Assessment of a Surface Water Transportation System Concept for ISRU Operations on Mars

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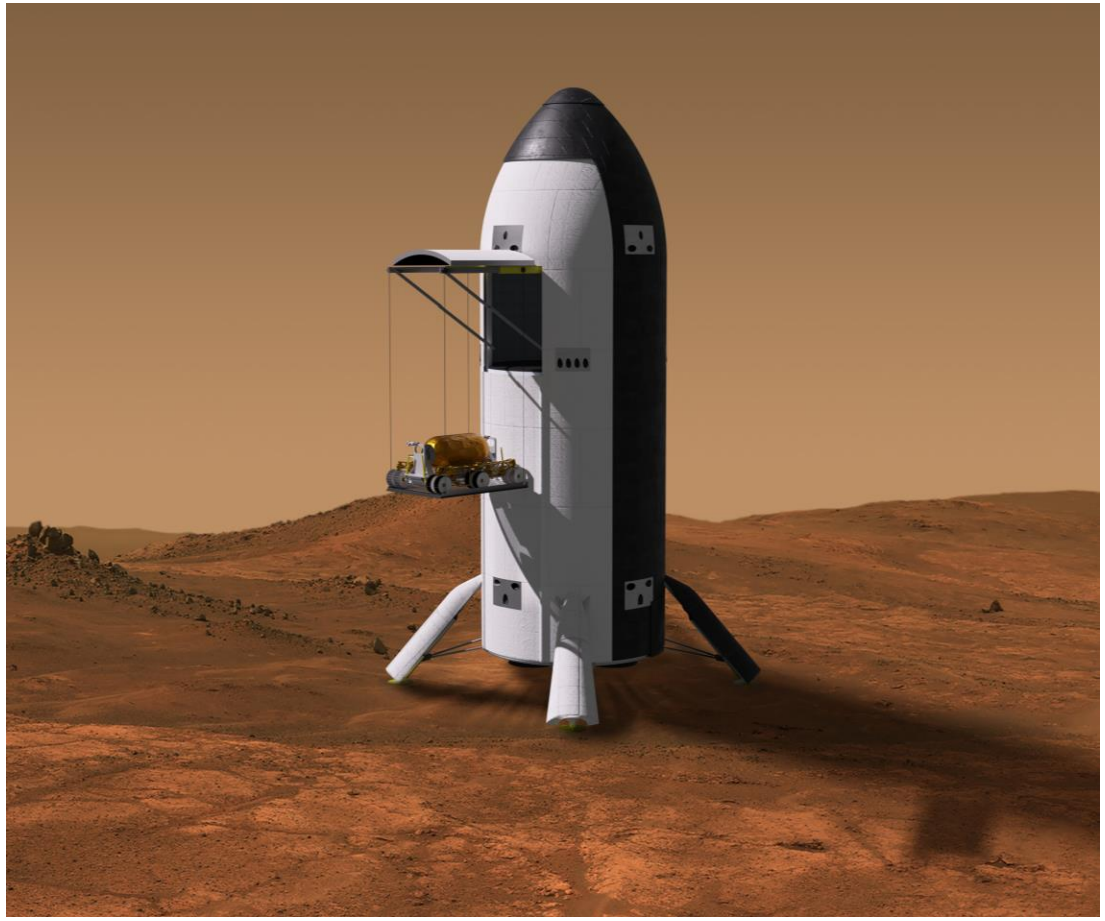
Introduction

- 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

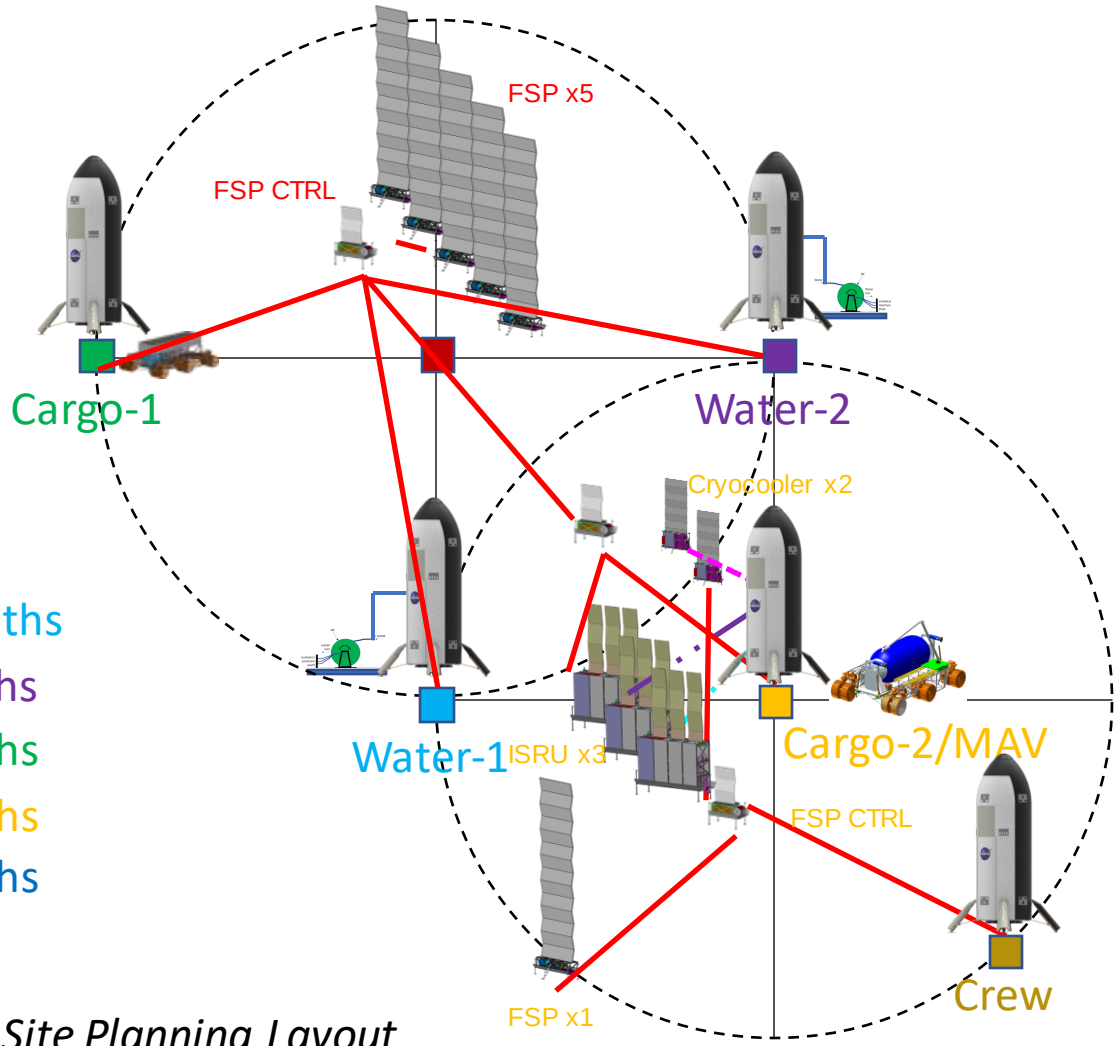


Trade Space

- 75t payload capacity vertical lander
- Integrated ascent vehicle
- Cryogenic propellant (LOX/LCH4)
  - —300 t cryo propellant required for MAV launch
- Propellant manufacturing using In-situ Resource Utilization technologies*
  - —Earth-delivered resources plus local resources
  - —Requires plentiful power

*Oleson, S., et. al., "Kiloton Class ISRU Systems for LOX/LCH4 Propellant Production on the Mars Surface," *AIAA SciTech Forum*, Submitted for Publication, AIAA, Orlando, FL, 2024.

Concept of Operations

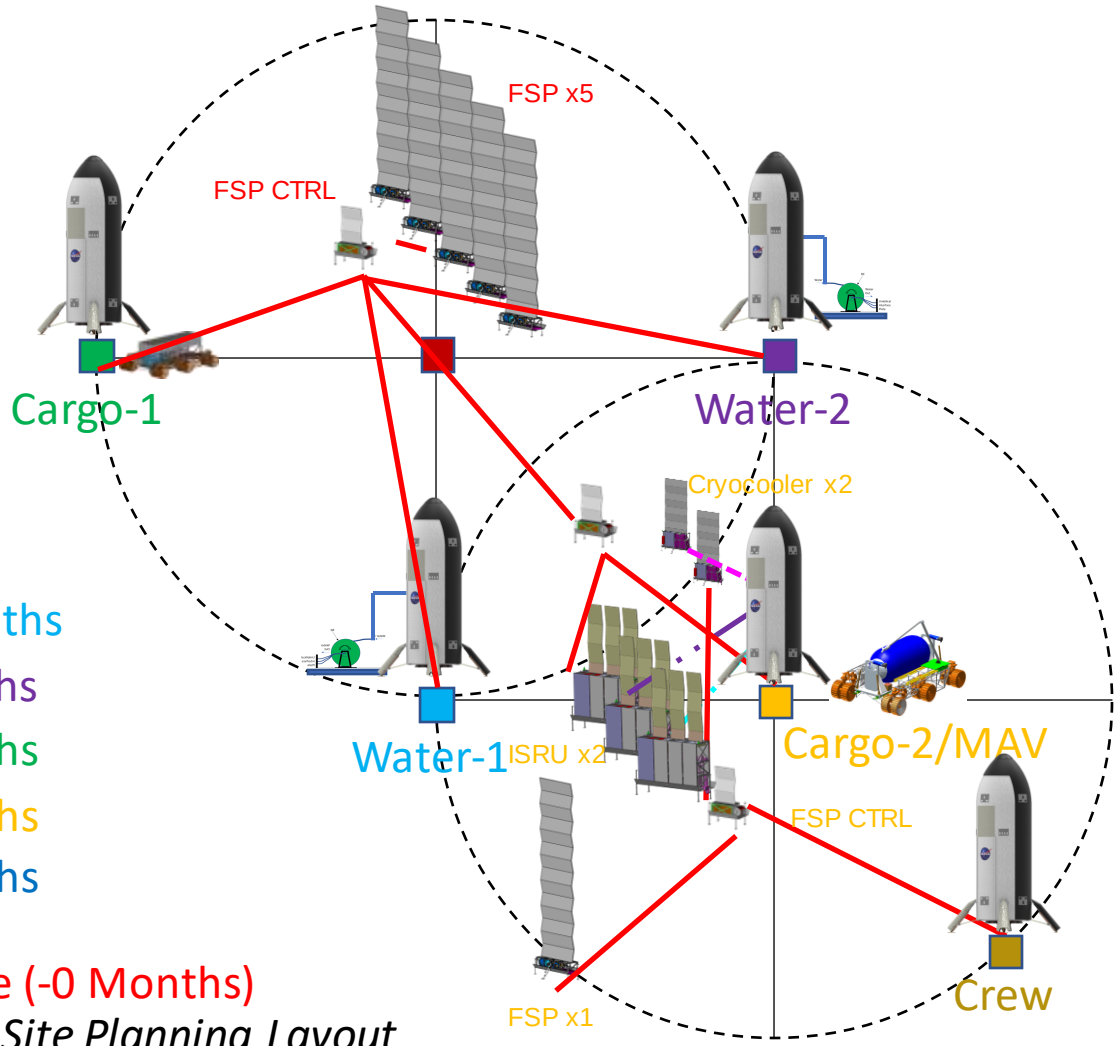


-104 Months
-78 Months
-52 Months
-26 Months
-23 Months
-1 Month

Notional Site Planning Layout
(1 km radius circles)

- Water delivery Mars Ascent and Landing Vehicles (MALVs) (Water-1 and Water-2) arrive at first two opportunities
- Payload remains quiescent
  - i.e. no deployment activity
- Some amount of housekeeping/heater power needed, unless payload water is allowed to freeze.
- Cargo-1 MALV delivers 1x Mobility Transport Chassis, 5x 40 kW Fission Surface Power (FSP) units and 1x Surface Water Transportation Pallet
- Mobility Transport Chassis Deploys FSPs and cabling systems
- FSPs provide power to Water MALVs
  - Allows water to thaw if frozen
- Cargo-2 delivers second Mobility Transport Chassis, 1x 40kW FSP, 3x ISRU Propellant Production Plants, 2x Liquefaction Pallets and 1x Surface Water Transportation Pallet
- Mobility Chassis Deploys FSPs, cabling systems, ISRU Pallets and Cryocoolers
- Cargo-2 also serves as the MAV and will be loaded with propellant
- Water delivery MALVs deploy downcomer hose/mating system via elevator
- Water transportation pallets aboard MT chassis alternate delivering 5t water to ISRU plants
  - Approx. 30 trips required
- Estimated water consumption of ISRU plants is ~13kg/hr (approx. 16 Earth days to empty tanker)
  - Water Transportation Pallet pressurization maintained with local atmosphere pressurized by small onboard scroll compressor
- ISRU pallets have 1 sol water capacity onboard to allow for tanker swap.
- Second water tanker on standby. Takes on water prior to switching operation.
  - Fill rate of 4.5 kg/min to fill tanker within 1 sol period. (Goal to allow tanker pallet failure contingency)

Concept of Operations (cont'd)

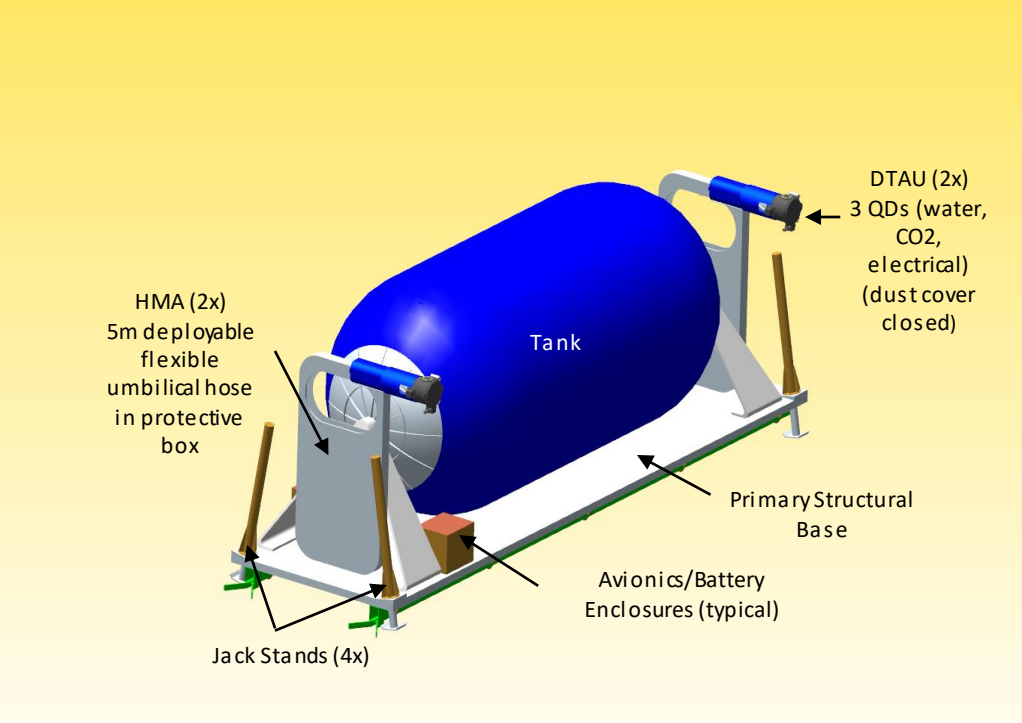


-104 Months
-78 Months
-52 Months
-26 Months
-23 Months
-1 Month
Departure (-0 Months)

Notional Site Planning Layout
(1 km radius circles)

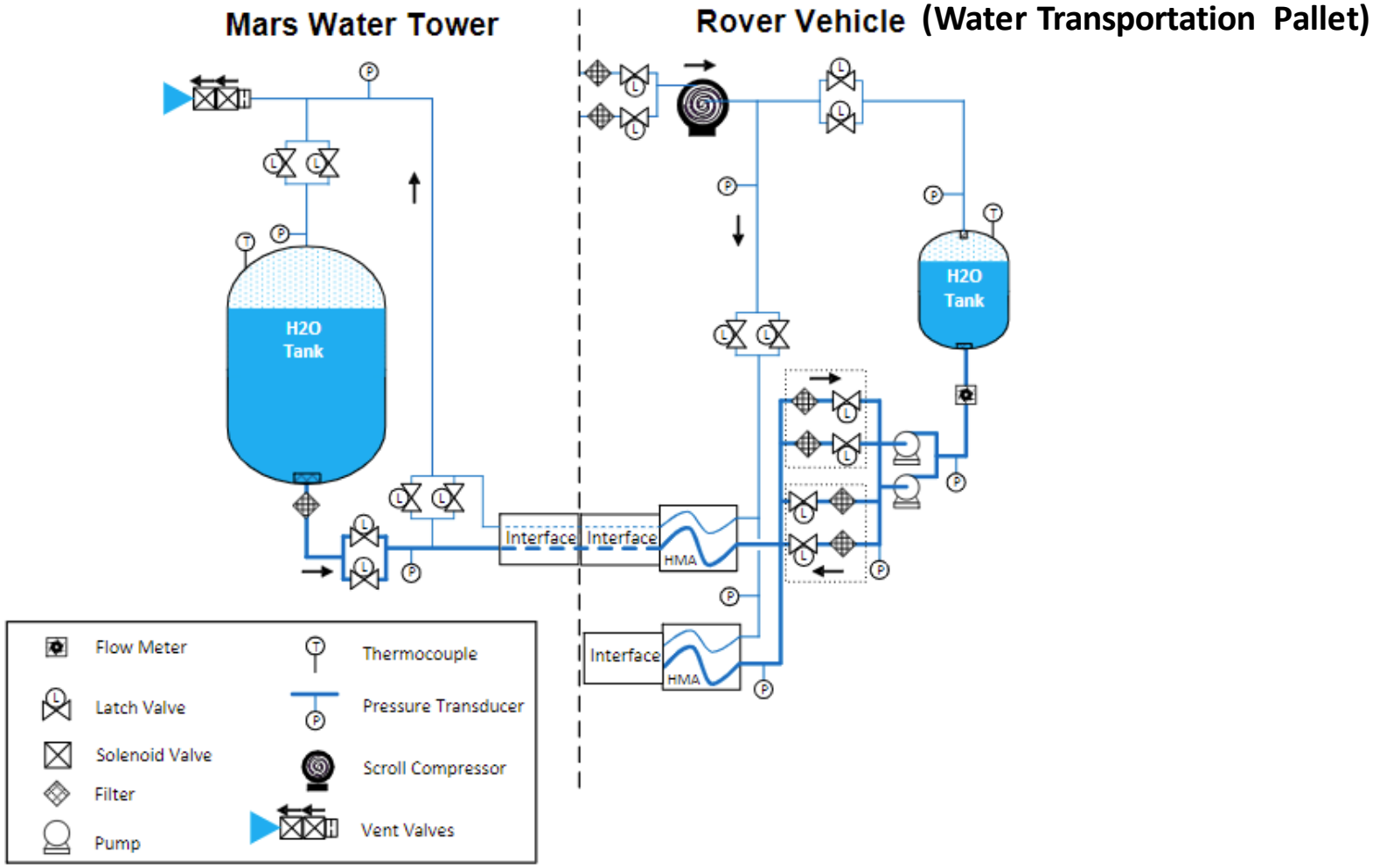
- MAV ISRU operation MUST be complete prior to crew landing
- ISRU, cryocooler, and tanker systems moved by mobility to safe distance and placed in standby mode for possible reuse.
- Water-1, Water-2, and Cargo-1 are abandoned in place.

Surface Water Transportation Pallet

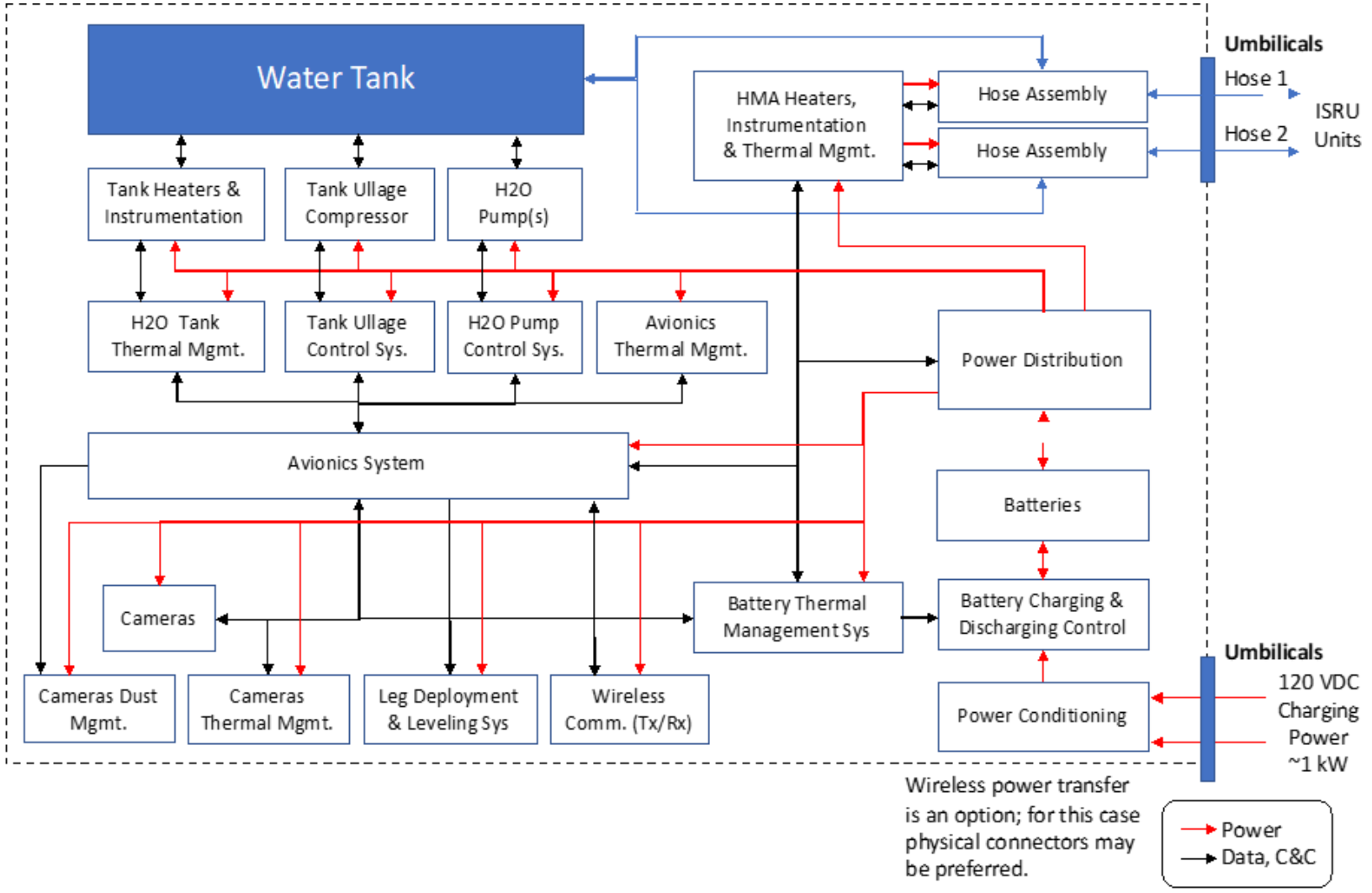


- Two pallets landed to support ISRU operations
- 5m^3 tank pressurized with local atmosphere via scroll compressor.
- Two hose management assemblies (OSAM-1 derived) to mate to ISRU units.
  - Water connection
  - CO2 connection (to support leak checks)
  - Power connection
- Dust Tolerant Automated Umbilical connections at mating surfaces
- Electrical jack stands
- Carrier chassis interface common to all pallets

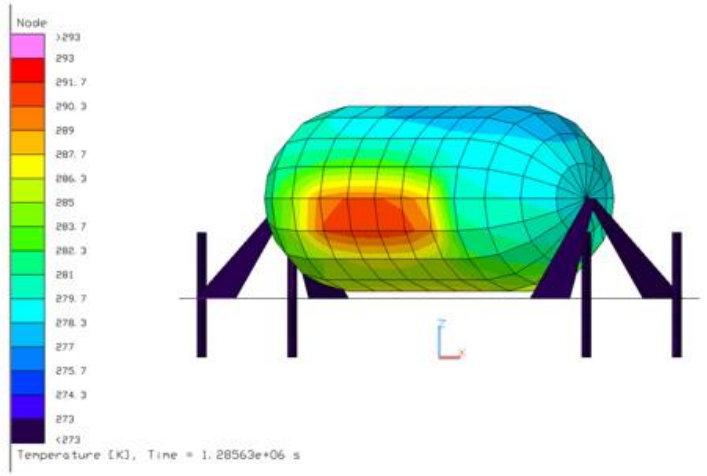
Fluid Handling and Pressurization Elements

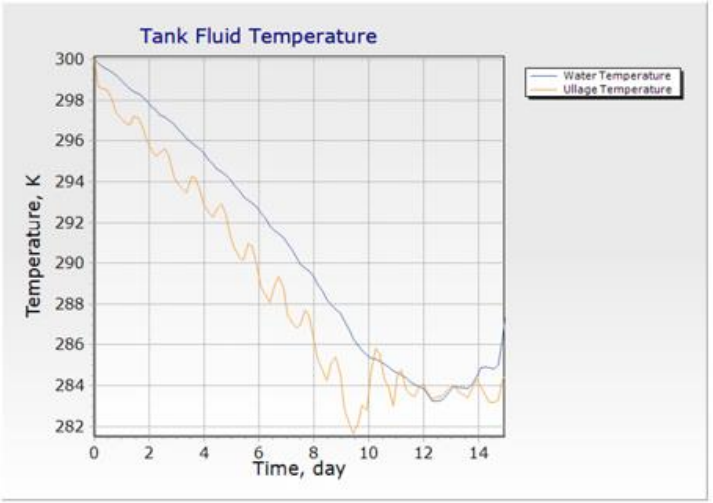


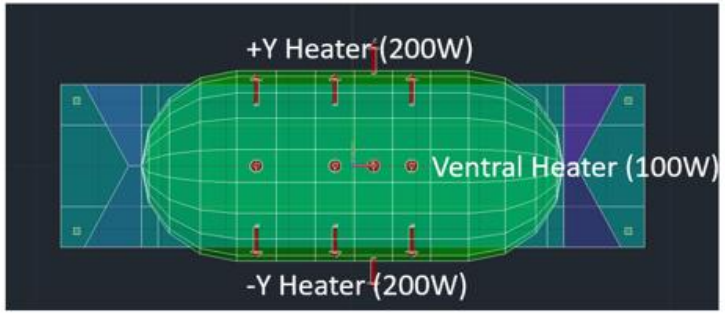
Water Transport Pallet Electrical System Block Diagram

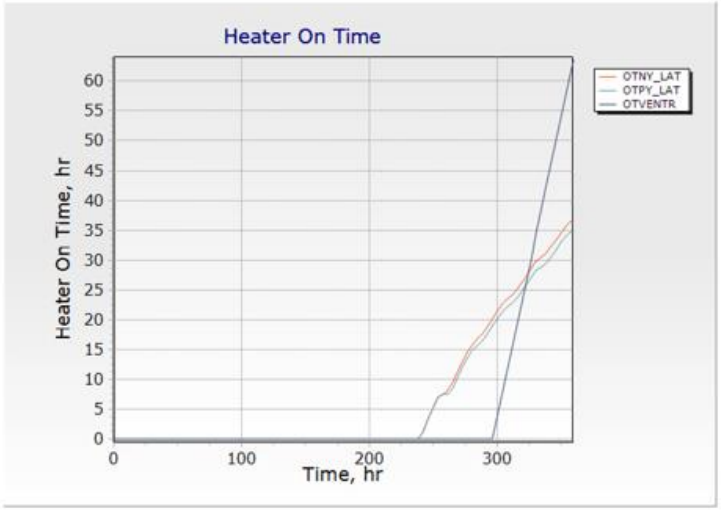


Thermal Design

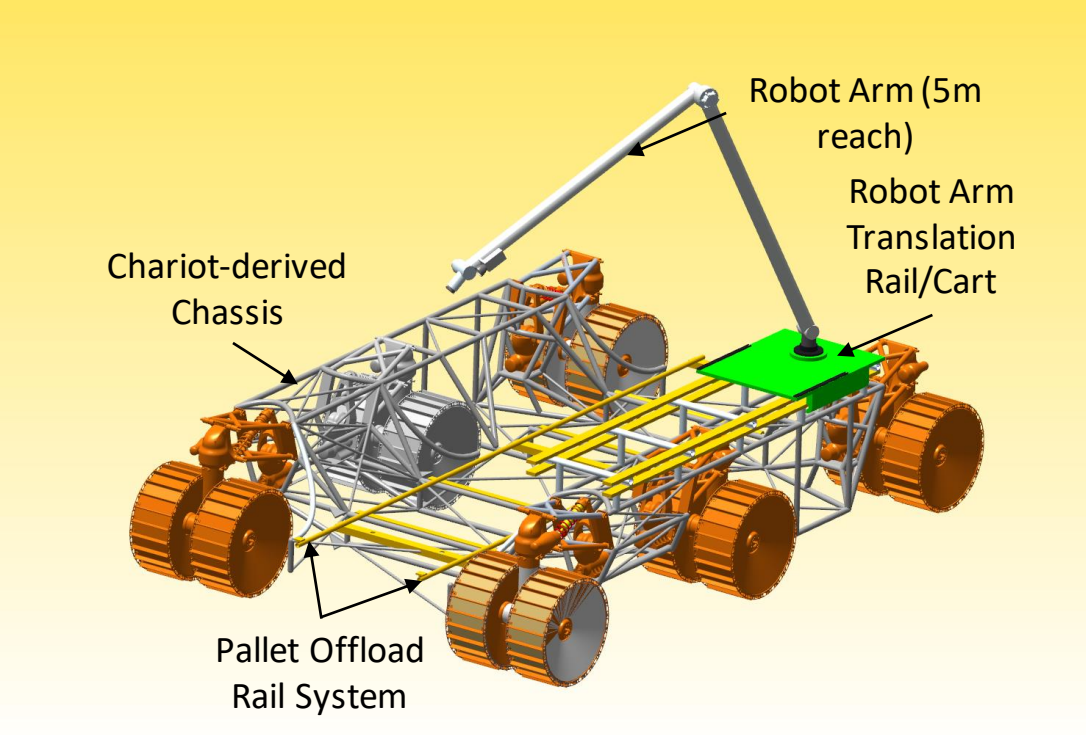








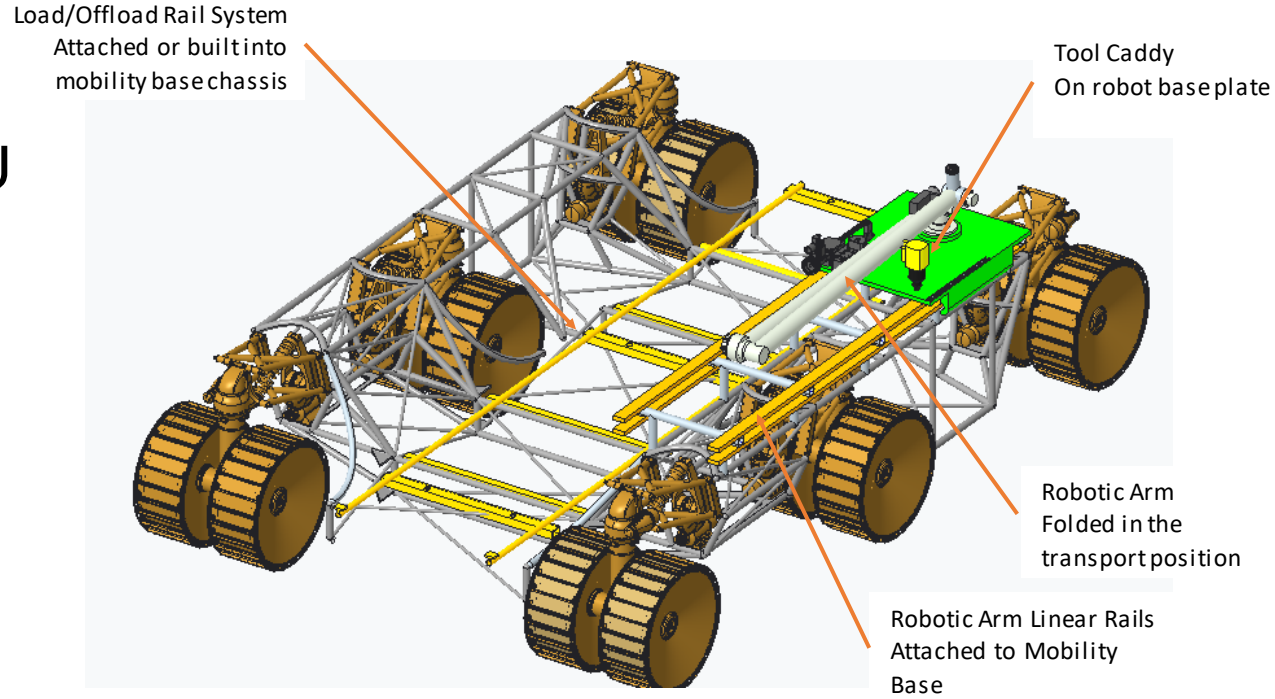
Mobility Transport Chassis



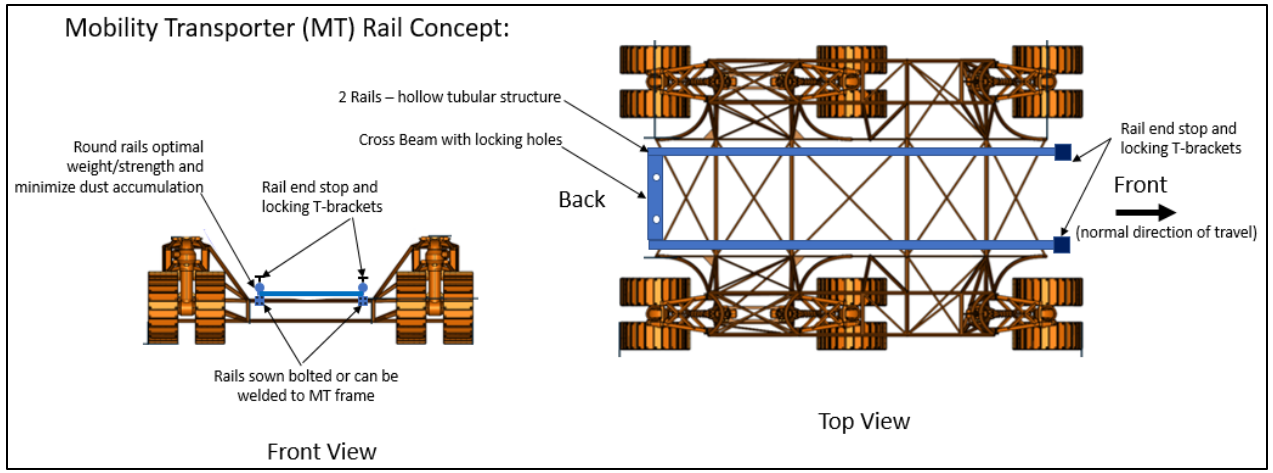
- Two chassis landed to support surface operations
- 7.1t estimated payload capacity
- Manipulator arm adapted from Robotic Umbilical Arm studied for fluid servicing between Artemis pressurized rover and surface habitat elements.
- Translation rail/cart analogous to ISS Mobile Transporter
- Load/offload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

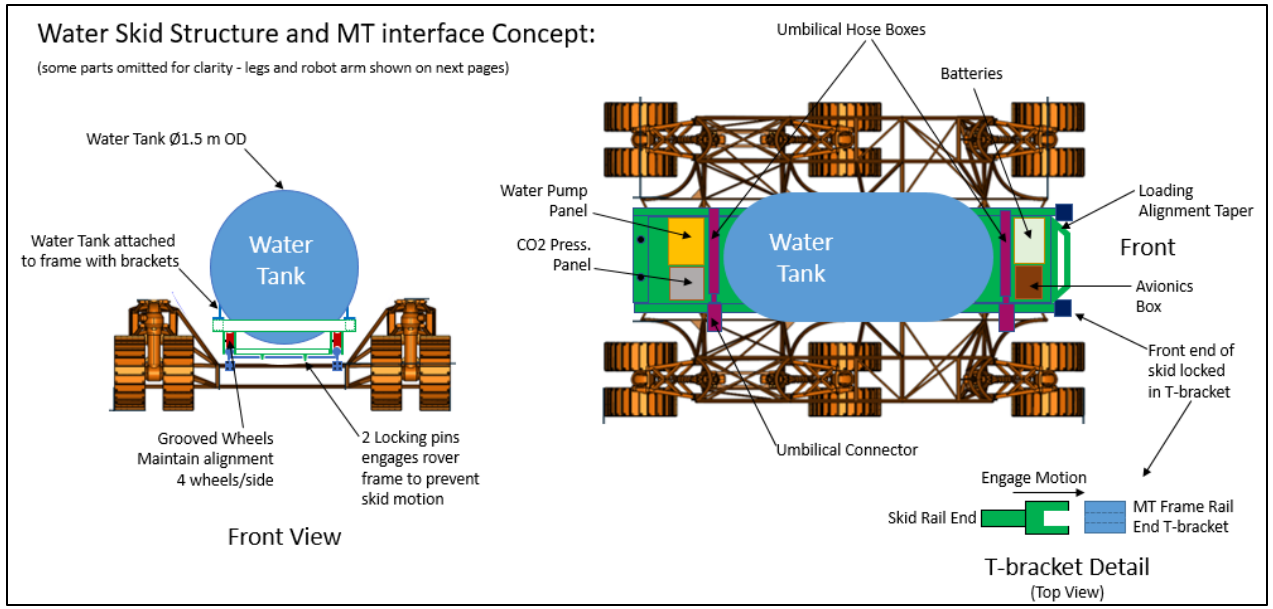
Manipulator Arm

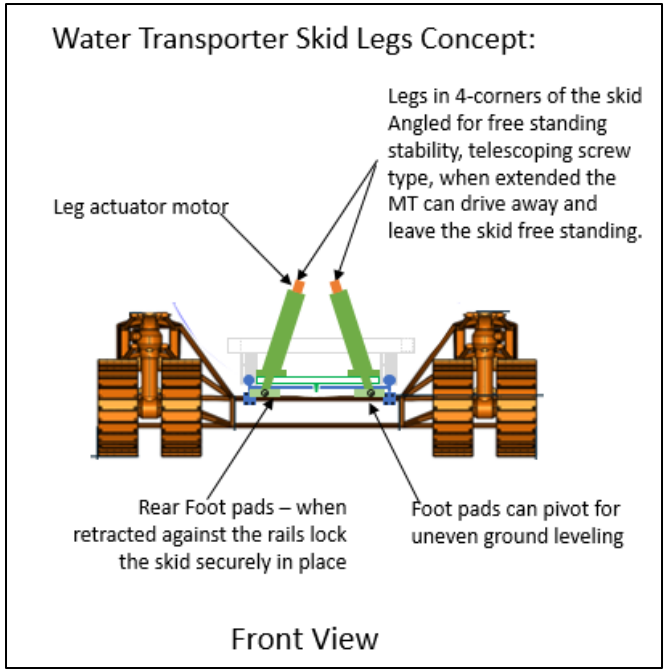
- Make/break connections between various surface elements, particularly the Water Transportation Pallet and the ISRU propellant plant.
- 5m reach + translation rail
- End effector toolkit for other operations as needed
- Inspection/alignment camera at tip



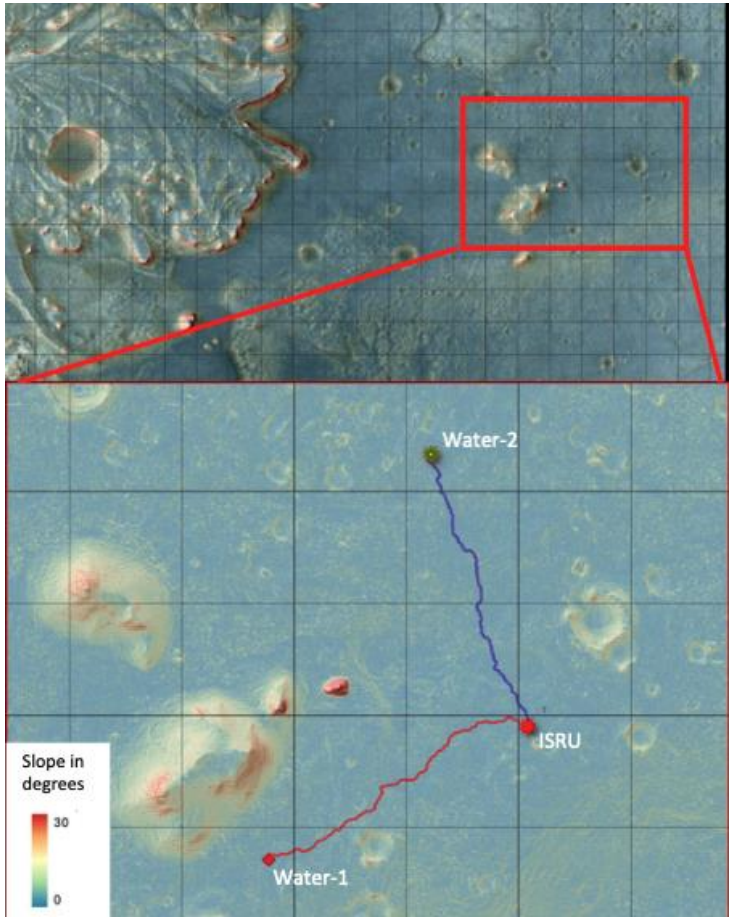
Load/Offload Rail System



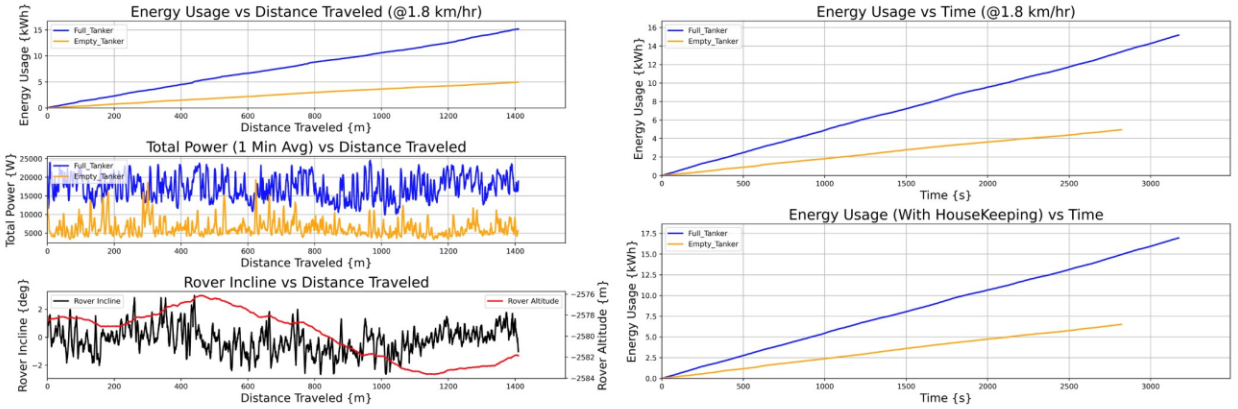




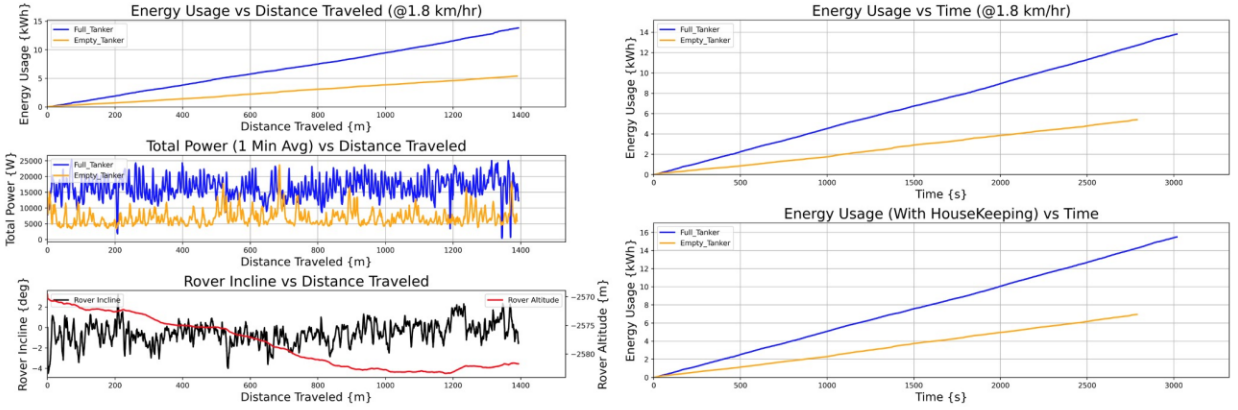
Energetics



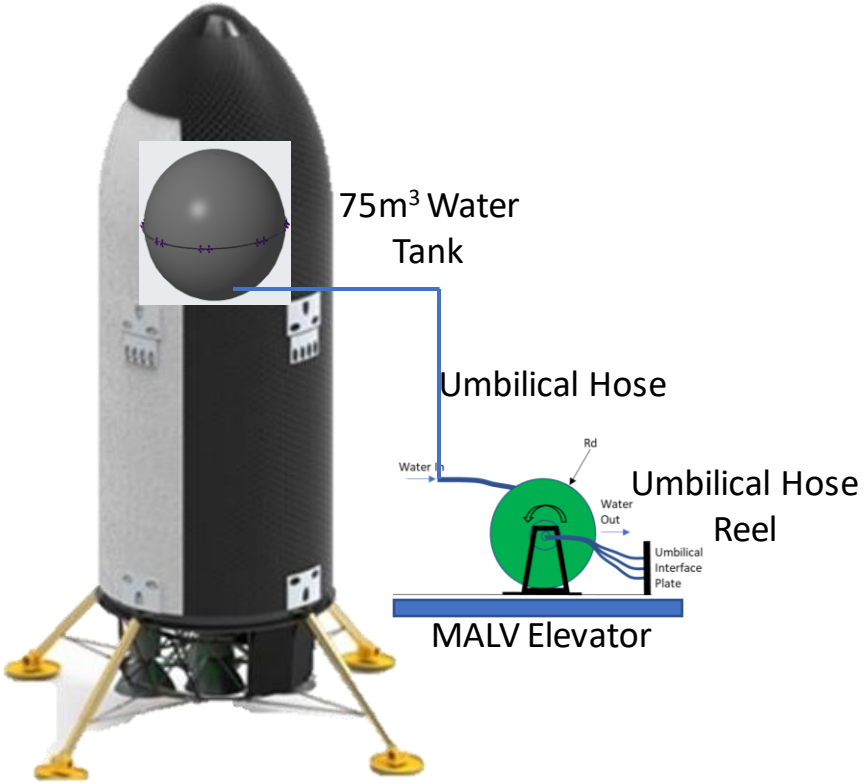
Water-1 to ISRU



Water-2 to ISRU

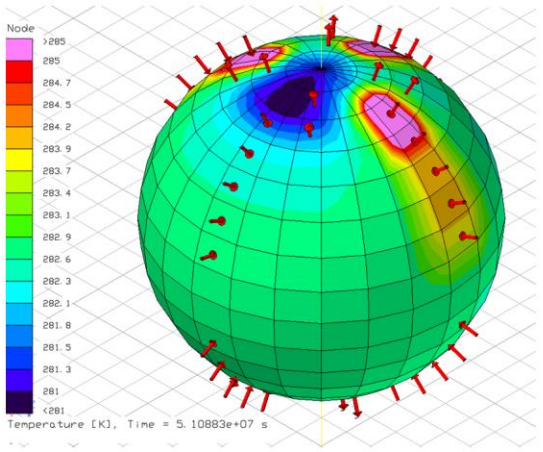


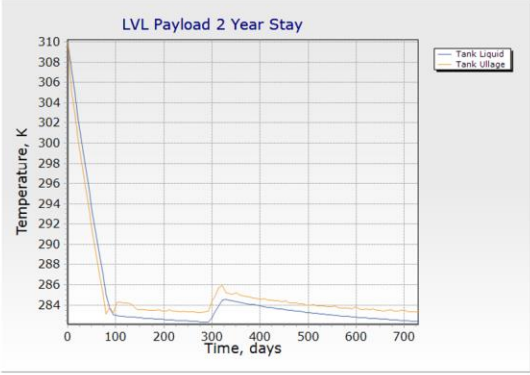
Water Delivery Lander

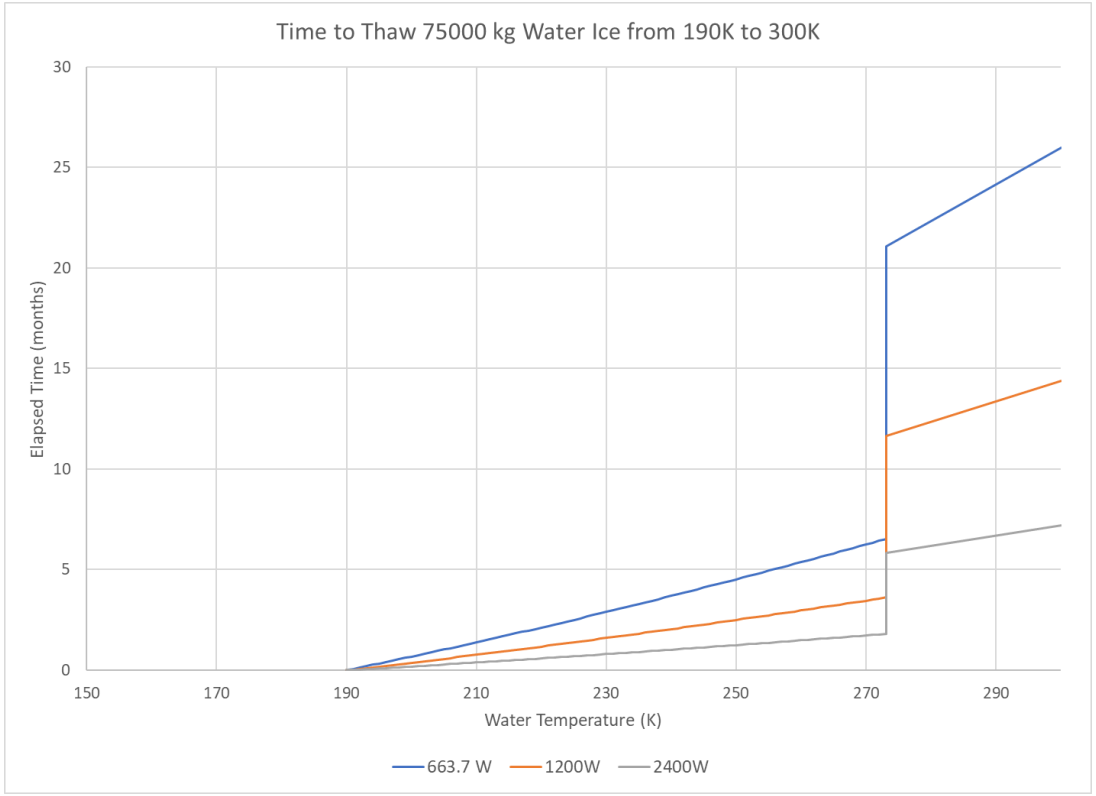


- Two Delivery MALVs landed to supply water for ISRU
- Umbilical hose passively deployed via reel assembly by lowering MALV elevator
  - Water connection
  - CO2 connection (to support leak checks)
  - Power connection
- DTAU connection at umbilical interface plate

Water Delivery Lander Thermal Analysis







Technological Needs

- Systems would operate in a Martian environment and would be critical for successful crew return for an ISRU-based return architecture
  - 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

Questions?