LEVITATE

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Motivation

Apollo Style:
+ Access entire globe
– No reuse of launched mass

Lunar Outpost:
+ Significant material reuse
– Exploration limited by roving capability

Solution

LEVITATE allows both visions by providing a vehicle which can:
- Perform a 14 day mission with two astronauts
- Access the entire lunar surface
- Return 500kg of scientific cargo
- Utilize lunar resources for fuel
- Allow for substantial lunar settlement development while maintaining the ability to perform science across the entire lunar surface

Design Summary

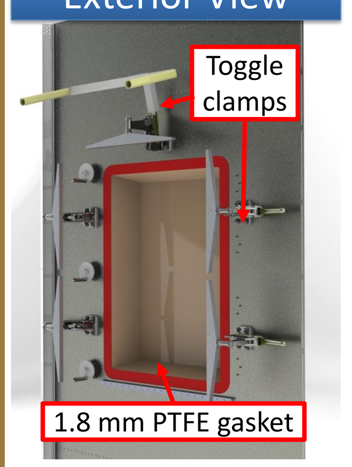
Design Goal	Proven With
Access entire lunar surface	Orbital calculations, vehicle mass
ARES-V Class deliverable	Overall size, vehicle mass
500 kg cargo return	FASTRACK cargo modules
Fuel supply from lunar resources	CECE and RCS use LOX and LH2
Sustain 2 crew on 14 day mission	Life support system
Safety of crew	Use of codes and standards
Operational simplicity, reliability	Flight-proven technologies
Manufacturability	Technical drawings

Outreach

@uw_levtiate uw-levitate.blogspot.com

Suitport Airlock

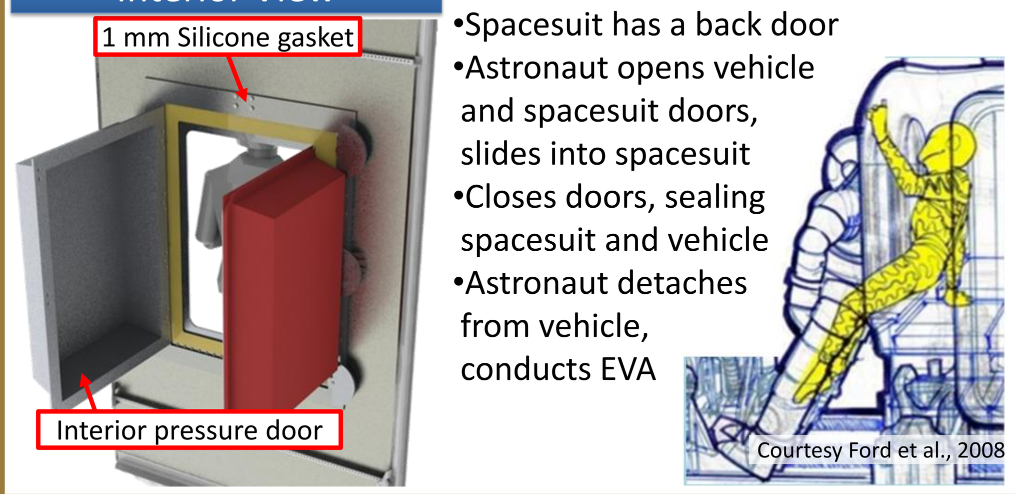
Exterior View



Major Benefits
- Minimizes regolith entrance
- Eliminates separate airlock chamber
- Shortens egress/ingress times
- Doubly sealed when occupied
- Completely manual
- Locks are adjustable, repairable, replaceable

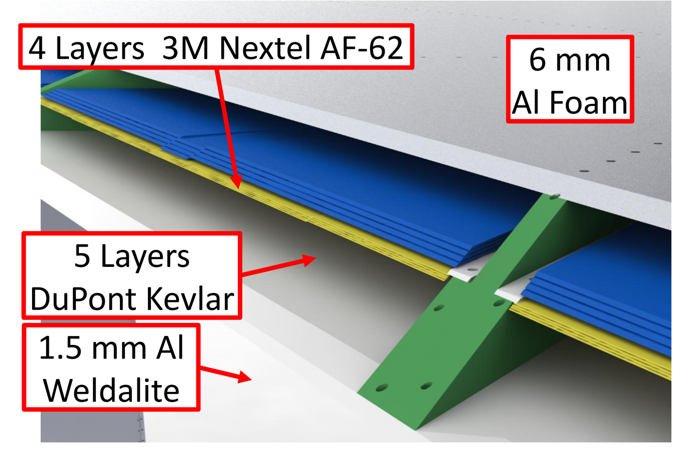
Very promising, included in Constellation
Design inspired by the literature

Interior View

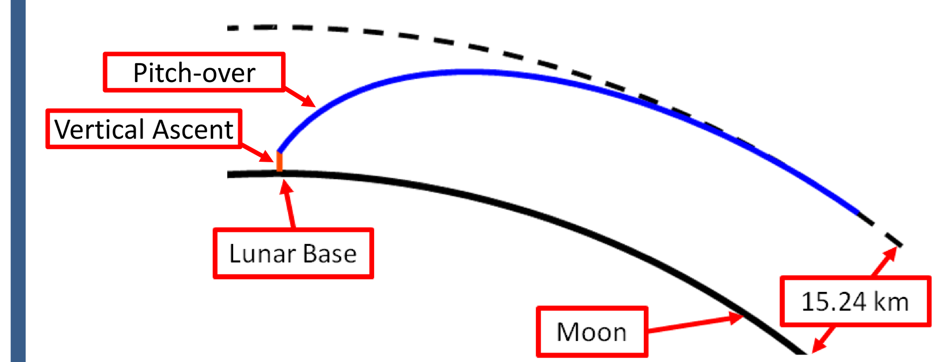


Concept
- Spacesuit has a back door
- Astronaut opens vehicle and spacesuit doors, slides into spacesuit
- Closes doors, sealing spacesuit and vehicle
- Astronaut detaches from vehicle, conducts EVA

Micrometeoroid Shield



Typical Flight Trajectory



Based on Apollo, balances efficiency and operational risk

Radiation Protection

Protects against energetic radiation from Sun
NASA MSIS 5.7.2.2.1-1 requires < 50 rem/yr
Shield provided by:
1. Al in micrometeor shield
2. Al in pressure vessel walls
3. 11 cm Borated HDPE

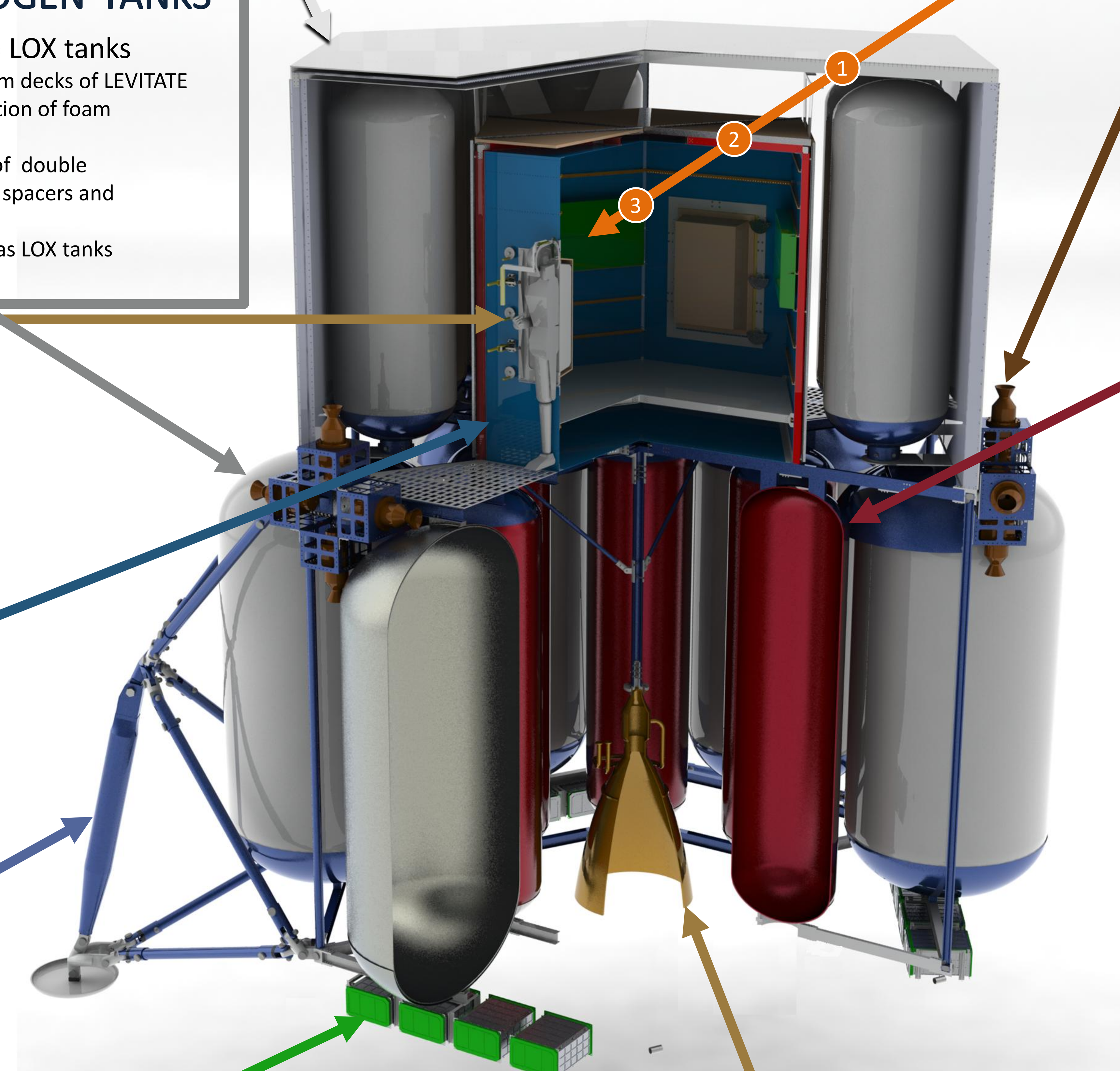
Design requirement validated by HZETRN transport code

Reaction Control System

1000 lbf bipropellant thrusters
- Thrust: 4.45 kN
- Fuel: LOX/LH2 (3.5:1 mixture ratio)
- Powerful for pitch maneuver
- Same fuel as CECE
- Redundant propulsion for emergency landing

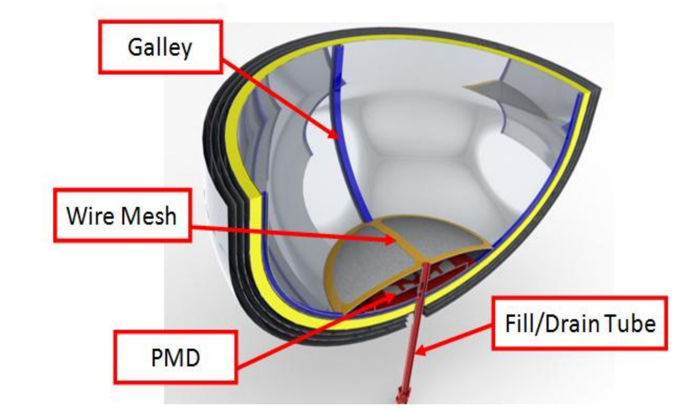
Liquid Hydrogen Tanks

Many similarities to LOX tanks
- Located on top and bottom decks of LEVITATE
- Insulated with a combination of foam and MLI
- MLI consists of 45 layers of double aluminized Mylar, Dacron spacers and Dacron bumpers
- Uses same PMD concept as LOX tanks



Liquid Oxygen Tanks

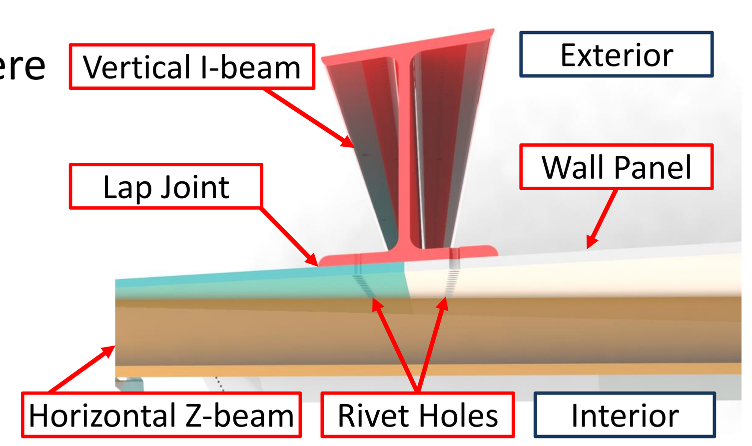
Insulated tank concept
- Located on bottom deck near the engine
- Uses 1 in of BX-265 foam as main insulation
- Uses thin layer of HEXCEL AS4Ccarbon fiber to contain foam
- Surface tension PMD uses wicking along galleys and wire mesh
- Both LH2 and LOX tanks have emergency pressure release port located on the top of the tank



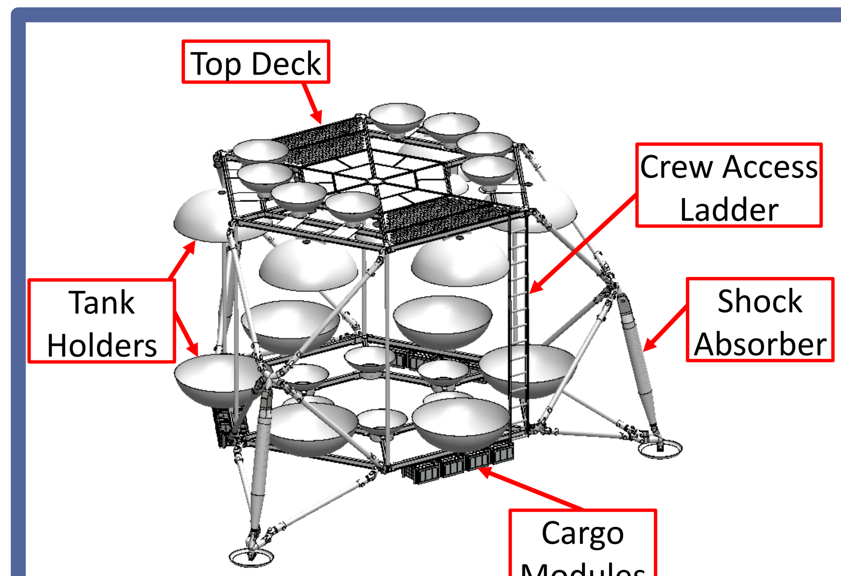
Pressure Vessel

Retains up to 14.7 psi atmosphere
Construction:
- 2.8 mm thick Al Weldalite panels
- Riveted lap joints seal structure

AIAA S-110-2005 requires SF of 1.4:
- Panel SF is 1.67
- Roof SF is 2.17



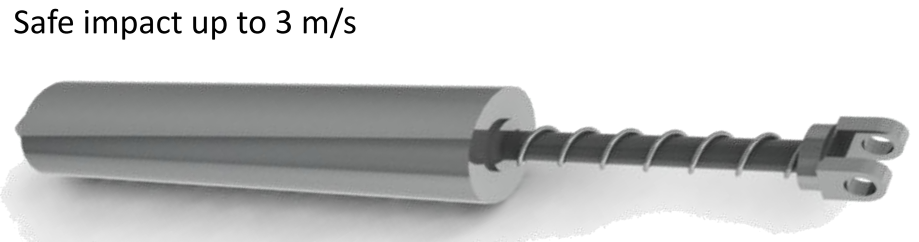
Structure



Hexagonal Frame
- AIAA-S-110 2005 requires SF of 1.4
- Made of Aluminum Weldalite 049-T8
  - 25% increase in yield strength, 3% decrease in density (7075)
- Pins and bolts have better understood failure modes than welds

Shock Absorbers

EFDYN 4 inch Bore Spring Return Model Custom Orifice Shock
- Silicone-oil Working Fluid – Apollo Rover
- 2 ft Stroke, room to depress
- Weight Equivalent 40-256 kN
- Safe impact up to 3 m/s



Cargo Modules

12 Easy to Access Modules
- 1 m off the ground
- Integrate with lunar architecture
- 1 m³ interior volume

Common Extensible Cryogenic Engine

Flexible engine based on proven technology
- CECE is powerful enough to launch LEVITATE on the Moon
- Thrust: 66.7 kN
- Specific Impulse: 445 sec
- Fuel: LOX/LH2 (5.5:1 mixture ratio)
- Throttling range: 9% to 102%
- Fuel can be obtained via ISRU
- Throttling range sufficient for each descent maneuver (lowest value is around 14%)

Environmental Control System (ECS) (Not Shown)

Trace Contaminate Removal System

Purpose : To remove contaminants from the atmosphere arising from metabolic processes and electronic off gassing.

Accomplished With:

Charcoal Media Bed

Removes high molecular weight contaminates (toluene, ammonia etc.)

Catalytic Oxidizer

Removes low molecular weight contaminates (methane, ethanol etc.)

Temperature and Humidity Control

Purpose : To arrest regolith, move air through the main ventilation lines and control temperature and humidity levels.

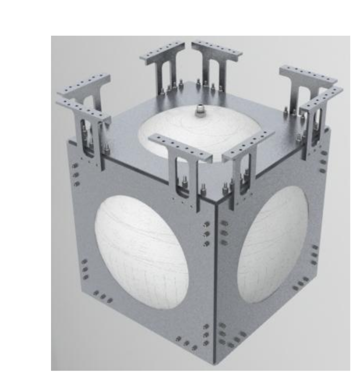
Accomplished With:

Air Filter **Temp & Humidity Sensor** **Heat Exchanger**

Nitrogen and Oxygen Control

Purpose : To maintain nitrogen and oxygen partial pressures in cabin.

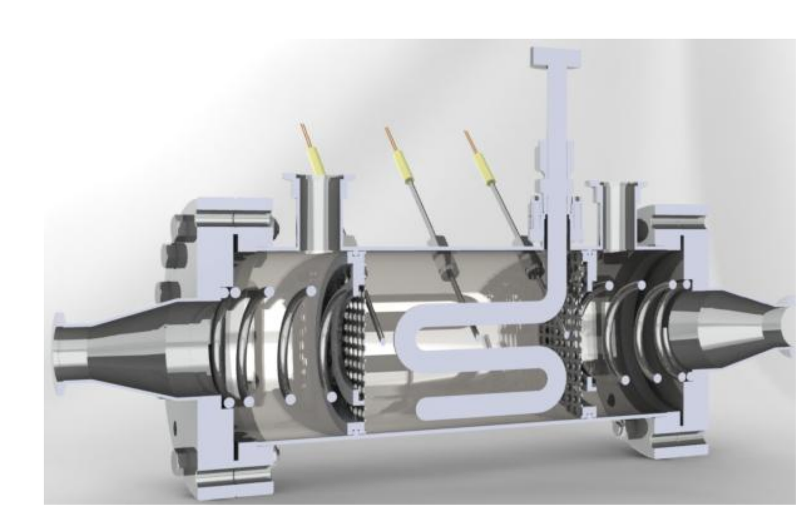
Accomplished With:
Cryogenic Liquid Oxygen and Nitrogen Tanks



Carbon Dioxide Removal Systems

Purpose : To remove excess carbon dioxide from human respiration.

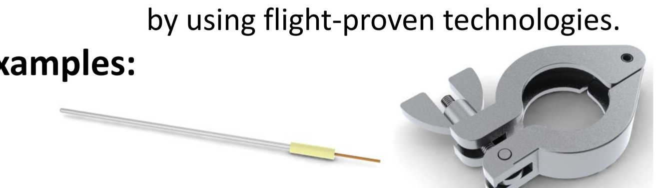
Accomplished With:
Zeolite Media Bed



Commercial Off-The-Shelf Components

Purpose: To reduce design cost and risk by using flight-proven technologies.

Examples:



Thermocouples from OMEGA Engineering

Kwik Flange Fittings From MDC-Vacuum

Accesses Entire Lunar Surface — **Fueled by Lunar Resources** — **Flies from Lunar Base** — **Returns 500 kg to Outpost** — **Supports 2 Astronauts** — **Missions Last 14 Earth Days**