Cosmos Corp Moon Base Mission

Department of Aerospace Engineering

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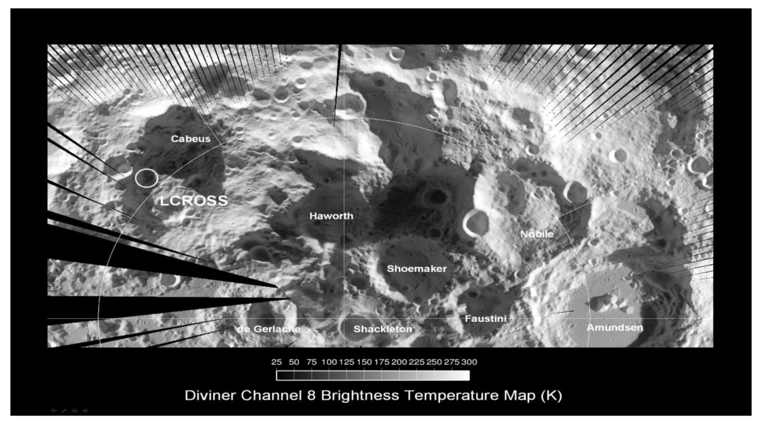
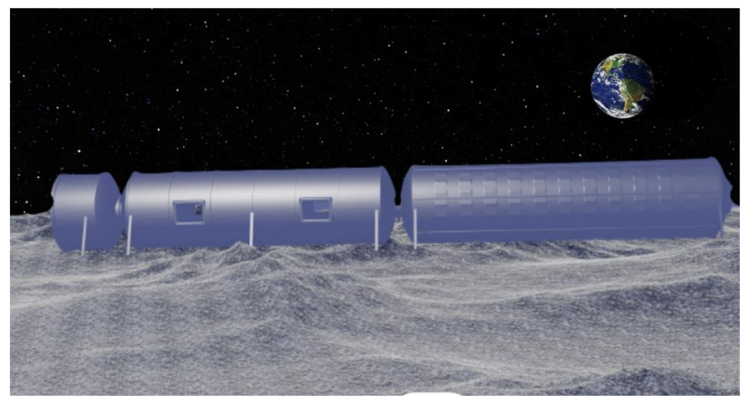
Abstract and Mission Purpose

NASA's Artemis program aims to return to the Moon in the coming years. Various proposals have been made for permanent bases on the lunar surface. One of the most promising regions is the lunar South Pole due to the suspected presence of water-ice in the permanently shadowed regions of many of its craters. The water-ice would permit the local produciton of Oxygen and potable water for human crews. Our proposal is for a base located near the rim of the Shackleton crater. The base would be small enough to fit within a single SpaceX Starship, featuring an inflatable section to expand the usable internal volume.





Requirements

Critical Requirements
- A complete pre-constructed habitat shall be delivered to the lunar surface for long-term habitation as an addition to the Artemis Program.
- The habitat shall be suitable for human habitation by a crew of four.
- The habitat shall be delivered by a single SpaceX Starship currently in development, with accompanying equipment delivered by the Starship HLS.

High Level Requirements
- The habitat shall be delivered to the Shackleton Crater near the lunar South Pole.
- The habitat shall be a partially inflatable design to increase internal volume.
- The crew shall rendezvous with the Lunar Gateway before proceeding to the lunar surface.
- The mission shall be completed in FY 2030.

Functional Requirements
- The habitat shall not exceed 100 metric tons in mass and 1000 cubic meters in volume when launched.
- The habitat shall include at least 2 airlocks for ingress/egress or as attachment points for future modules.
- The habitat shall be constructed from composite materials to exploit advances in materials science.
- The habitat shall withstand a maximum temperature of 135°C and minimum temperature of -240°C.
- The habitat shall be equipped with electrolysis facilities for oxygen production.
- The crew of the mission shall utilize water-ice harvesting equipment delivered by prior missions to maintain water and oxygen production.
- This list is not exhaustive, and additional functional requirements exist.

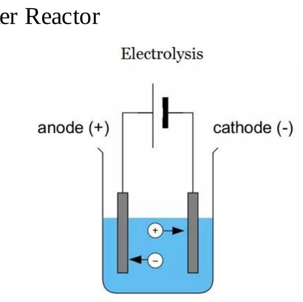
Systems Engineering

	Thermal	Power	Comms	Mechanical	Propulsion	ADCS	OnBDH
Requirements	-50 > T > 50C	Solar: 80kW generation Battery: ~60 kWh capacity	1 > Freq > 5Ghz Ant: high gain, directional Amp: high output over wide range of freq	F.S. > 2 > 1.5 GPa yield P < 182 psi	Thrust > 64800 N	Large impulse/ control, simple/ reliable	Open source Real time buffer Multiple fail safes/ fall backs
Options	Active: HVAC Passive: Surface finish, Radiator/ Louver	Li P.V.	Sband Parabolic reflector TWTA/ SSPA	Cylindrical monocoque Al 3.3 GPa	Boosters: Engine Fuel Oxidizer	Thrusters	F prime
Simulations	T between Treq	P ~= Preq	Successful Comm C/N = C/Nreq	FEMAP: F.S. > 2 yield = 3.3 Gpa Pmax = 192 psi	Thrust > landing weight	Yes	Yes
Req Met/ Not Met?	✓	✓	✓	✓	✓	✓	✓

Life Support System (LSS)

WRS
- Recoverable Water is processed through multiple filtration beds, purified, and deionized.
- Water is reprocessed until QC determines it is potable.
- WRS can reliably reclaim 90 percent of recoverable water.

OGS
- Electrolysis-based Oxygen Generation System
- Stored or WRS is fed to the OGS to be converted into reactants.
- Sabatier Reactor

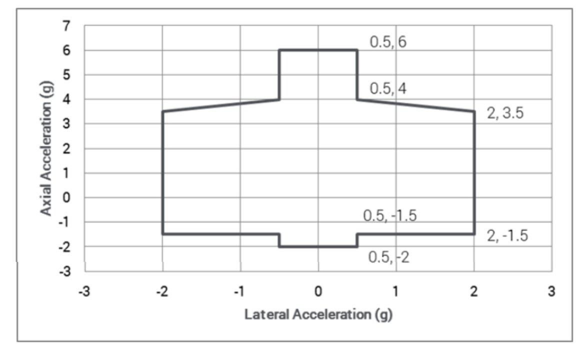


AFRS
- HVAC Systems move air through the cabin and into several filters and beds.
  - Charcoal
  - Catalytic Oxidizer
  - Lithium Hydroxide
- Trace contaminants of human respiration, dust, and other particles are monitored, filtered, and/or captured.
  - Carbon dioxide is captured behind a molecular sieve.

Design Overview

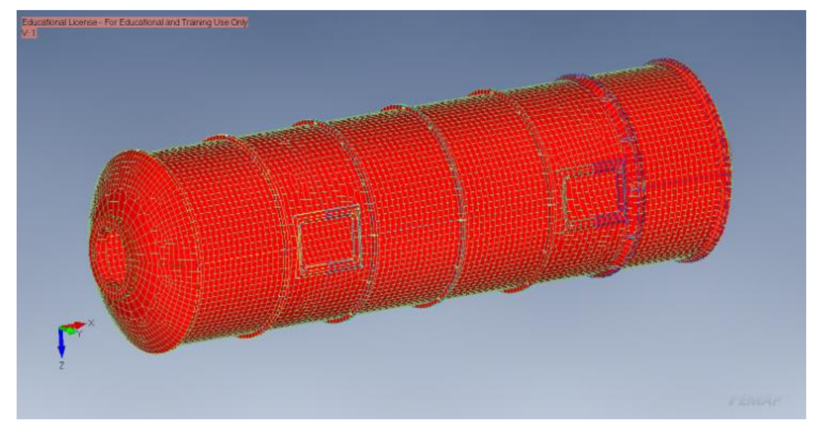
Mechanical

Requirements:
- Maintain structural integrity after exposure to environmental conditions with min cost, min mass, and max reliability
- Minimum factor of safety of 2.0
- Cylindrical monocoque Aluminum structure
- FEMAP found minimum margin of 2.11



Assumptions

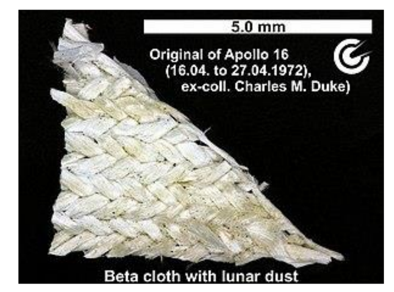
- HexMesh
- Non Structural Mass
- Rigid RBE2
- Acceleration Loads
  - 1.25 MUF
- Model Checks
  - Free-Free
  - Unit Displacement
  - 1 g Body



Thermal

Shackleton Crater

- 80K - 260K
- 80.62% illumination
- 200 days of sunlight



Materials

Requirements:

- Thermal protection from radiation
- Energy/shock absorbent protection
- Pressure and air containment
- Internal protective barrier

MLI (beta cloth)	Inorganic fireproof silica fiber cloth. Resistant to long-term degrading space environment
Nextel 312 AF-62	High temperature ceramic oxide yarn, stronger than aluminum, shock absorber
Kevlar KM2	Shock/energy absorber, strengthens nextel fabric
Vectran fabric	Pressure containment, stronger than steel
Urethane Pressure Bladder	Nylon liner, impermeable to air
Aramid Internal Barrier	Internal protection

Environmental concerns for material selection:

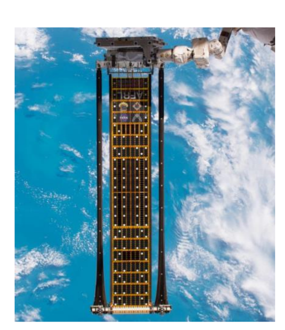
- Two types of radiation on the moon:
  - Galactic cosmic radiation
  - Solar energetic particle event radiation
- Temperatures near the Shackleton Crater ranges from 80 to 260 K

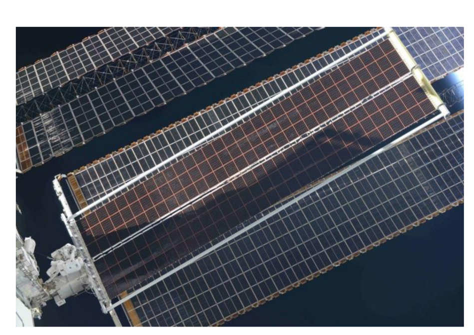
Requirement	Material	Properties	Suitability
Thermal protection	MLI beta cloth	Tight weave (d = 0.0004) resistant to AO Useful temp < 204 celsius	✓
Energy/shock protection	Nextel + Kevlar	Yield strength = 3.3 GPa	✓
Pressure/air containment	Vectran + Urethane	Can withstand 192 psi. NASA safety requirement = 182 psi	✓
Internal protection	Aramid fabric	No melting point	✓

Power and Communications

Arrays	4 x 20 kW ROSA	5 x 20 kW ROSA	80 kW traditional	100 kW traditional
Max Wattage	80 kW	100 kW	80 kW	100 kW
Mass	2760 kg	3450 kg	~3500 kg	~4400 kg

LSE134 Capacity	60 kWh	120 kWh	240 kWh	480 kWh	720 kWh
Mass	~3640 kg	~7280 kg	~14560 kg	~29120 kg	~43680 kg
Typical Ni-H2 Capacity	60 kWh	120 kWh	240 kWh	480 kWh	720 kWh
Mass	~10900 kg	~21800 kg	~43600 kg	~87200 kg	~130800 kg





III. Link Budget

Component/System	Quantity	Unit
Transmitter output power per carrier (p_t)	-30	dBW
Multiple carrier loss	0.3	dB
Transmitted carrier power (p_r)	-34.77	dBW
Transmitting antenna gain (g_t)	40.6	dB
Received antenna gain (g_r)	985.33	dB
EIRP	1059	dBW
Free Space loss (L_{FS})	211	dB
Other loss (L_0)	5	dB
Total transmission loss	-2	dB
Gain over system temperature (G/T)	923	dB/K
System noise figure (NF_S)	10.14	dB
Boltzmann's constant	−228.6	dBJ/K
Received (C/N_{0r})	555.26	dBHz
Transmitted (C/N_{0t})	549.86	dBHz
Margin	0.1	dB

Timeline and Systems Tool Kit (STK)

<u>Design Period Ends with Theoretical Project Approval</u>
Begin Acquisition of Parts/Labor/Facilities
December 31, 2023

<u>Manufacturing Begins</u>
Assembly begins at various contracted facilities (JPL, Kennedy Space Center)
Testing begins on components during construction
October 15, 2024

<u>Manufacturing Ends</u>
Final structure assembled
Completed structure testing commences
July 1, 2028

<u>Testing Completed</u>
All major testing completed
January 1, 2030

July 1st, 2030, 16:33:36 TCG: Launch from Boga Chica.

July 1st, 2030, 17:43:01 TCG: Start Lunar Injection Maneuver from Lower Earth Orbit (LEO).

July 3rd, 2030, 16:03:27 TCG: Begin Slow Down Maneuver before entering Lower Lunar Orbit (LLO).

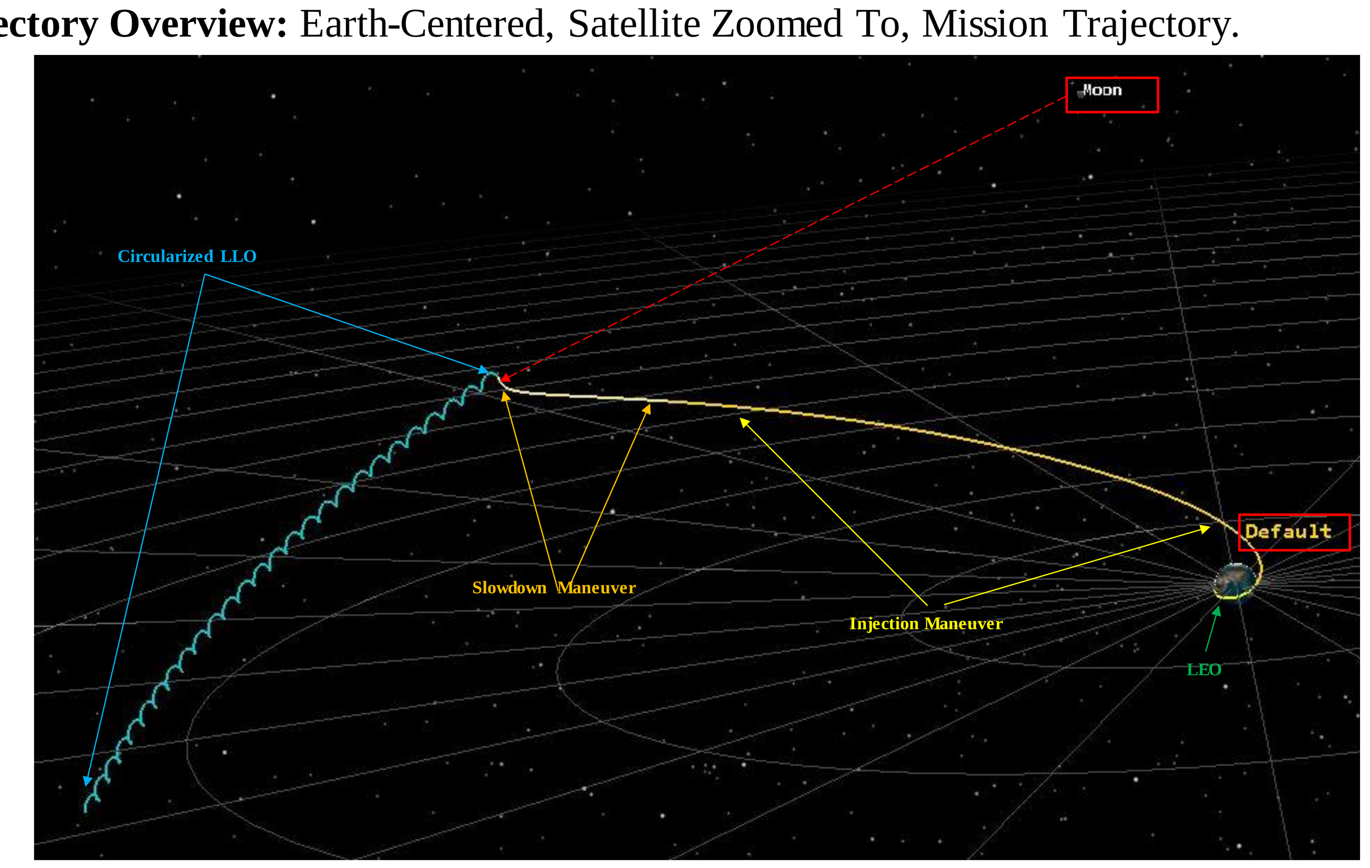
July 4th, 2030, 22:23:46 TCG: Start Circularize Maneuver into LLO.

July 7th, 2030, 22:00:00 TCG ~: Start Landing Sequence After LLO Orbit For 3 Days.

Delta-V's:

Initial Dry Mass & Fuel Mass	33,862.5 kg & 32,215.4 kg
Boca Chica > LEO	7.738 km/sec
LEO > Injection	3.12 km/sec
To Leave Earth Orbit	11.2 km/sec (7.738 + 3.12 = 10.858 km/sec)
Injection > Periselene Maneuver	0.991 km/sec
Periselene Maneuver > LLO	1.957 km/sec

Trajectory Overview: Earth-Centered, Satellite Zoomed To, Mission Trajectory.



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