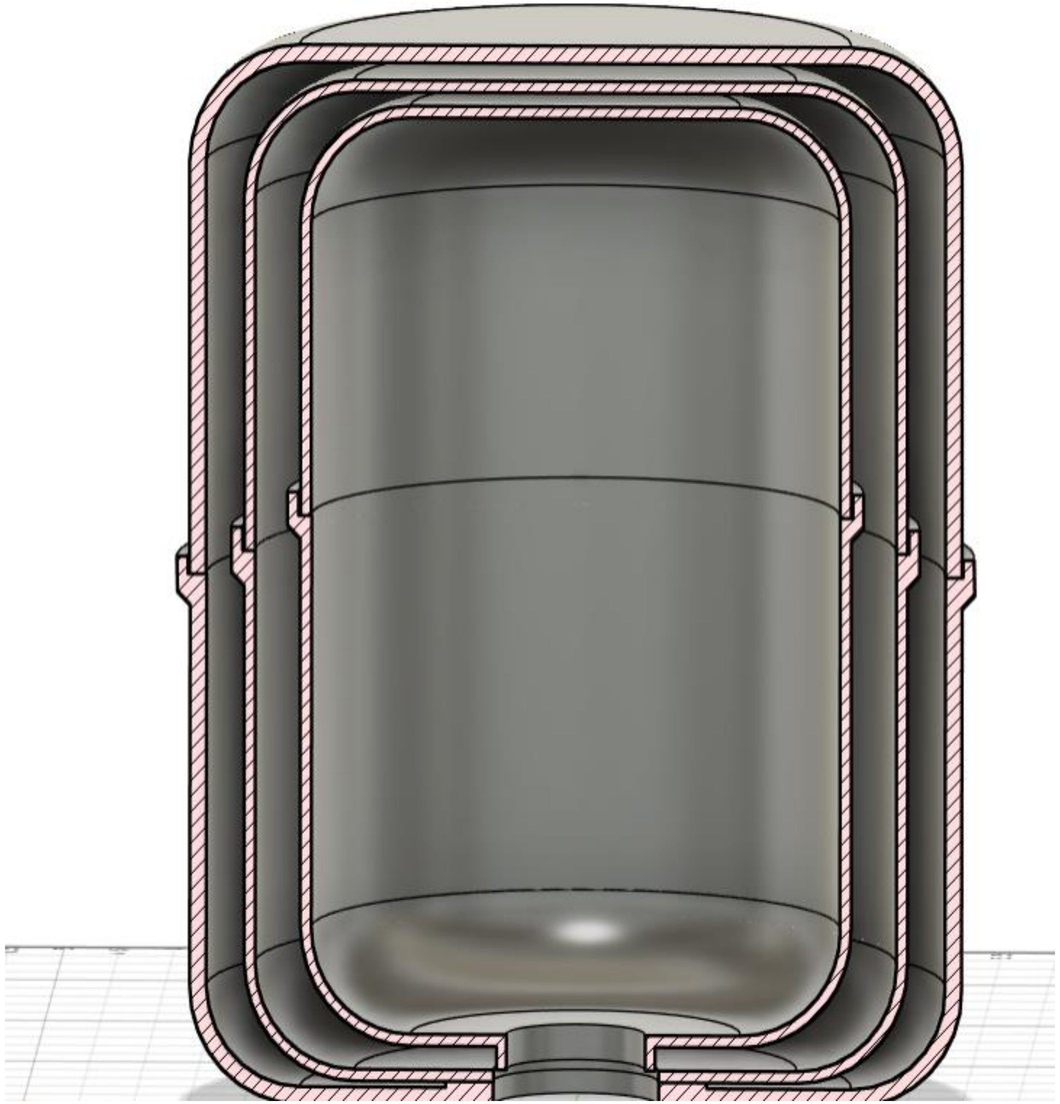


Problem Statement

- Artemis and Gateway missions require sustained fuel transfer across Moon-Gateway-Earth.
- No current system exists to store and distribute cryogens efficiently in cislunar space.
- **Long-term presence on the Moon depends on a modular, reusable, standardized cryogenic infrastructure.**



Overview

- **UCST enables reliable, reusable cryogenic fuel storage and transfer** for lunar, orbital, and deep-space missions.
- **Standardized, modular design with passive thermal control and automation** minimizes fuel loss and eliminates the need for human handling.
- **Supports long-term sustainability** by integrating with in-situ resource systems and reducing reliance on Earth-based resupply.

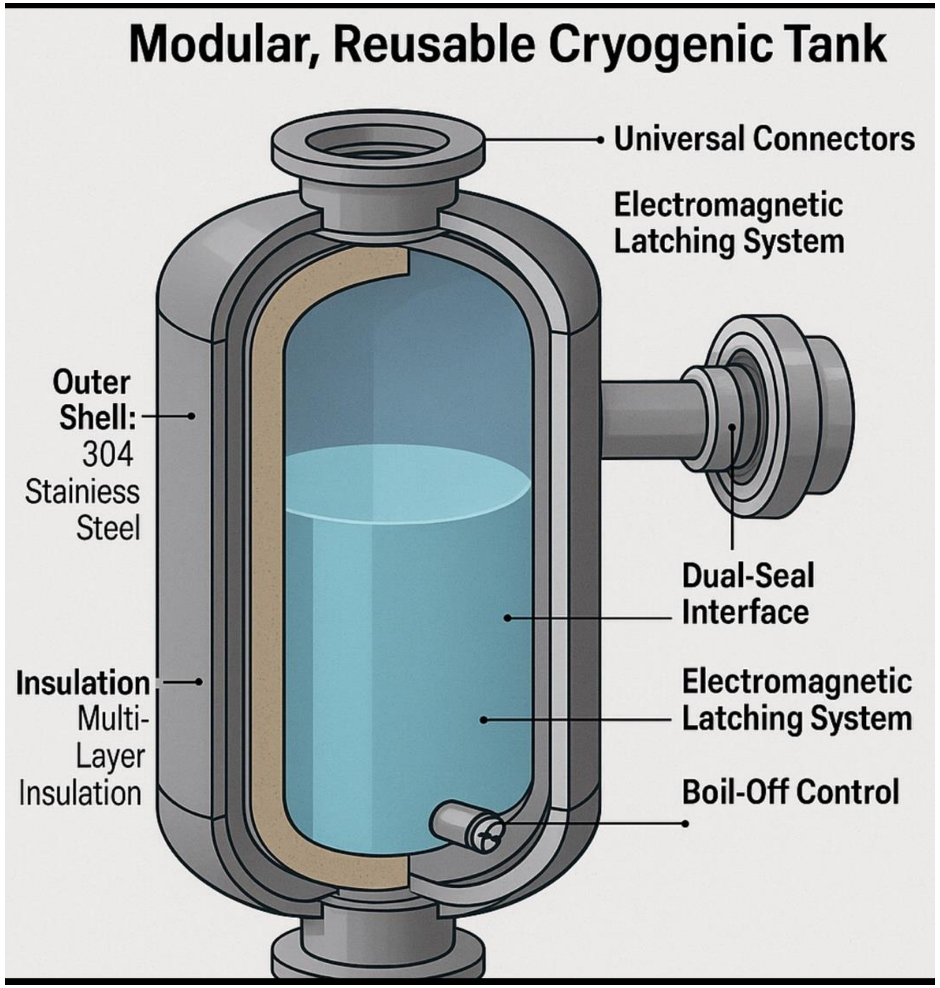
UCST:
The Universal Cryogenic Storage Tank

UCST

Key Features:

- **Form & Function:** a steel-composite cylinder sized for standard cargo bays, each holds ~1 000 m^3 of cryogen
- **Handling Interfaces:** ISO trunnions align within ±0.5 m; robotic latches apply 10 kN preload to seal automatically
- **Mass Optimization:** uses an Al-Li 2195 core wrapped in CFRP to keep dry mass ~1 150 kg despite its size
- **Automated Flow:** bayonet-style connectors lock in one motion; motorized valves cycle in under 2s for unmanned ops

Construction



Core & Skin:

- Al-Li 2195 core (yield 450 MPa; density 2.66 g/cm³)
- CFRP wrap reduces skin mass by 25 % vs. all-metal

Structural Ribs:

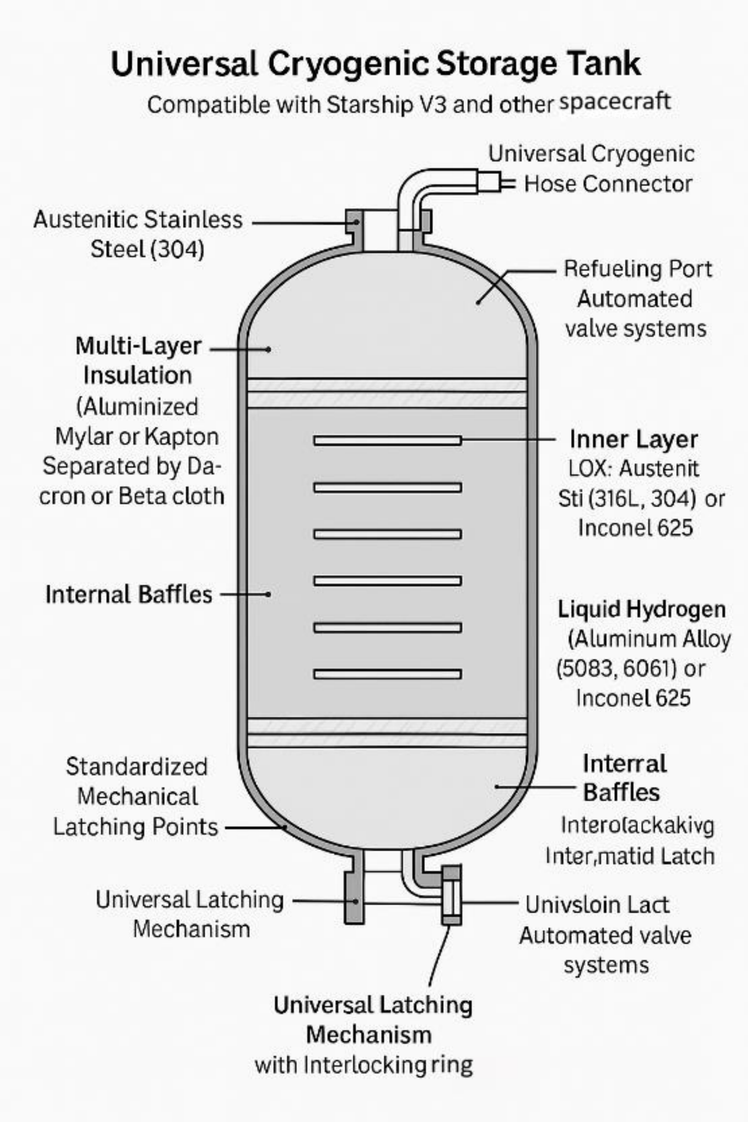
- Closed-cell foam ribs at 1 m spacing withstand 0.2 g launch loads
- Limit slosh amplitude to <5 % of volume

MMOD Shield:

- Whipple bumpers spaced at 50 mm; mitigate 0.5 g impacts at 7 km/s

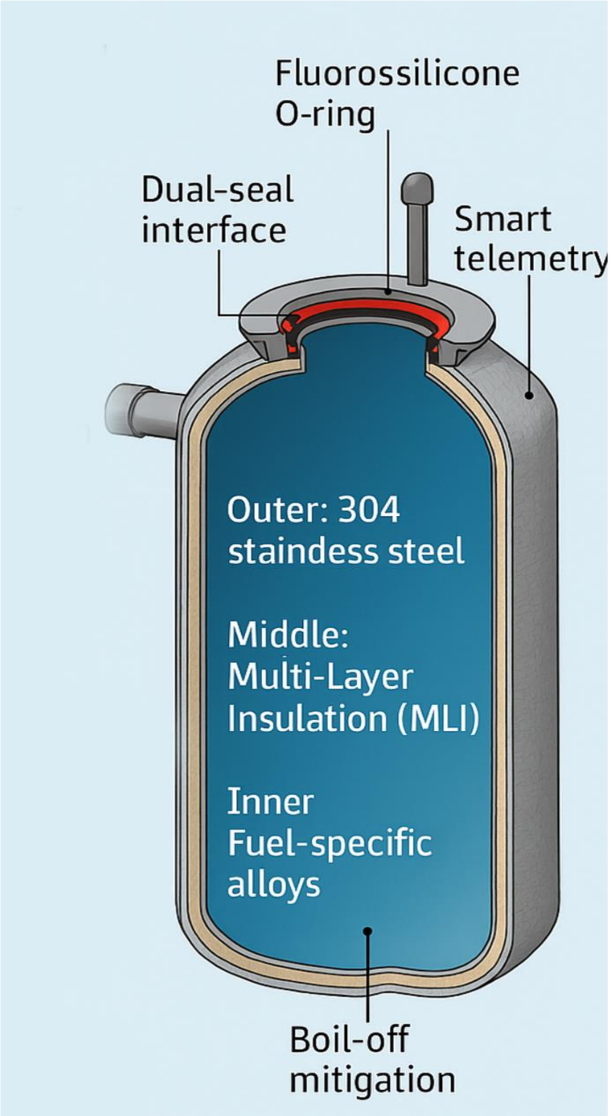
Three Layers

- **Outer Shell** (304 SS): 2 mm thick stainless steel provides impact resistance, corrosion protection, and a smooth weldable surface
- **Insulation** (MLI): 5–30 Mylar/Kapton sheets with Dacron mesh between layers, yielding <1 W/m² radiative heat flux and minimal conductive paths
- **Inner Liner**: fuel-specific material that prevents chemical interaction—316L SS with Teflon/epoxy for LOX, Al 7075/Inconel 718 for LH_2 toughness, and epoxy-phenolic composite for CH_4



Sealing and Interface Technology

- **Primary Seal**: silver-coated nickel alloy gasket matched to core's CTE (±5 ppm/°C) for zero-stress sealing
- **Backup O-Ring**: fluorosilicone rated to –200 °C sits in a redundant cavity to catch leaks
- **Debris Caps**: spring-loaded stainless-steel covers automatically retract upon docking to block regolith
- **Leak Testing**: helium mass-spectrometry confirms $<1\times10^{-9}$ scc/sec per seal before deployment
- **Telemetry Bus**: ARINC 429 output streams sensor data (pressure, temp, fluid-level) in real time



Accessory Systems

Hose Connectors: bayonet fittings lock with 10 kN pull-off strength; quick-release lever allows emergency disconnect

Automated Valves: 2″ cryo-rated ball valves open/close in <2 s and withstand >10 000 cycles

Cryo-Pumps: deliver up to 0.5 kg/s flow; integrated Joule–Thomson loop recaptures boil-off for reuse

Safety Suite: burst discs at 1.2× operational pressure; smart telemetry logs 50+ parameters/sec for anomaly detection

Usability and Versatility

Usability and Versatility

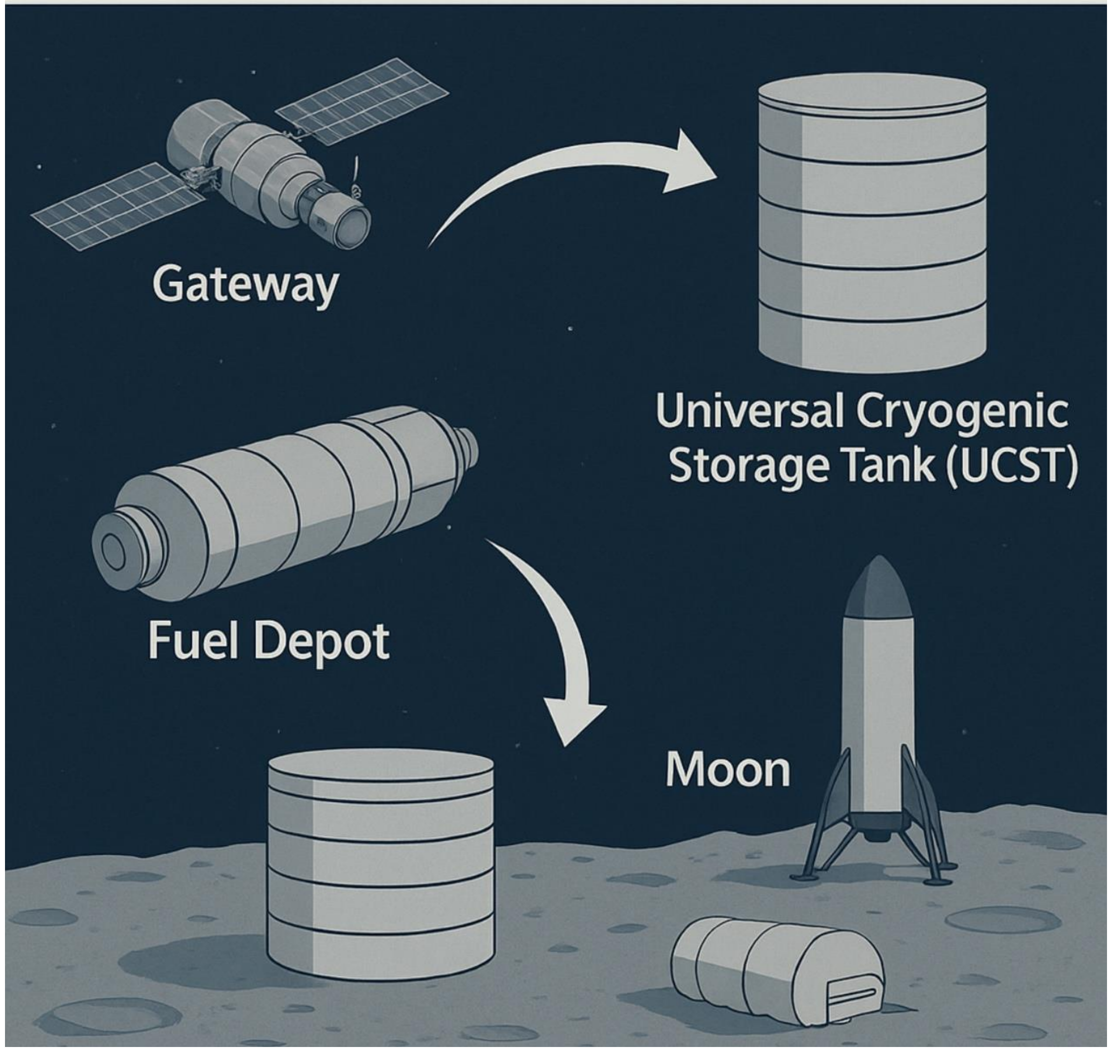
- Designed for both cryogenic storage and durable transport
- Canisters are insulated to maintain cryogenic state of LOX and LH2 in extreme environment
- Modular and interconnectable cannisters will be easily replaceable, into cargo bays, storage complexes, and spacecraft.
- Each Canister will be refillable and reusable and will be returned to the lunar surface where they can be refilled with LOX and LH2 for their next use.

Deployment Environments

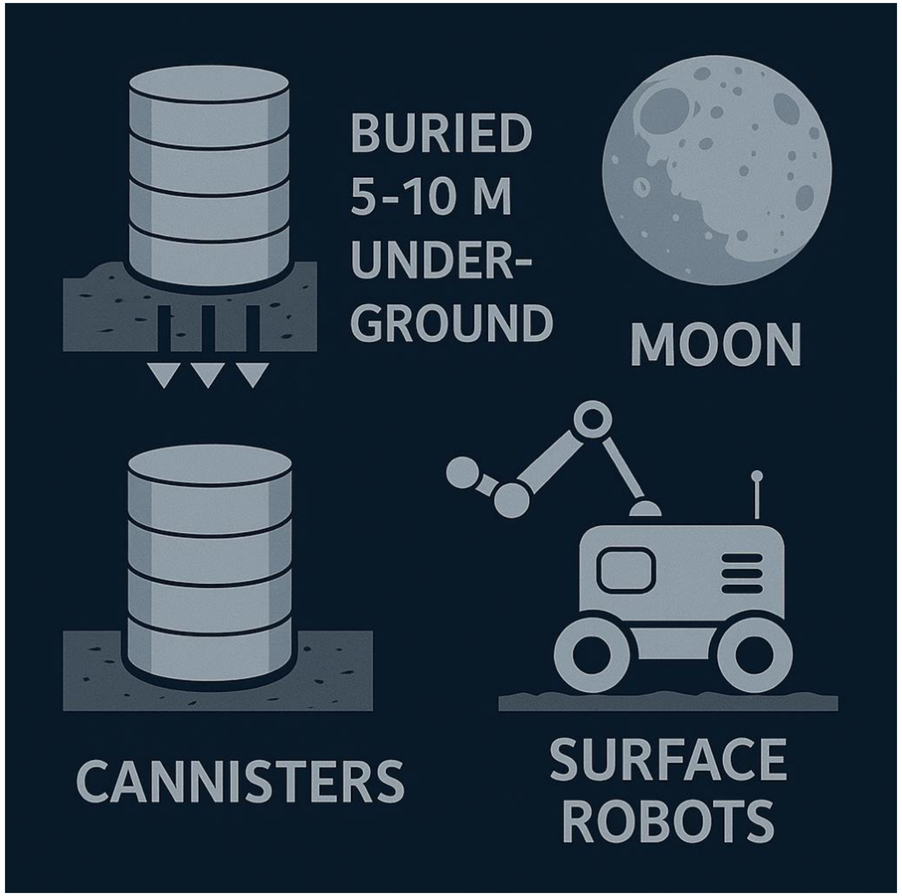
Fuel Farm

Fuel Depot

Gateway



Fuel Farm

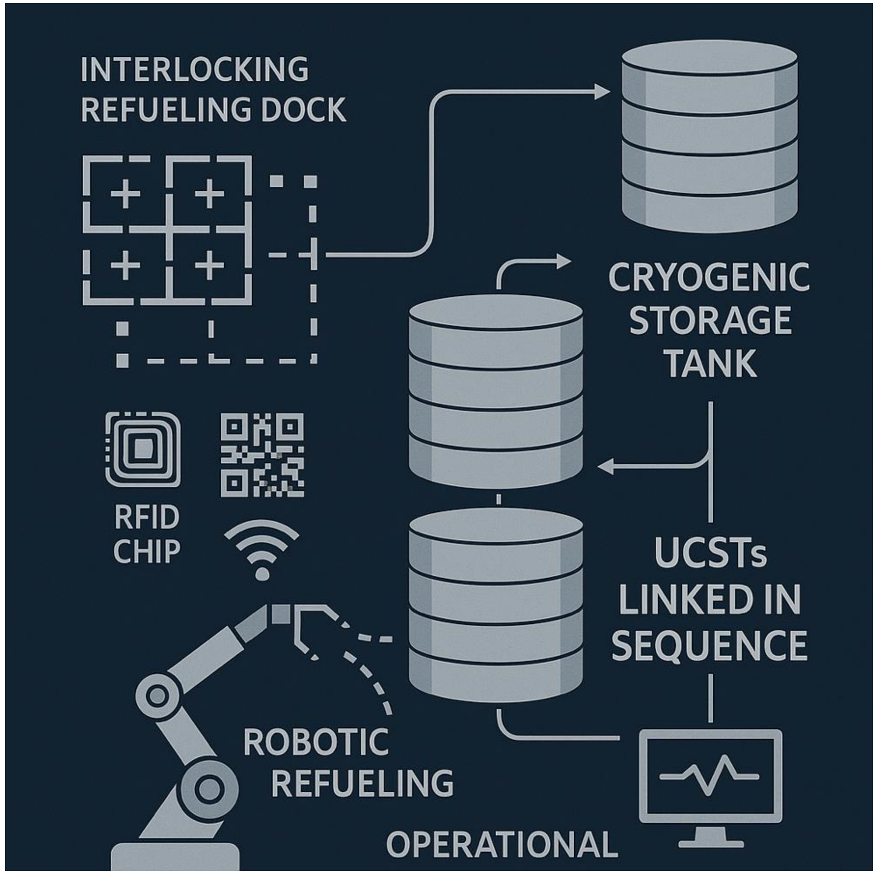


UCST cannisters will deployed on the moon surface and buried 5-10 meters underground.

Surface operations will have partially buried cannisters with exposure to the interface for daily operation.

Surface robots equipped with standard grappling tools will access and refill UCSTs without human intervention.

Fuel Depot



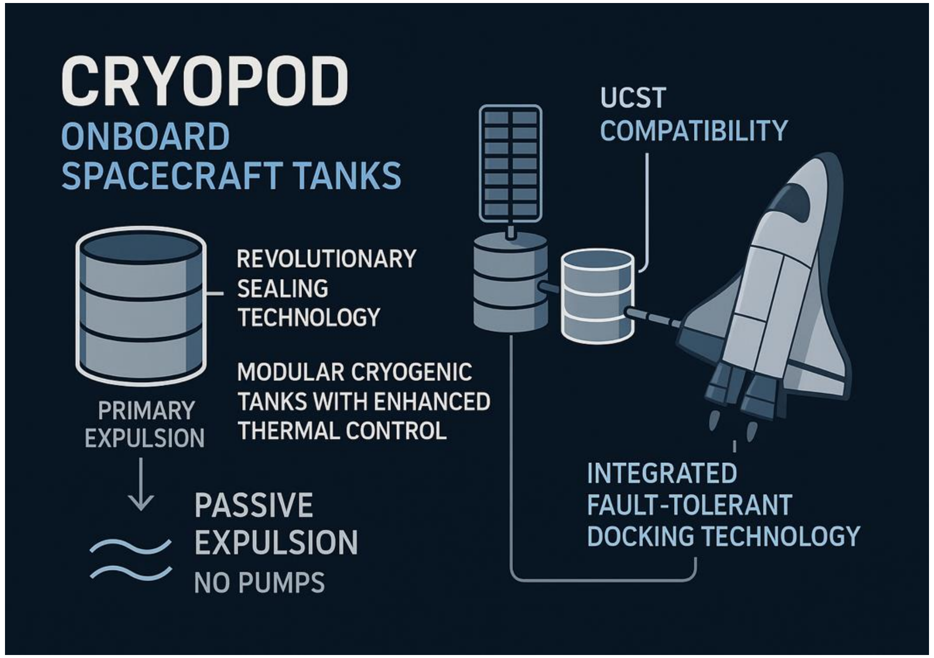
UCSTs linked in sequence will form a scalable, in-space cryogenic fuel storage

Interlocking system enable modular grids and customizable refueling docks

RFID chips, QR-coded fiducials, and thermal beacons support robotic alignment and health diagnostics.

Each UCST logs operational history for mission planning and lifecycle assessment

Onboard Spacecraft Tanks



- Used as a primary fuel tank for HLS-type spacecraft
- Mission optimized variants: Shuttle units use passive expulsion (no pumps)
- Standardized keg-style connector with compatibility with Blue Moon landers, Starship 3 and derivatives, and Gateway service modules.
- Fault-tolerant collars: able handle robotic misalignment
- Standardized docking interface makes UCSTs swappable between vehicles without a “one-size-fits-all” compromise.

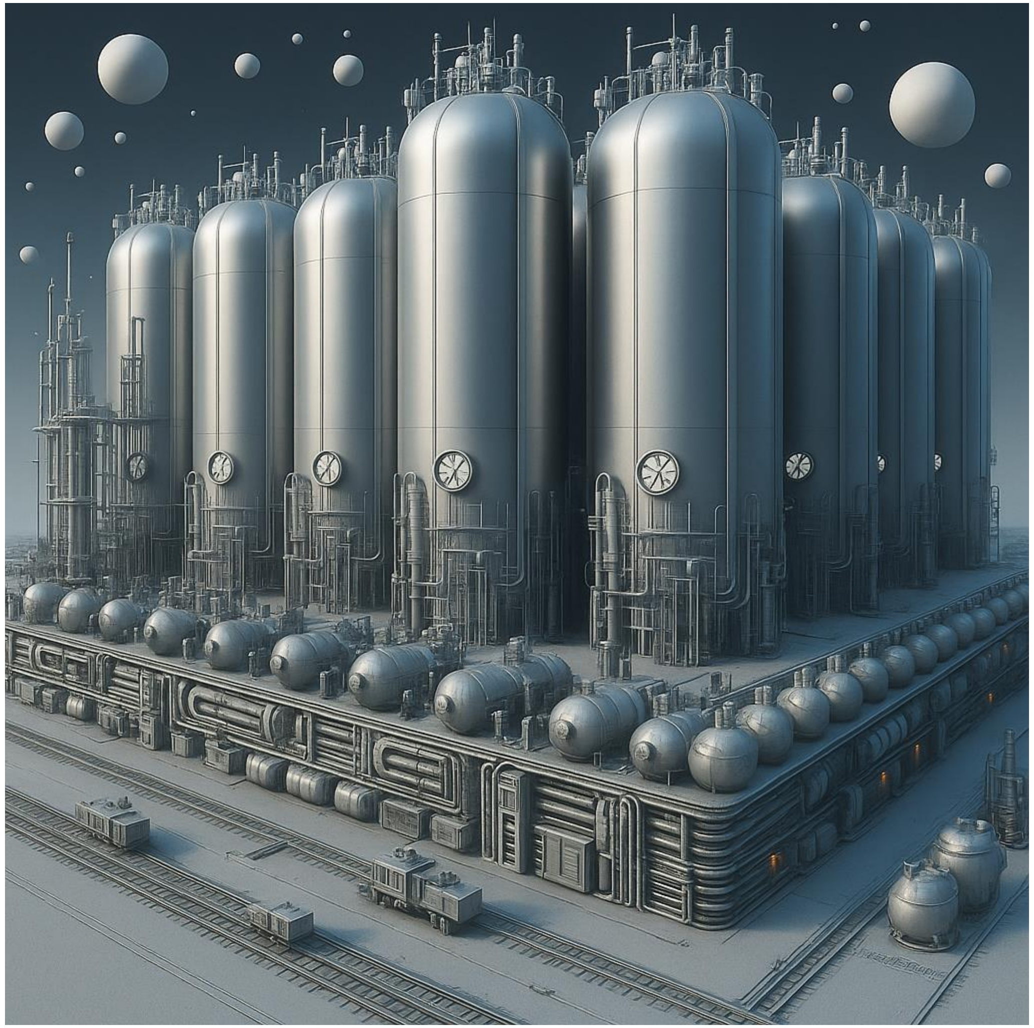
Earth to Cryogenic Complex

Earth to Cryogenic Complex – Launch and Transit

Launch Frame Design	V-block supports tuned to a 5 Hz natural frequency using adjustable preload springs, isolating the tank from launch vibrations
Vibration Testing	Flexible mounts and real-time accelerometers absorb and monitor shocks so internal components and seals stay secure.
Thermal Protection	Multi-layer insulation and directed vent paths minimize heat entering the tank, keeping cryogens cold throughout the journey.
Environmental Monitoring	Built-in sensors continuously log pressure, temperature, and motion data to track tank health during flight.

Lunar Fuel Farm Mining And Refueling Operations

- Lunar Regolith provides oxygen, hydrogen, and water ice for propellant production
- Automated Mining Equipment extracts water ice from lunar craters
- Water is electrolyzed into oxygen and hydrogen, stored on-site
- Uses in-situ resource utilization (ISRU) to convert mined resources into LOX & LH2
- Refueling stations store & pump LOX and LH2, into reusable canisters.



Depot to Moon Shuttle (Cislunar Transfer)

Lunar mining	• Extract LOX, LH2m and methane from lunar regolith • Reusable cannisters are refilled at lunar station
Lunar Surface Launch	• Shuttle rocket Designed for low lunar gravity • Uses Lightweight UCST tanks with lunar-optimized structure
Ascent to Cislunar Orbit	• Transit time: 3-4 days
Dock with Fuel Depot & Gateway	• Deliver Propellant to UCSTs for mission usage • Compatible with standard fueling ports
Resue & Repeat	• Same canisters can be reused for multiple missions from the Lunar Surface • Cuts launch costs and supports sustainable lunar operations

Verification Tools and Facilities

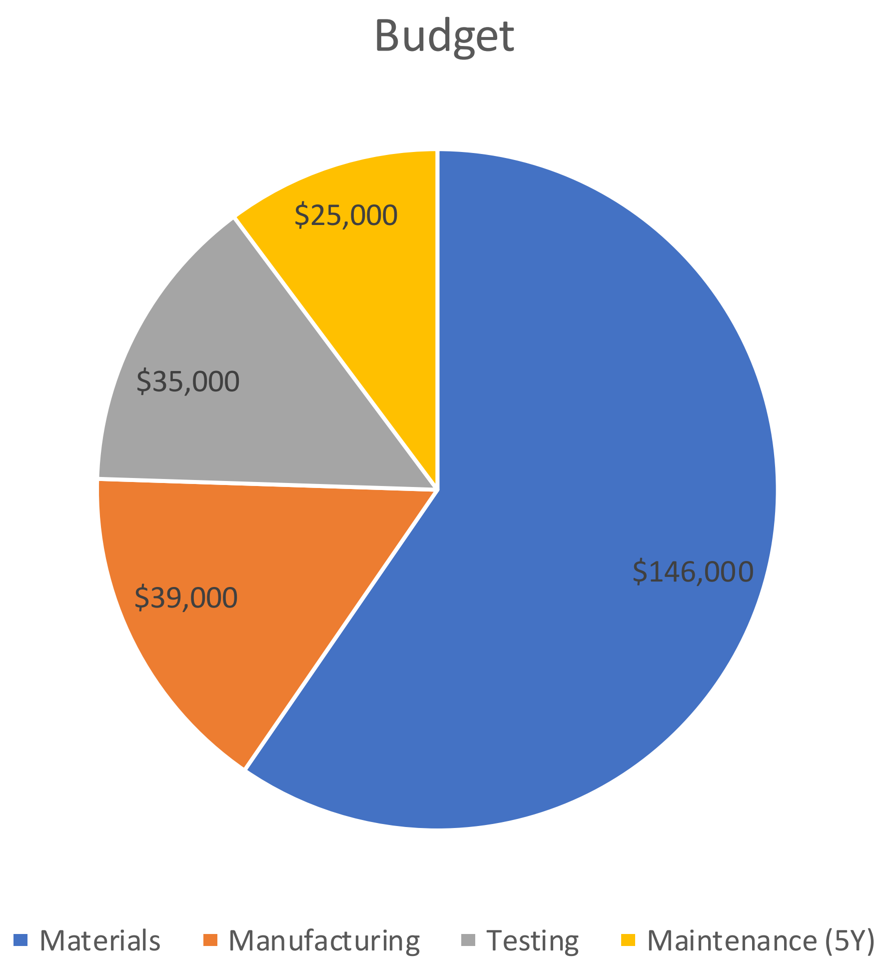
- **Testing sites**: UCF Cryogenics Lab, Nasa Marshall
- **Built-in sensors**: strain gauges, RTDs, and Capacitance-based liquid level sensors.
- **Docking tests**: robotic rigs setup to check seal degradation with UCSTs over 200+ cycles.
- **Additional tools**: Leak detectors, infrared imaging for thermal mapping, 3D photogrammetry scanners for post-test dimensional verification.

Timeline

0-6 months	• Complete PDR/CDR reviews • Finalize CAD/FEA procure materials • Build 50 L LN subscale
6-12 months	• Subscale testing and seal/rib optimization; • Document boil-off, leaks; seal review
12-18 months	• Fabricate 300 L prototype with full accessory suite • Run vacuum, thermal and vibration-cycle tests
18-24 months	• Build and instrument full-scale tank • Life-cycle stress, automate operations
24-30 months	• Deploy AI health diagnostics, conduct depot and grappler interoperability drills
30-36 months	• Final documentation, complete HLS certification, deliver demo units to lunar orbit and surface

Budget Breakdown

Developmental Phase	Cost (USD)	Description
Materials	$146,000	Teflon, Al-Li 2195, Mylar, Pryogel, CFRP (~1000 kg total)
Manufacturing	$39,000	Labor, Cutting, Assembly, and Tooling ($39/kg avg)
Testing	$35,000	Cryogenic Performance, Structural Integrity, Radiation Resistance
Maintenance (5Y)	$25,000	Routine Inspection, sealing replacement, upgrades
Launch to LEO	$11,500,000	Based on 1150 kg @ $10,000/kg via Falcon 9, Vulcan, or Starship
Total	**$11,745,000**	



Conclusion

- **Reusable** UCST’s store & transport LOX, LH2 and methane from earth to moon, Gateway, and Fuel Depot
- **Supports sustainable** lunar exploration – Vital for Artemis, Gateway, and Future missions
- **Modular** adaptable design with low leakage, high durability, and robust materials
- **Scalable,** field-replaceable, solution- foundation for next-gen propellant management

NASA

HuLC

HUMAN LANDER CHALLENGE

CRYOGENIC COMPLEX

JACKSONVILLE UNIVERSITY

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Questions?