

Assessment of a Surface Propellant Transportation System Concept for Operations on Mars

National Aeronautics and
Space Administration



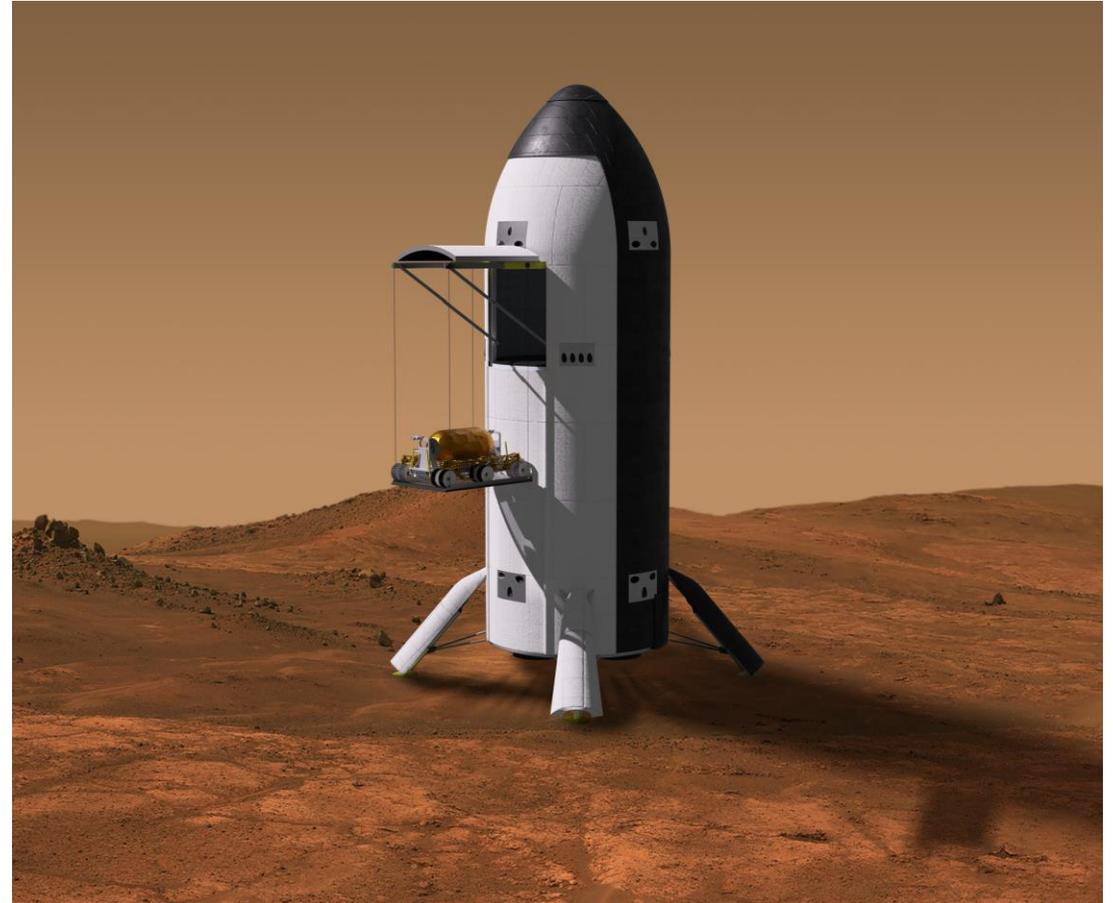
Jared Congiardo
NASA/Kennedy Space Center
AIAA Scitech Forum
January 6-10, 2025



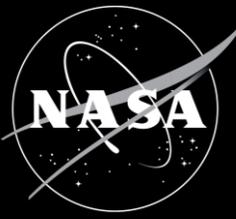
Introduction



- Mars Ascent Vehicle (MAV) likely largest indivisible payload predeployed to Martian surface
- Entry, Descent, and Landing limitations may make landing MAV without ascent propellant advantageous
- Options for strategies to acquire ascent propellant prior to crew arrival being studied



Trade Space

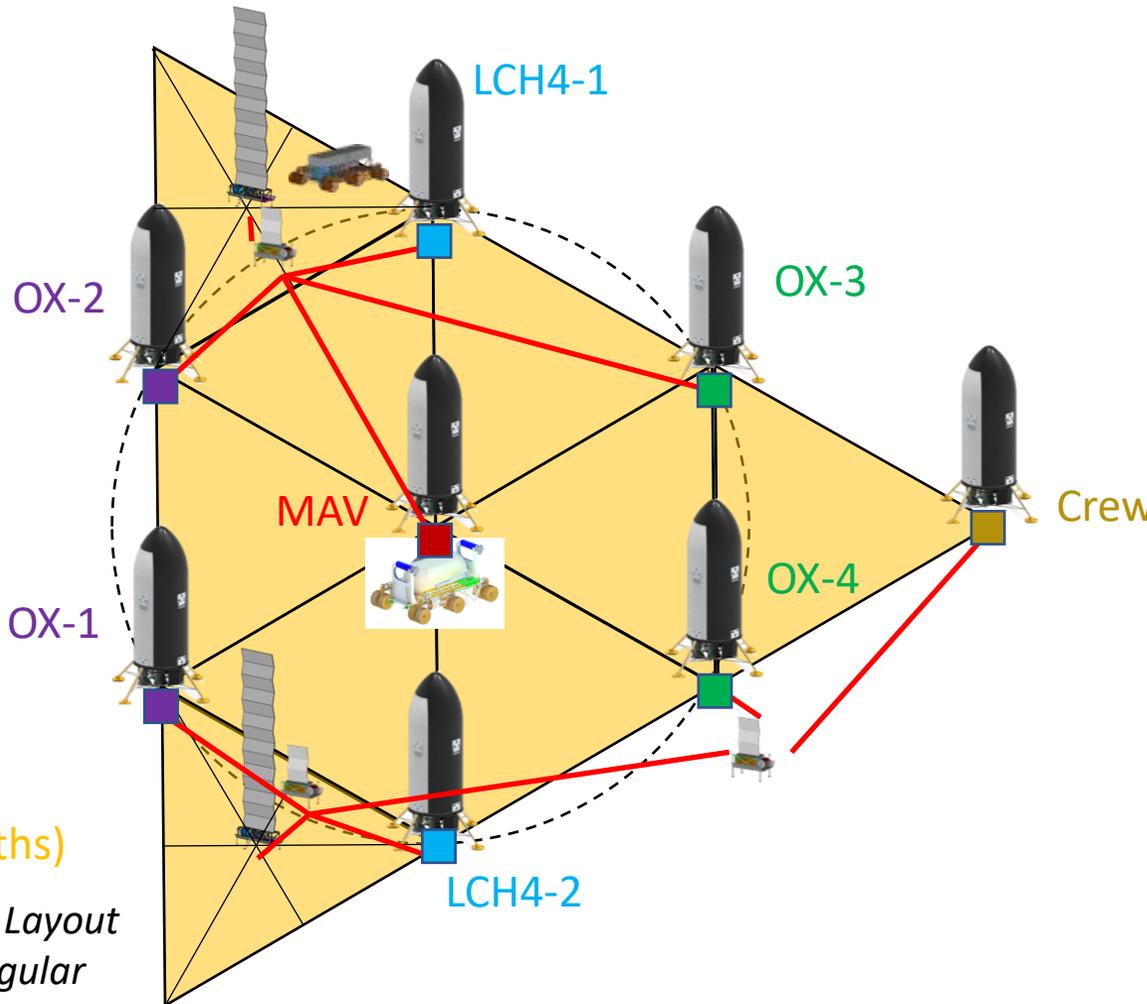


- 75t payload capacity vertical lander
- Integrated ascent vehicle
- Cryogenic propellant (LOX/LCH₄)
 - 300 t cryo propellant required for MAV launch
- Delivery of all required propellant from Earth
 - No In-Situ Resource Utilization (ISRU) propellant production performed

Concept of Operations



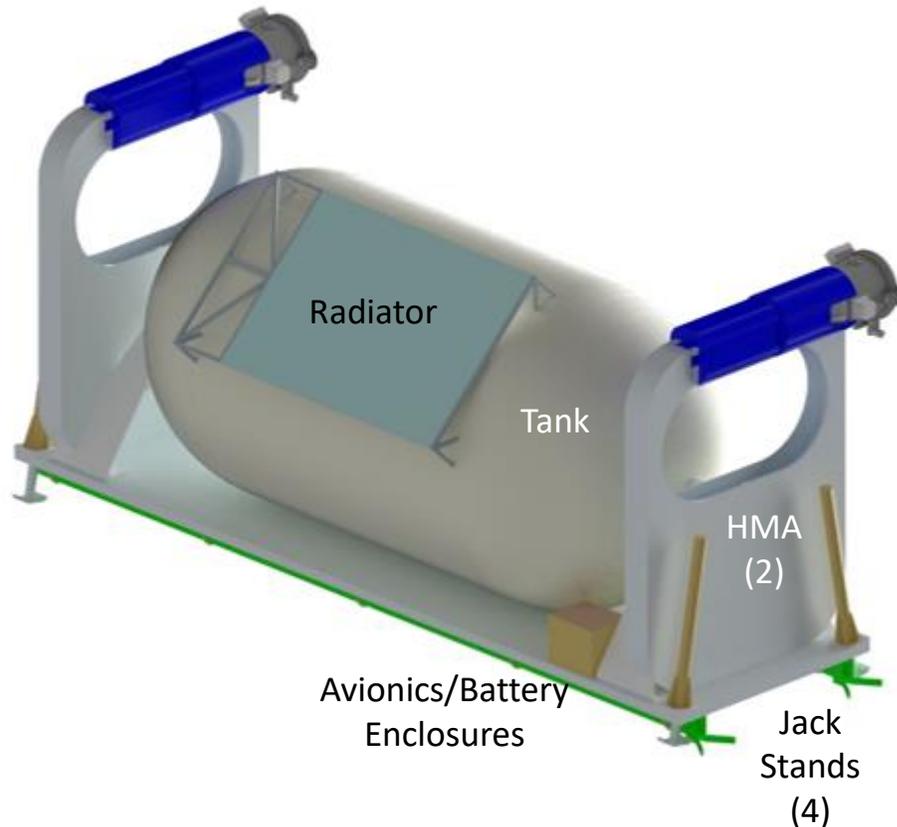
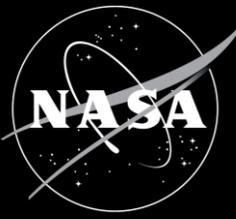
- 104 Months
- 78 Months
- 52 Months
- 26 Months
- 23 Months
- 1 Month
- Departure (-0 Months)



- 2x Methane Tankers land
- Each carries an FSP system and a Mobility Chassis
- Respective Mobility Chassis deploy FSP to predetermined point (currently centroid of adjoining grid triangle)
- First two oxygen tankers land and are connected to the FSP grid to power onboard cryocoolers
- Second two oxygen tankers land and are connected to the FSP grid to power onboard cryocoolers
- MAV lands carrying 3x cryo transport pallets (if no room on methane tankers)
- Mobility chassis retrieves transport pallets and connects the MAV to the FSP grid
- Following commissioning, cryo transport pallets complete minimum one round trip/day to load propellant to MAV
 - Load LOX first, then methane
 - 48 trips LOX/40 trips LCH4
- Purge gas available if a cryo transport pallet must change service
- Crew arrival
 - MAV load must be complete prior to landing
- Crew Departure
 - Mobility systems (Chassis + cryo transport pallets) relocated to safe distance
 - Tanker landers abandoned in place

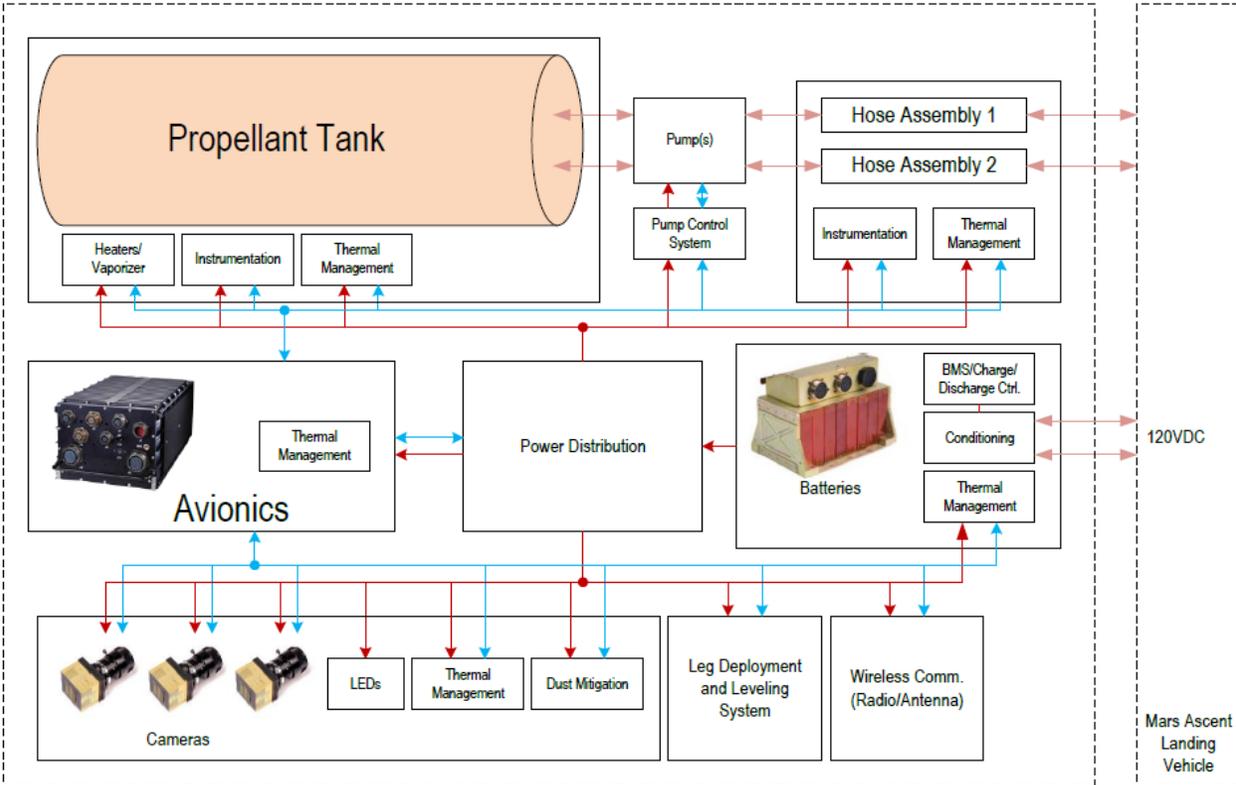
Notional Site Planning Layout
 (1 km equilateral triangular
 grid)
 Strategy & Architecture Office

Propellant Tanker Pallet



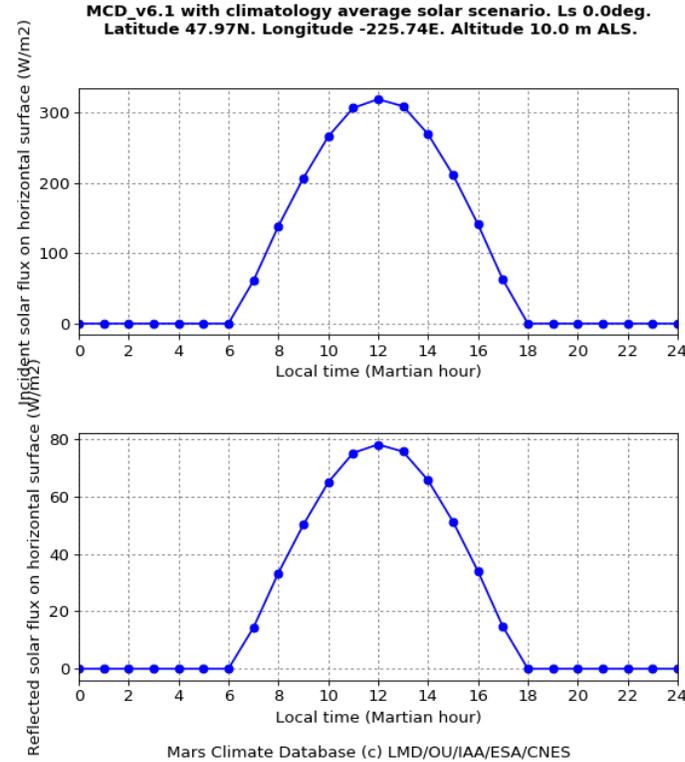
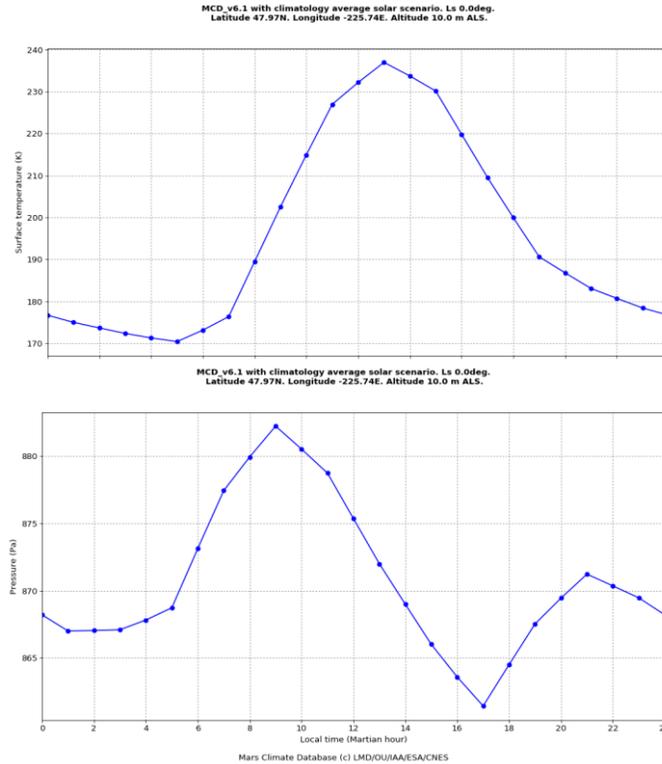
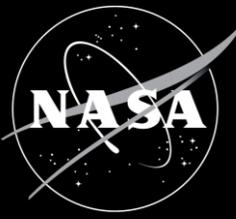
- Three pallets landed to support propellant transportation operations (2x operational/1x reserve)
- 5m³ tank autogenously pressurized with 2.3 kW heater.
- Two hose management assemblies (OSAM-1 derived) to mate to MALV.
 - Propellant connection
 - Gas connection (to support leak checks)
 - Power connection
- Dust Tolerant Automated Umbilical (DTAU) connections at mating surfaces
- Electrical jack stands
- Carrier chassis interface common to all pallets

Propellant Transport Pallet Electrical System Block Diagram



Propellant Skid Electrical Block Diagram

Boundary Conditions

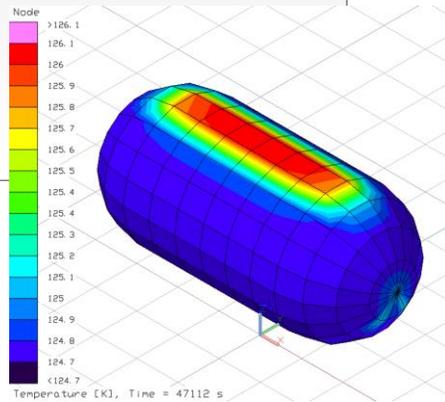
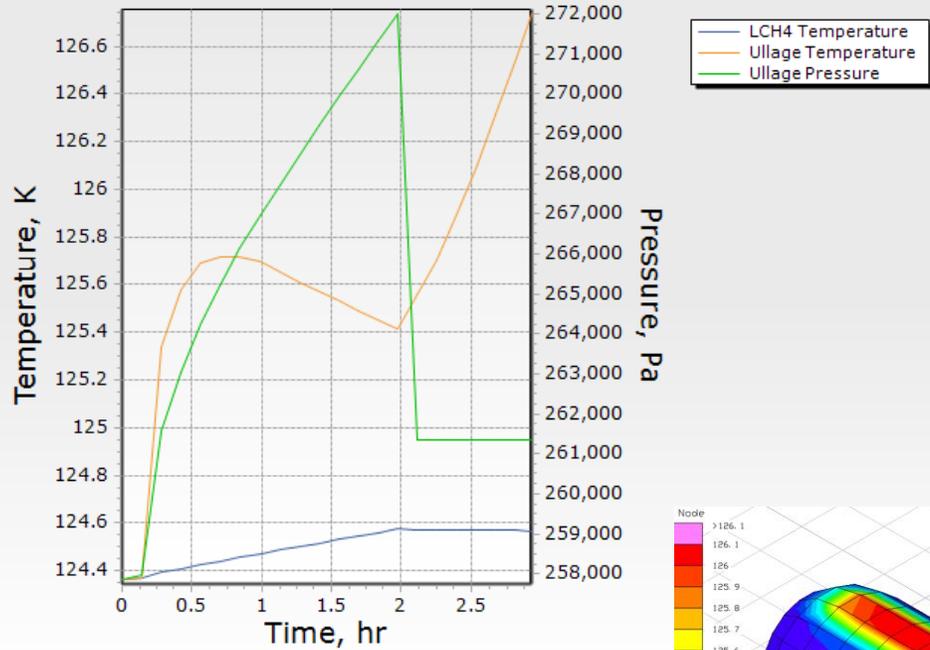


- Data for Viking II Landing Site from http://www-mars.lmd.jussieu.fr/mcd_python/
- Pallet tank is Al-6061 with 2" BX-265 SOFI insulation assumed coated with white paint $\alpha=0.33$ $\epsilon=0.65$
 - SOFI used due to risk of CO₂ solidification within insulations such as aerogel

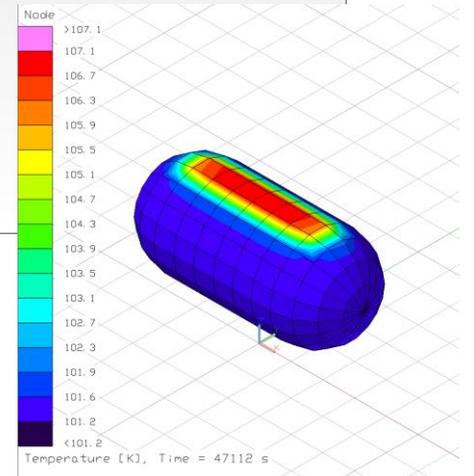
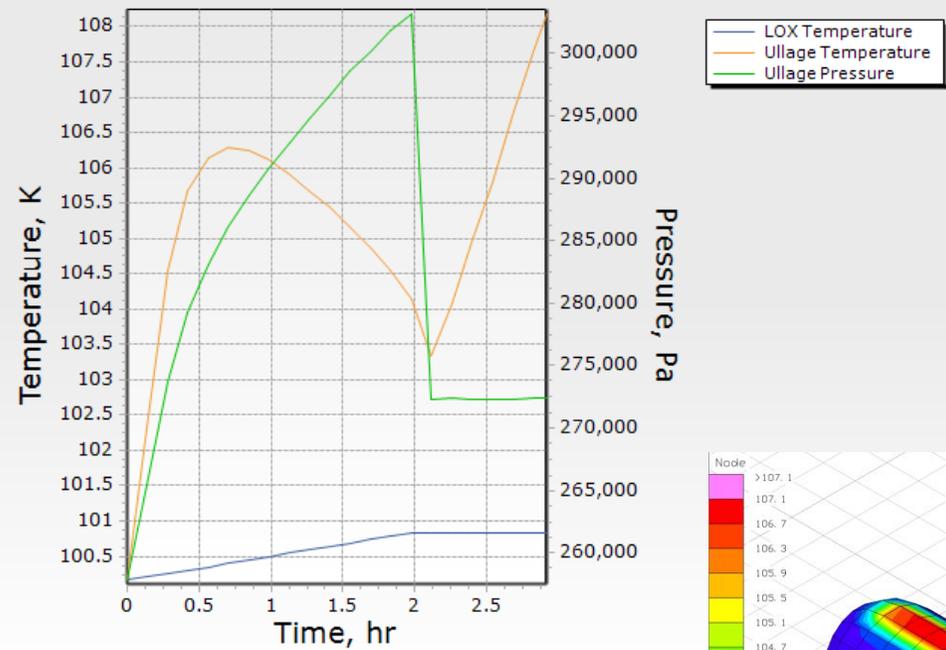
Tanker Pallet Thermal



LCH4 Tank Fluid Temperature/Pressure



LOX Tank Fluid Temperature/Pressure

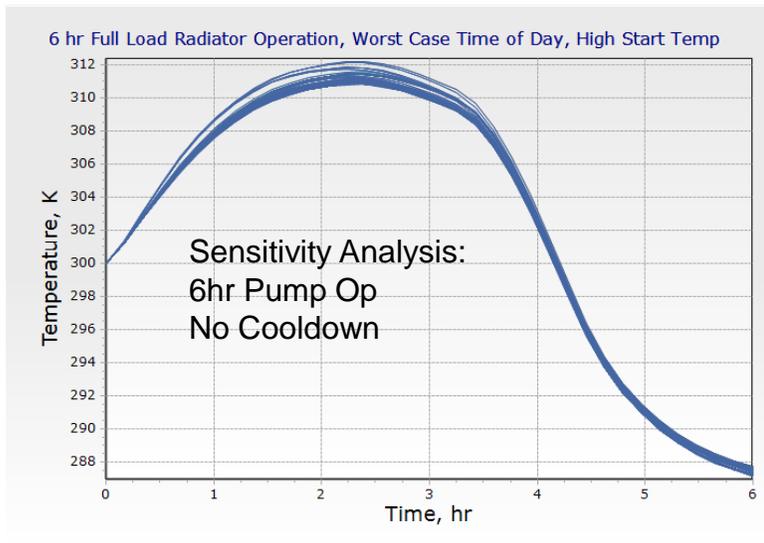
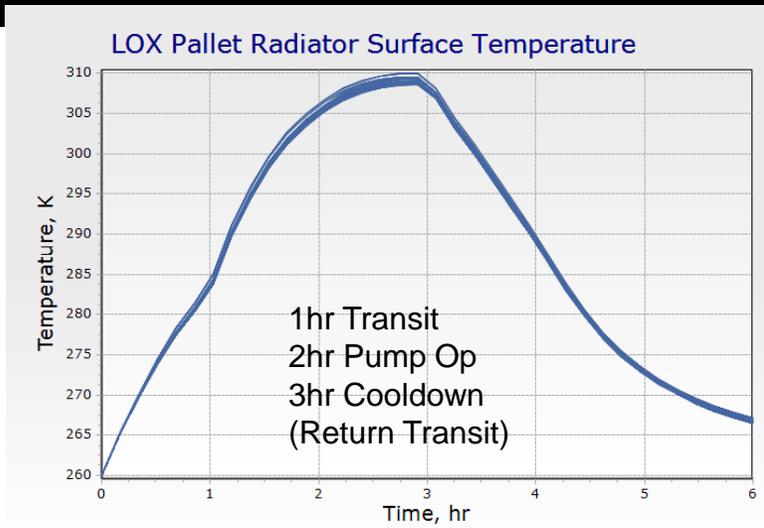
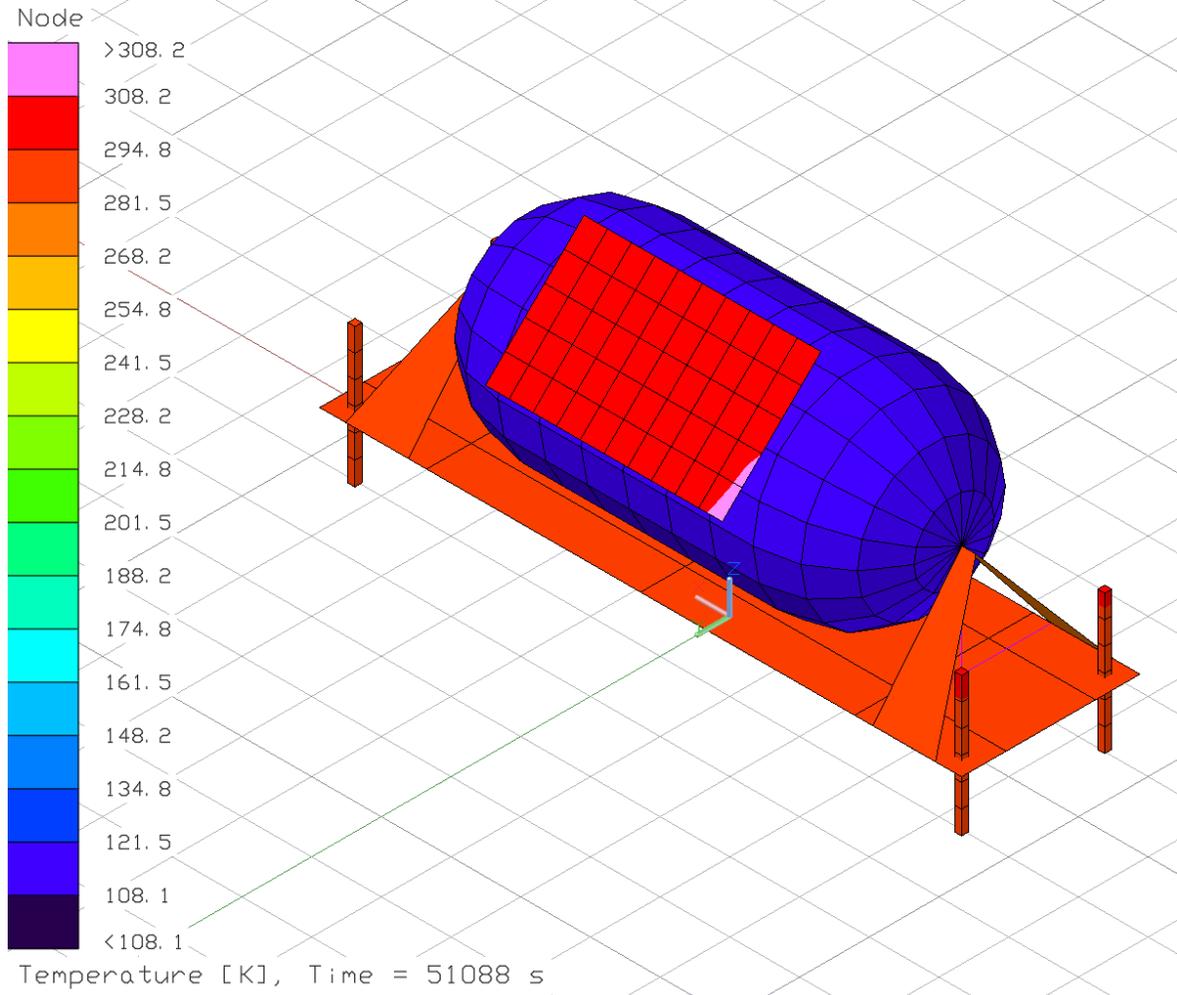


Radiator Design

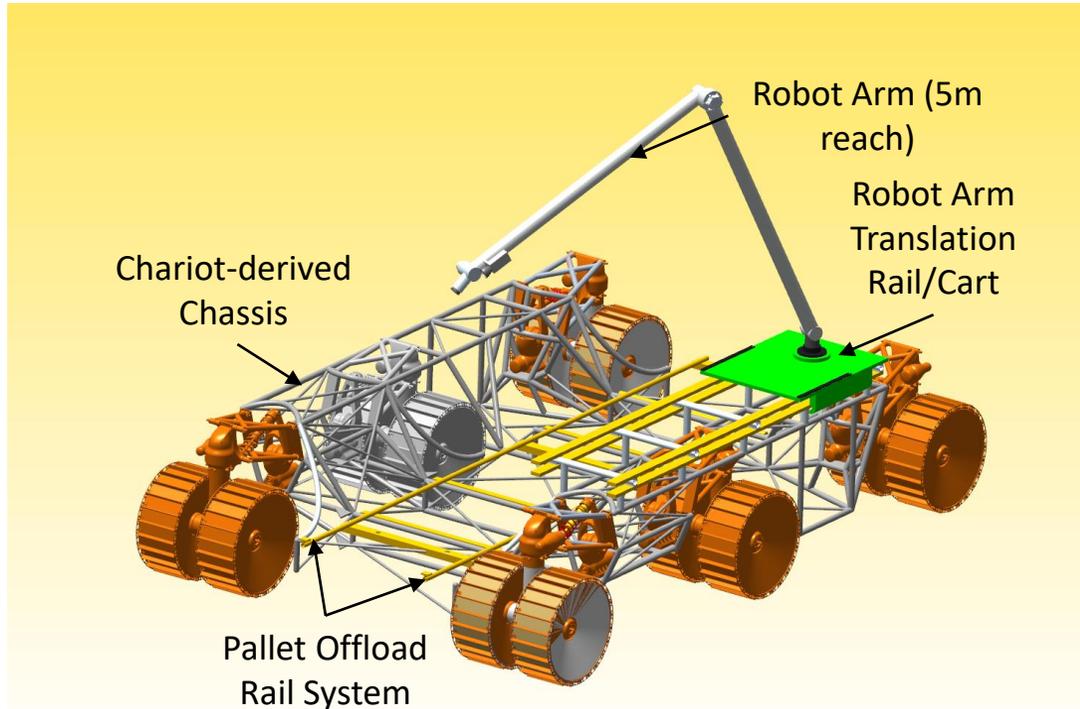


- Powered equipment heat rejection necessitates the addition of a radiator to the pallet design
 - 263W standby/transit
 - 412.7W active transfer
 - Momentary higher peaks of +40.6W per solenoid valve at actuation
 - 10% Margin Added
- Radiator assumed to reject to environment at ~310K max
- Size estimate required for mass impact
 - 5mm 6061 aluminum
 - Radiating surface coated with white paint, EOL with 40% dust coverage
 - $\alpha=0.4$ $\epsilon=0.85$
 - Opposite surface insulated with 25.4mm aerogel
 - Heat flow system (heat pipe vs pump heat loop) not traded. Bookkept as 100% MGA overage
- Radiator placed at 45° angle to top of tank on pallet side opposite to interface connection
 - Maximize sky visibility while minimizing radiation exchange with ground or MALV
- Thermal Desktop model iteratively run to determine size
 - 1.75m² radiator area optimal

Radiator Design

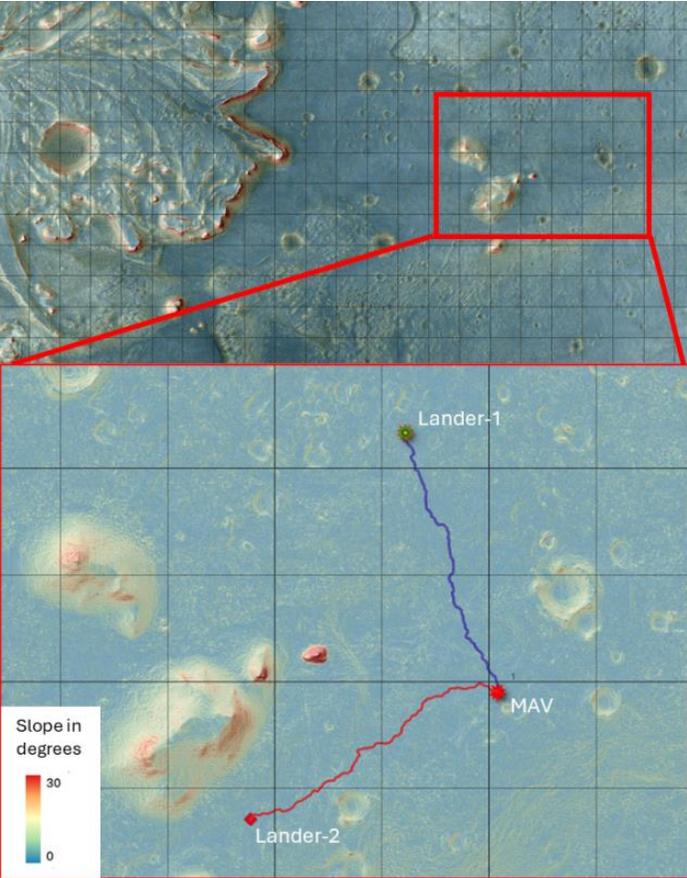


Mobility Transport Chassis



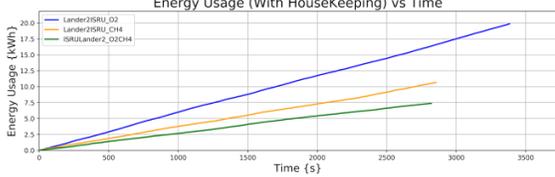
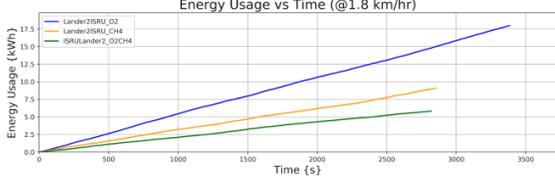
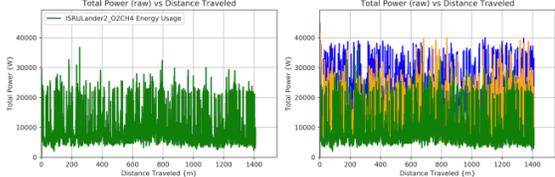
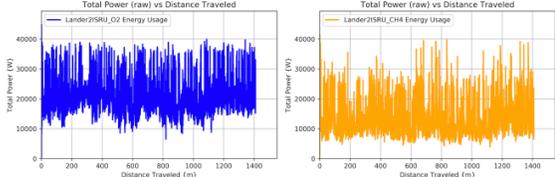
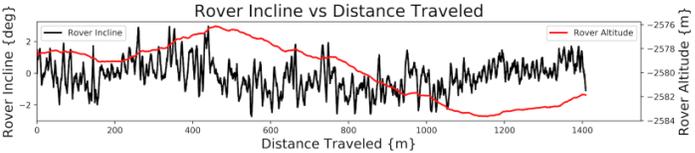
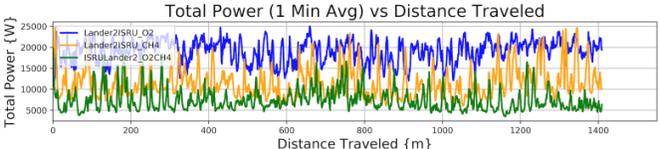
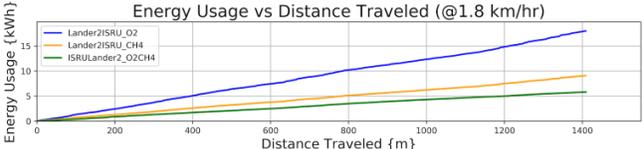
- Two chassis landed to support surface operations
- 7.1t estimated payload capacity
- Manipulator arm adapted from Robotic Umbilical Arm studied for fluid servicing between Artemis pressurized rover and surface habitat elements.
- Translation rail/cart analogous to ISS Mobile Transporter
- Load/offload rail system to enable pallet deployment

Energetics

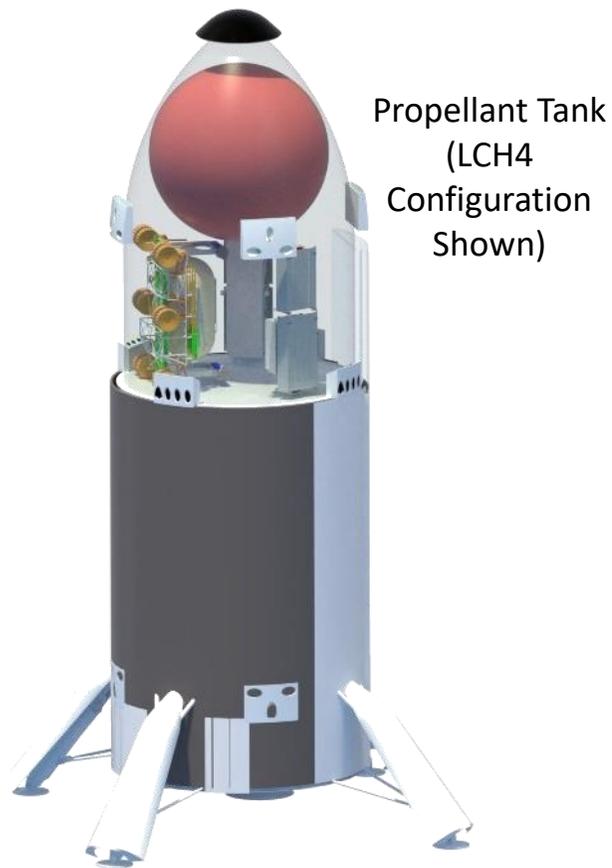


Comparison - Full Traverse

LOX:	10382.3323 kg
LCH4:	7059.4233 kg
Empty Tanker:	5076.7233 kg



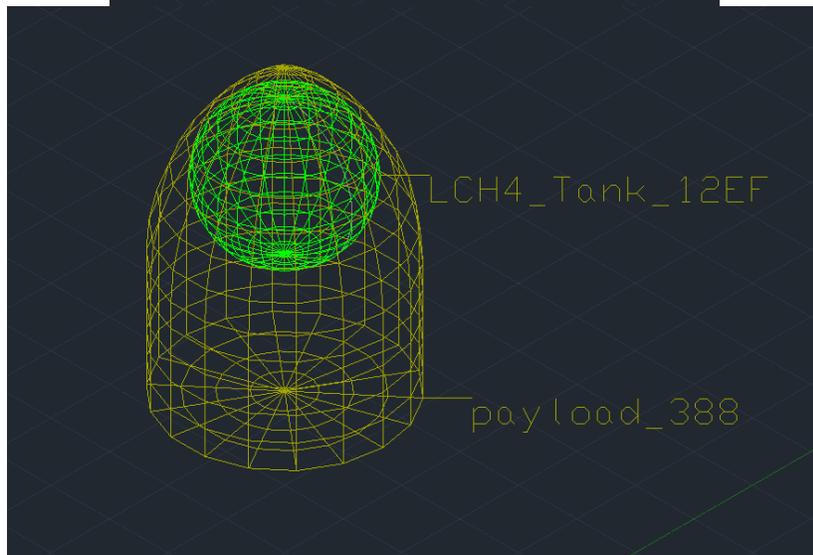
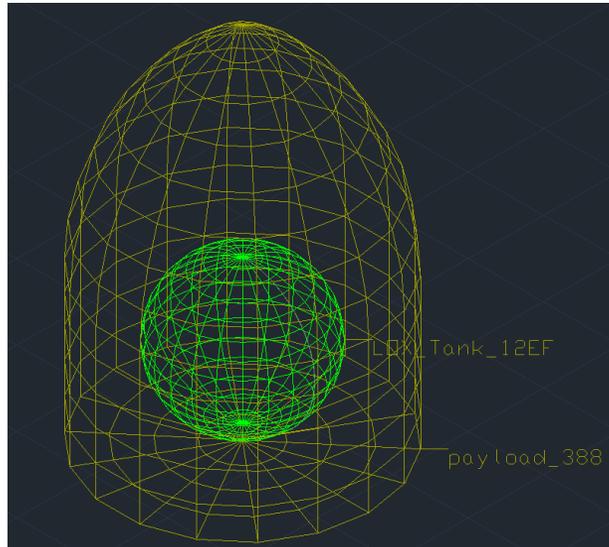
Propellant Delivery Mars Ascent and Landing Vehicle



Propellant Tank
(LCH4
Configuration
Shown)

- Six Delivery MALVs landed to supply MAV propellant
 - Four LOX (~60 m³ per lander)
 - Two LCH4 (~105 m³ per lander)
- Umbilical connection assumed common with vehicle umbilical plate
 - Prop connection
 - gas connection (to support leak checks)
 - Power connection
- DTAU connection at umbilical interface plate

Payload Thermal

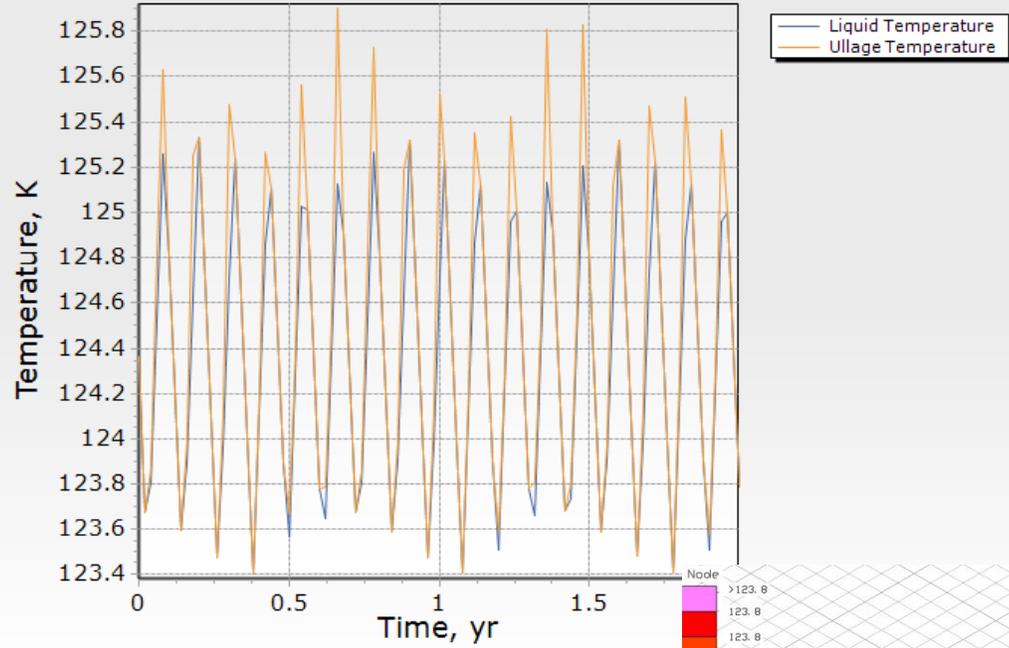


- Payload tank is Al-6061 insulated with 3" BX-265 SOFI.
- Free convection with CO₂ at atmospheric pressure is modeled between sphere and payload ogive interior.
- Tank surface and payload ogive interior optical properties modeled as Aluminized Kapton $\alpha=0.12$ $\epsilon=0.03$
- Payload ogive exterior optical properties modeled as half TUFROC and half Advanced Flexible Reusable Surface Insulation
- LCH₄ Tank mounted forward in nose to accommodate additional payload
- Utilize existing MALV cryocoolers: 2x operational + 1 spare. Each unit 150W thermal lift; 1267W power consumption

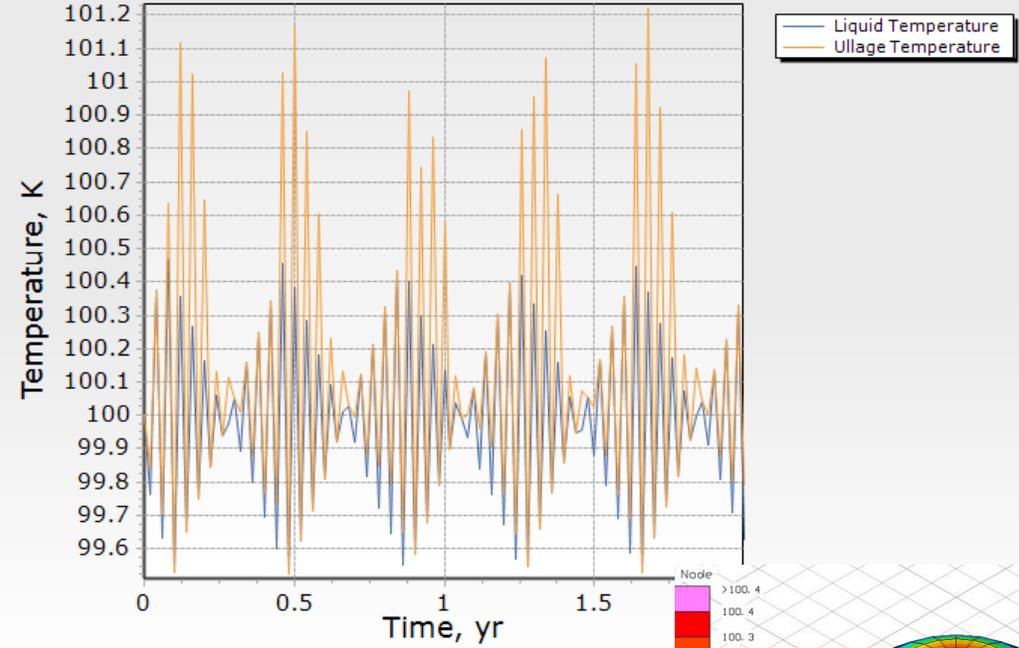


Lander Payload Thermal

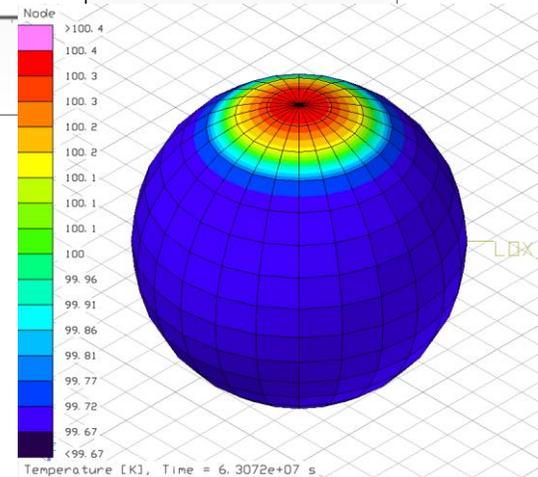
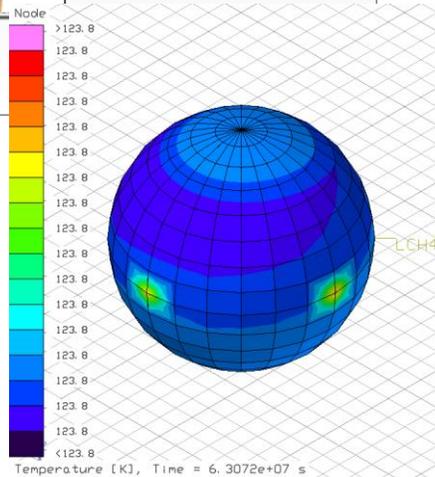
LCH4 Payload 2 Year Stay



LOX Payload 2 Year Stay



Onboard cryocoolers are maintaining propellant conditions within 2K for both commodities over extended periods.



Technological Needs

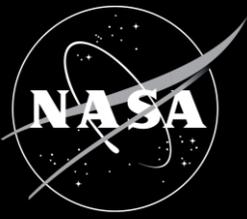


- Systems would operate in a Martian environment and would be critical for successful crew return
 - System reliability
 - Fault detection, isolation, and recovery
 - Repeated, reliable umbilical mating/demating
 - Autonomous robotics/operations
 - Autonomous navigation, path planning, and maneuvering
 - Autonomous task processing and scheduling
 - Autonomous manipulator system operations

Concept Animation

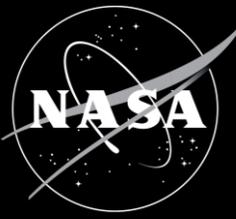


Note: animation developed for previously presented water delivery ISRU concept. Relevant transportation operations for cryogenic propellant are nearly identical.



Questions?

Full Author List



- Jared F Congiardo—NASA/Kennedy Space Center
- Mark E Lewis—NASA/Kennedy Space Center
- Carey M McCleskey—NASA/Kennedy Space Center
- Christopher T Reeves—NASA/Kennedy Space Center
- Adam M Swanger—NASA/Kennedy Space Center
- Gabor Tamasy—NASA/Kennedy Space Center
- Paul Bielski—NASA/Johnson Space Center (retired)
- Zu Qun Li—NASA/Johnson Space Center
- Paige A Whittington—NASA/Johnson Space Center
- Collin W Blake—CACI International
- Keaton C Dodd—CACI International
- Stephen J Hoffman—The Aerospace Corporation
- Taylor Phillips-Hungerford—The Aerospace Corporation
- Michael Chappell—NASA/Marshall Space Flight Center
- Andrew J Choate—NASA/Marshall Space Flight Center
- James E Owens—ESSCA