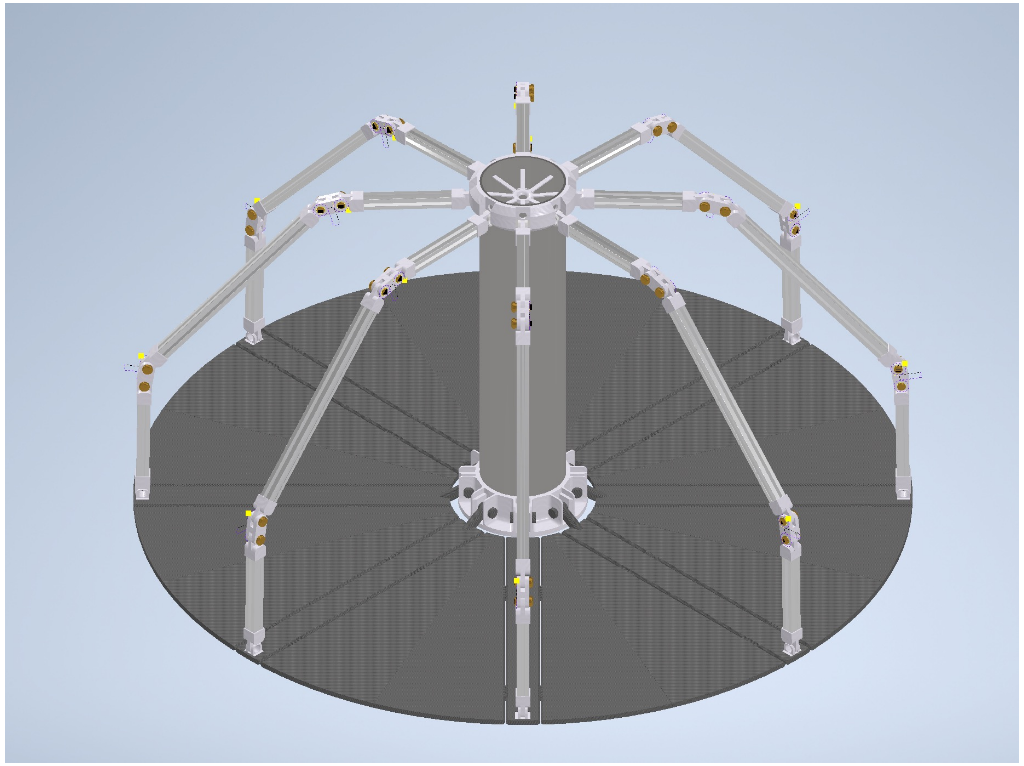
Moon 2 Mars

Critical Design Review (CDR)



Meet The Team


Project Manager
Adam Ctverak


Systems Engineer
Peter O'Brienhalla


Arms Subsystem Lead
Anthony Paluch


Electrical lead
Thomas Trevisan


Membrane Lead
Xavier Tomei


Center Column
Damarion Smith

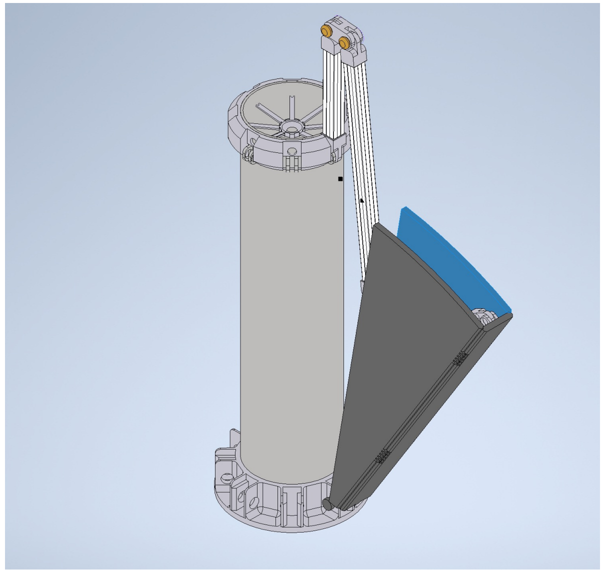

Center Column
Lead Jared Benigno


Arms and Deployment
Avery Pagliuso


Base Plates
Ahmad Albladi

1.0 Executive Summary

This presentation was prepared for the CDR review for Moon 2 Mars, a 2023-2024 capstone design team at Florida Institute of Technology with the purpose to provide an update on progression of the project.



Motivation: The team's motivation is to design, build, and operate a habitat on the Moon and other planetary surfaces.

Importance: Need for the next generation of reliable, accessible, and safe lunar habitats.

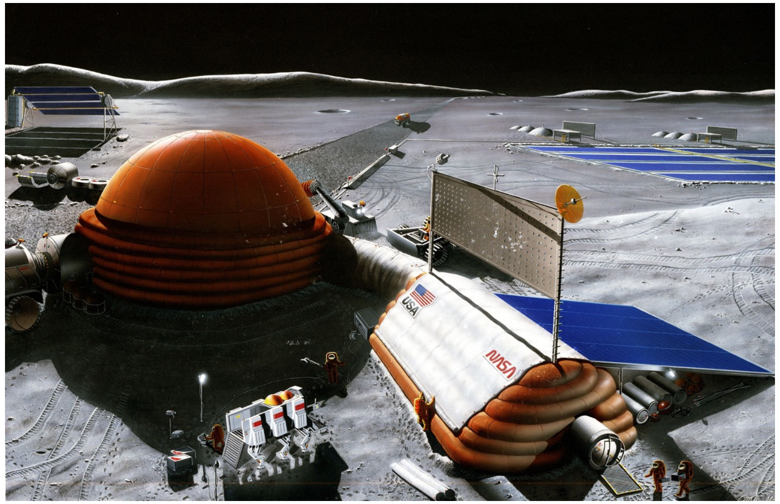
Objectives: Build and test a scaled model of the lunar habitat we designed.

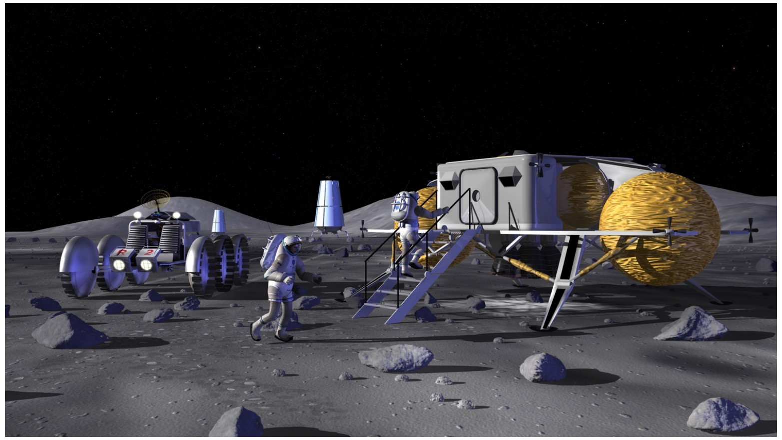
Adam: Project Manager
Peter: Systems Engineer

2.1 Problem Statement

NASA states that in the next chapter of lunar exploration, we will create a long-term human presence on and around the Moon. If humans are to stay on the surface of the Moon for a prolonged period, structures must be established to ensure their survival. Furthermore, these structures shall provide opportunities for lunar research to grow. The systems shall provide habitable conditions to support the life of four astronauts for at least 90 days (about 3 months).

A need exists for a habitat to be prototyped to increase the simulation and testing capabilities of future manned missions to the Moon. The habitat shall withstand intense structural loads, atmospheric pressure, and cryo-thermal cycling.





Anthony: Arms Subsystem Lead

2.2 Objectives

Objective #	Objective Text	Objective Rationale	Will the objective be met?
OBJ-01	The team shall design, build, and test an autonomous and deployable model of a lunar habitat.	This model demonstrates the functionality and scalability of the design.	Full Compliance Expected by Showcase
OBJ-02	The team shall develop FEA models and conduct structural loading tests to verify the structural integrity of the design.	The most significant loads the system needs to withstand during transport of the habitat from the Earth to the moon are: (1) launch, (2) landing, (3) pressurization, and (4) regolith cover.	Team expects to limit the requirements only to the loads associated with its own weight and deployment.
OBJ-03	The team shall conduct pressurization tests to verify the pressure membrane non-permeability.	The habitat needs to be able to sustain positive pressure difference at all times.	The team expects to test pressurization on a subscaled article (baloon). Full-scale membrane has been removed due to financial reasons.
OBJ-04	The team shall develop an autonomous environmental control system to measure and maintain appropriate pressure and temperature within the habitat.	To create a sustainable living environment that minimizes dependency on Earth-based control.	Full Compliance Expected by Showcase
OBJ-05	The team shall develop a robust communication system to ensure continuous contact between the lunar habitat and Earth control centers.	Essential for mission control, monitoring, and astronaut safety.	Full Compliance Expected by Showcase

Adam: Project Manager

2.3 Deliverables

Deliverable	Will the objective be met?
All documentation and analysis required by the Senior Design course	Full Compliance Expected by Showcase
Engineering Drawings detailed with dimensions, materials, and specific standards for hardware fabrication	Fully Compliant
CAD models for each breadboard models: membrane along with primary and secondary deployment	Fully Compliant
CAD models of each subsystems: membrane, baseplates, arms, center column	Fully Compliant
Subsystem interface diagram showcasing subsystem operations and integration	Full Compliance Expected by Showcase
Primary Deployment System and Electronics Integration	Full Compliance Expected by Showcase
Deployable and airtight membrane	Due to costs an alternative option is being decided
Integrated systems anchoring both the arms and base plates to the structure	Full Compliance Expected by Showcase
Testing Plans and Reports associated with the functionality and integrity of the structure	Full Compliance Expected by Showcase
User/Operator manual for the habitat	Full Compliance Expected by Showcase

Jared: Column lead

2.4 Societal and Economic Impacts

Advancements in Research:

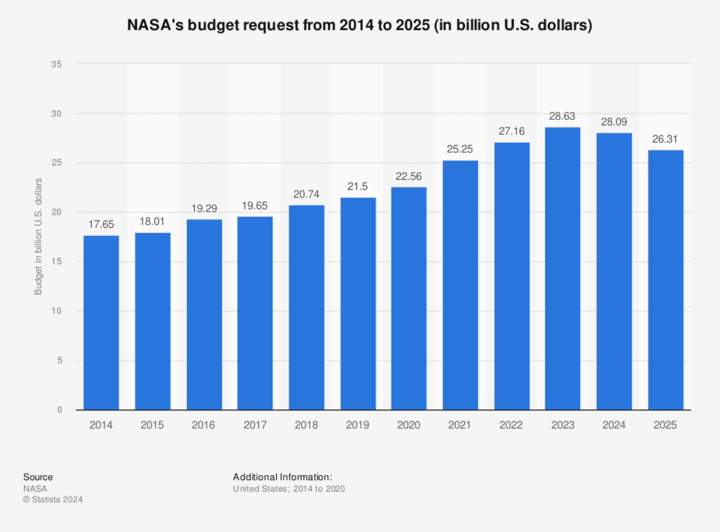
Our design opens new ideas for lunar habitat transportation and installation. Our habitat represents the beginning of the advancement of settlements that is both modular, and space effective. By designing our structure to be collapsable, there is more available payload volume, providing options for more supplies and technology, maximizing research and production of manned missions, thus becoming more cost effective.

New Insights:

Our design provides a new opportunity for long-term settlement on the Lunar surface. Trending design concepts do not have any structures that are collapsible to conserve space in the rocket fairing. Our design tests the limits of collapsible structures capable of deploying and assimilating to the Lunar surface, while still providing adequate habitable space within the habitat. This is a challenge that is crucial for the future of the Artemis program and the others that follow.

Experimental Platforms:

Our design concept is a unique method to provide shelter on an inhabitable location. We considered availability of cargo space, along with the size required to comfortable support life. With an expanded-contracted volume ratio of 2.2:1, we provide a unique opportunistic concept that provides a different perspective for solving the complications of current Moon/Mars habitat iterations.


NASA's budget request from 2014 to 2025 (in billion U.S. dollars)

Source
NASA
© Statista 2024

Additional Information:
United States; 2014 to 2020

"the current production and operations cost of a single SLS/Orion system [will be] $4.1 billion per launch for Artemis I through IV."

-Paul Martin, NASA head of the Office of Inspector General

Anthony: Arms Subsystem Lead

4. Level 1 System Requirements

Reqt #	Requirement Text	Requirements Rationale	Verification Method	Verification Strategy, Other Notes	Status
M2M.01	The demonstration model shall be scalable.	Required to prove that the design can be scaled up to provide living conditions for 4 astronauts for a 90-day mission.	Analysis	Analysis of habitat as size increases to determine changes in functionality and habitability conditions.	Full Compliance Expected
M2M.02	The demonstration model shall be autonomously deployable and inflatable.	Required for transportability, cost, and safety.	Demonstration	Demonstration of deployment sequence and inflation.	Full Compliance Expected
M2M.03	The lunar habitat shall be able to withstand ultrahigh vacuum.	Required for structural integrity and habitability.	Test	Vacuum test	Partial Compliance Expected Analysis only for cost reasons
M2M.04	The lunar habitat shall be able to withstand extreme temperatures.	Required for structural integrity and habitability.	Test	Thermal cycling test	Partial Compliance Expected Analysis only for cost reasons
M2M.05	Lunar habitat must be able to fit inside SLS Block 2.	Chosen as the primary launch vehicle due to mission design.	Inspection	Calculation	Full Compliance Expected

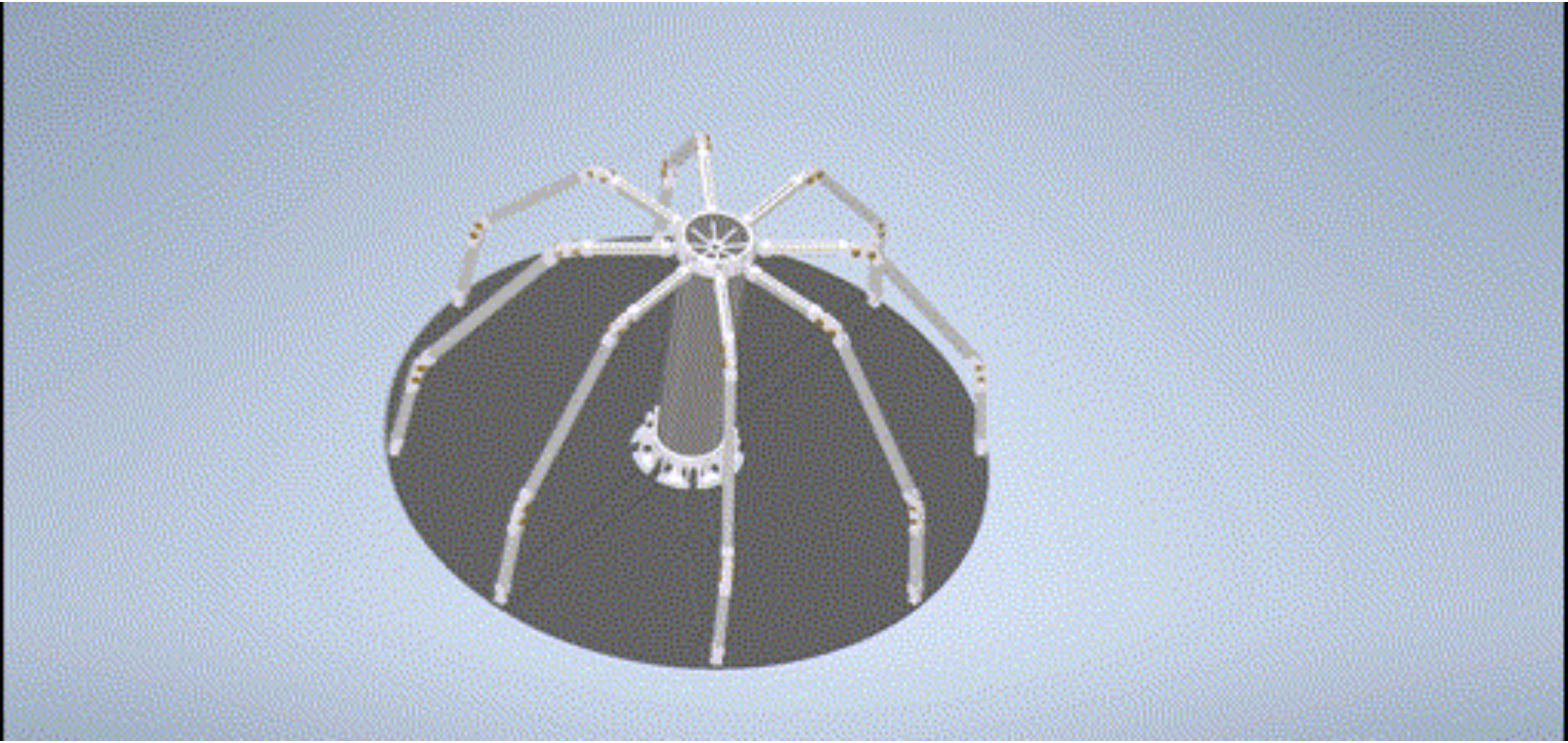
Adam: Project Manager

5.1 System Design

The engineering system designed for the M2M lunar habitat project is an autonomously deployed hybrid inflatable structure designed to support and protect human life from lunar environmental conditions. We will develop a small-scale model of this structure to demonstrate the functionality of our design without the need for extensive funding and to readily test the system's efficacy in lunar conditions.

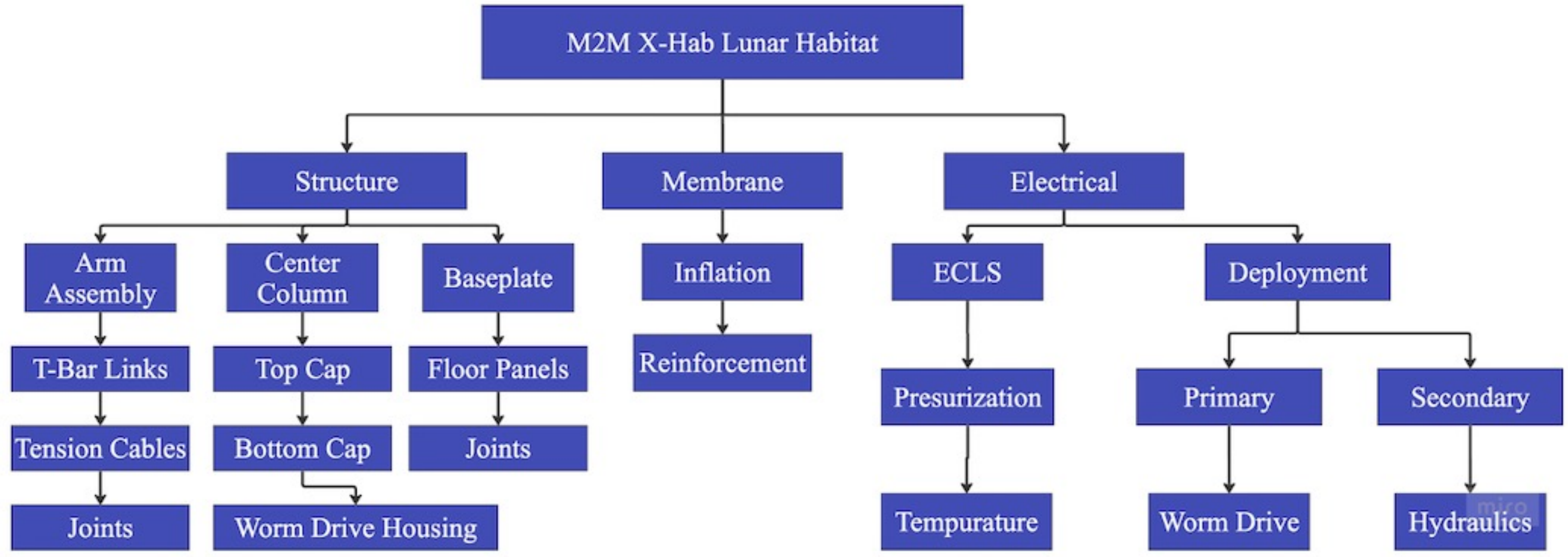
Adam: Project Manager

5.1 System Design



Anthony: Arms Subsystem Lead

5.2 System Architecture

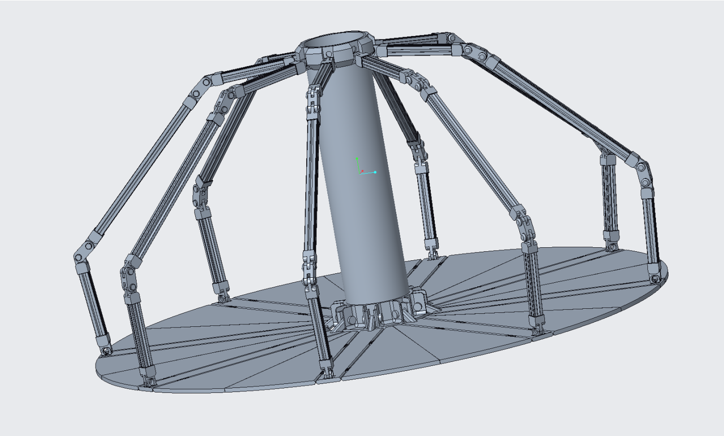


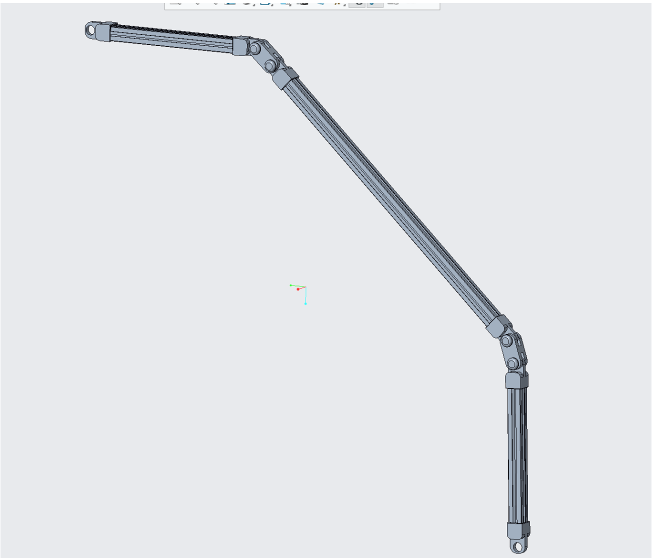
Xavier: Membrane Lead

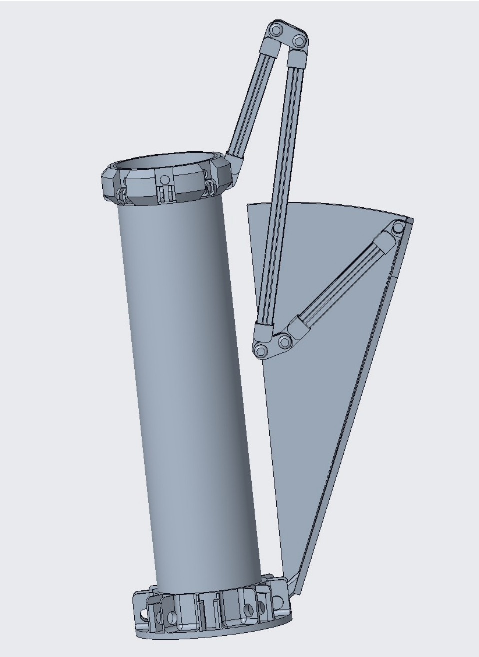
6.1.1 System Design - Arms

As the major component in primary deployment, the arms are responsible for lowering the baseplates and providing structural rigidity to the system

- To enable the most optimal design, the length of the second segment is extended while maintaining symmetry in the two outer segments. This ensures an optimal range of motion during primary deployment
- Double shear joints enables the assembly to fold onto itself, allowing the arm segments to sit parallel to each other before deployment
- T-slot aluminum extrusions provide a modular, compatible solution for the arm assembly, offering structural rigidity compared to other options.







Avery: Arms and Deployment

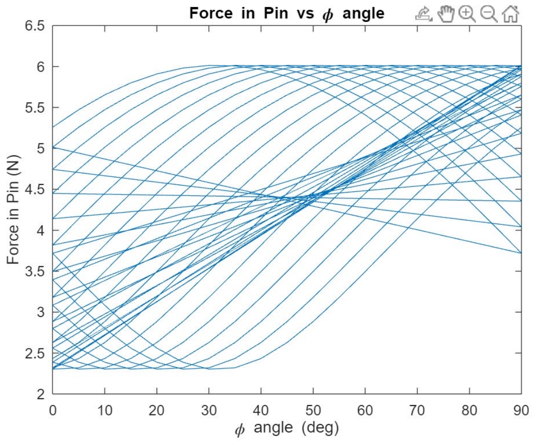
6.1.2 System Design - Primary Deployment

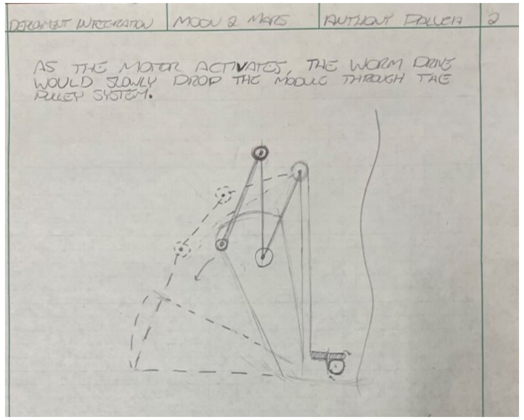
The Primary Deployment is responsible for pivoting the baseplates from their closed position, to lay flush to the Lunar surface.

The initial design of our deployment involved a system of pulleys that fed through each arm segment and was fixed to the baseplate. Although this design showed promise, the pulleys could not be integrated into the joints effectively without compromising their structural integrity.

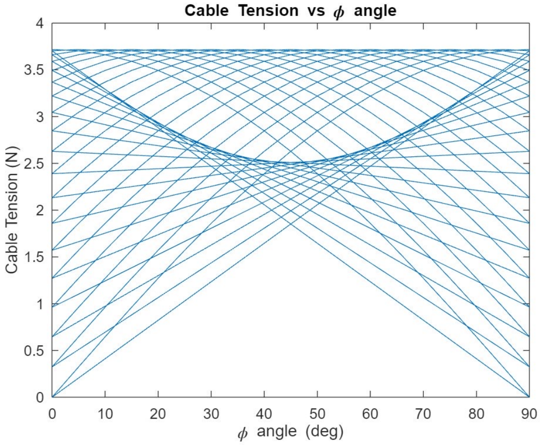
Our latest design features high strength cables fed through the track of the upper T-Bar extrusion only. The steel cables will be fixed to the first extrusion cap rather than being fed through all the arm segments.

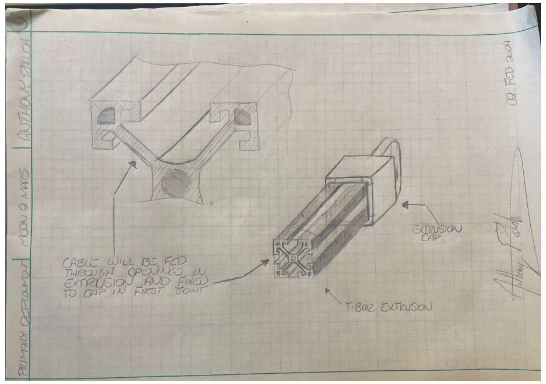
The cables will be driven and controlled by a worm-drive gear held within the central column. Prior to deployment, tension will be held within the cables and the gear assembly.





AS THE MOTOR ACTIVATES, THE WORM DRIVE WOULD SLOWLY DROP THE MODULE THROUGH THE PULLEY SYSTEM.





CABLE WILL BE FED THROUGH OPENINGS IN EXTRUSION AND FIXED TO CAP IN FIRST JOINT

Anthony: Arms Subsystem Lead

6.1 Subsystem Requirements - Primary Deployment

Number	Requirement	Requirements Rationale	Verification Method	Verification Strategy, other notes	Expected Status
PD-01	The primary deployment shall utilize tension cables to hold the habitat in folded configuration.	The habitat is designed to be deployable (M2M-02).	Demonstration	The cables selected shall withstand the tension	Full compliance expected
PD-02	The primary deployment shall utilize a motor to deploy the habitat into deployed configuration.	The habitat is designed to be deployable (M2M-02).	Demonstration	The motor selected shall withstand the torque	Full compliance expected
PD-03	The arm segments must provide a minimum range of motion of 180 degrees in both horizontal and vertical planes.	This requirement ensures that the arm assembly can achieve a wide range of positions necessary for effective deployment	Physical Testing / Simulation	Conduct comprehensive testing using simulation software to confirm that the arm segments can achieve the specified range of motion. Additionally, perform physical testing with the base plates in different configurations to validate the practical usability of the arm assembly.	Full Compliance Expected

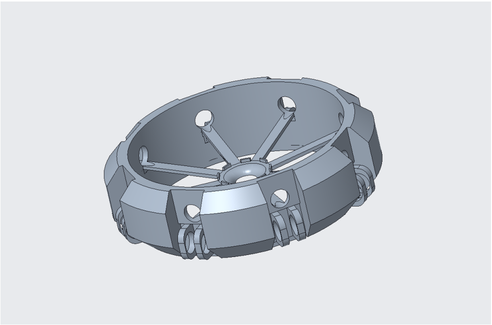
Avery: Arms and Deployment

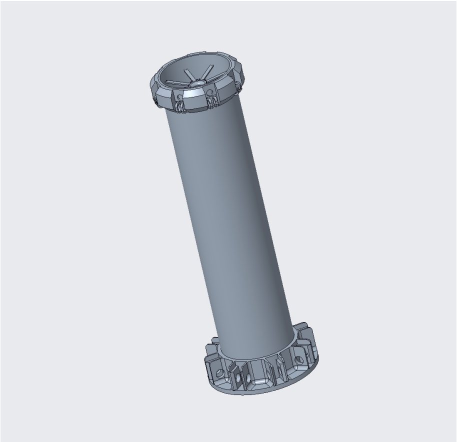
6.2.1 System Design - Center Column

- The Center Column shall uphold the structural integrity throughout the habitat while housing our primary deployment system and essential components, such as the worm-drive, motor, cables, and air tank.

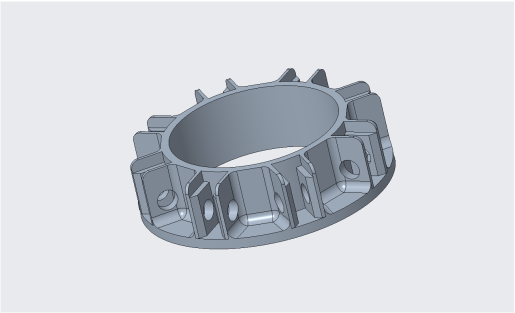
- Comprised of three integral parts:
  - Top cap: serves as an anchor point for the arms which features a web to prevent tangling in the cables
  - Center pole: houses the electronics and hardware for the habitat
  - Bottom cap: acts as the anchor and connection point for the base plates to the center column

Top Cap





Bottom Cap



Damarion: Center Column

6.2 Subsystem Requirements - Central Column

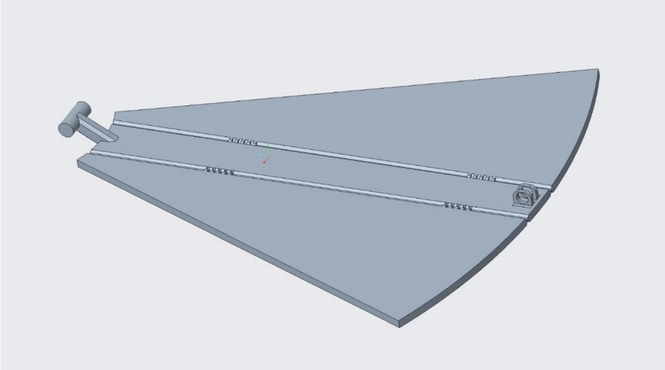
Number	Requirement	Requirements Rationale	Verification Method	Verification Strategy, other notes	Expected Status
CC.01	The center column shall provide the habitats structural support	Maintain the structural loads induced by the arms, baseplates, and outside sources	Structural analysis and loading test	Material selected shall withstand stress and strain	Full compliance expected
CC.02	Interior shall house the primary deployment system along with each electrical component	Storing the crucial components in the center to prevent environmental hazards and to facilitate central control/monitoring	Integration and Electrical Testing	Positioning each component properly to note damage or misplace parts along with preventing electonics from overheating	Full compliance expected
CC.03	Top cap shall serve as the anchor point for the membrane and arms	Anchor point for the 8 arms ensuring proper alignment of the arms and deployment of the base plates	Deployment and Visual Testing	Visual inspection to ensure each part is properly aligned and reinforce features for support	Full compliance expected
CC.04	The top cap shall prevent primary deployment cables from tangling	Reduces the risk of disruptions and allows for a smooth deployment of habitat components	Deployment Testing	Testing the deployment and movement of the worm-drive to assess the movement of the cables	Full compliance expected
CC.05	The bottom cap shall act as an anchor and connection point	Providing a distributed load amongst each base plate and throughout the habitat	Deployment and Alignment Testing	Inspections will be conducted to ensure the bottom caps effectiveness and proper connection	Full compliance expected

Jared: Center Column Lead

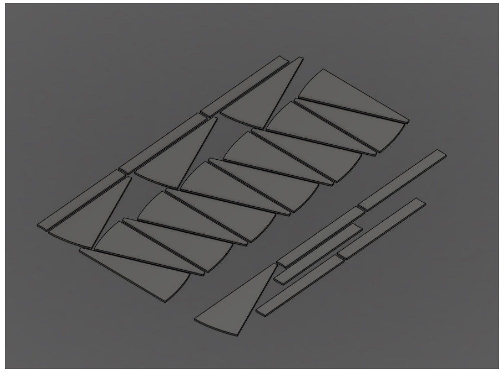
6.3.1 System Design - Base Plates

The Base Plates main function is to provide the habitat with an equidistant flooring around the center column to ensure stability on uneven lunar terrain.

- Our baseplates were designed in a semi-triangular shape which have multiple components to enable foldability for practicality and size reduction.
- We have a total of eight pair of base plates, with each pair broken down into three main parts : middle rectangle plate, two side plates, resulting in a total of 24 pieces.
- Other minor components:
  - T-shape joint that connects the middle part of baseplate into the center column.
  - Two piano hinges to attach the side plates into the middle plate
  - Circular joint at middle plate to connect with the arm



Base Plates



Ahmad: Base Plates

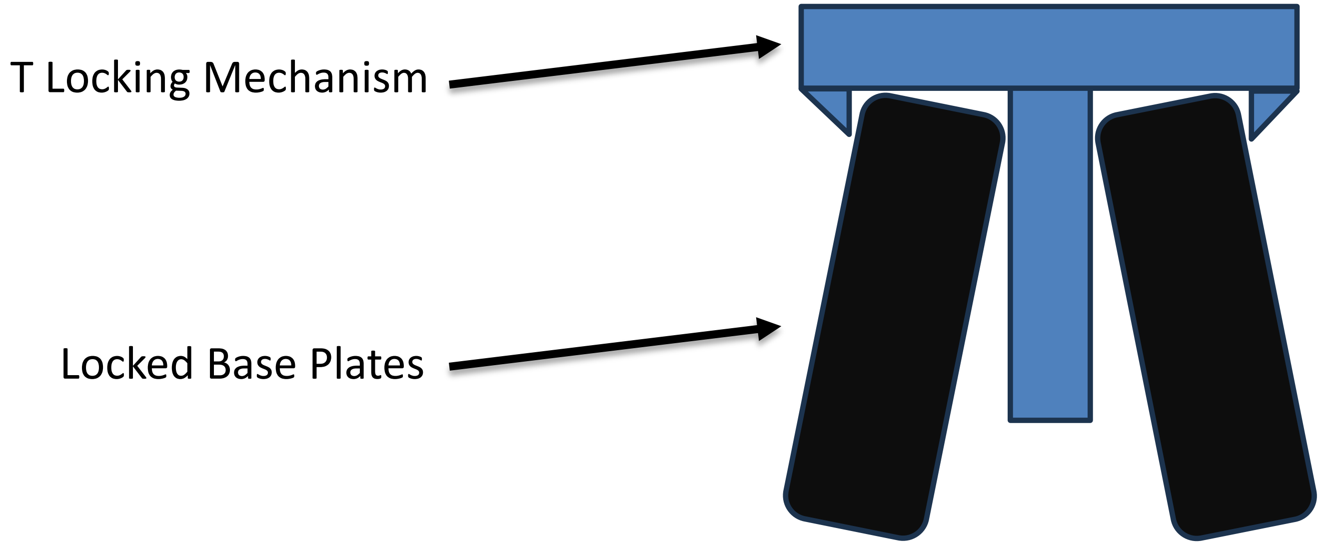
6.3 Subsystem Requirements - Base Plates

Number	Requirement	Requirements Rationale	Verification Method	Verification Strategy, other notes	Expected Status
BP-01	Base plates shall be as light weight as possible	Minimum weight required to ensure steady deployments	Deployment testing	Material selected is within the weight standard	Full compliance expected
BP-02	Base plates shall support the weight of four astronauts.	Maintaining the structure load standers is crucial to avoid failure points	Analysis	Applying analysis testing using Ansys workbench.	Full compliance expected
BP-03	Base plate shall operate with the secondary deployment.	The success of the secondary deployment is crucial for the structure set up	Deployment testing	Testing the manufactured plates and secondary deployment movement	Full compliance expected
BP-04	Secondary deployment shall keep the baseplates in a still state within the folded configuration	Base plates should stay still until the initiation of secondary deployment .	Locking mechanism testing	Testing the secondary deployment locking mechanism effectiveness	Full compliance expected

Ahmad: Base Plates

6.3.2 System Design - Secondary Deployment

- The goal is to create a system that locks the base plates in the folded positions until deployment
- A few different design solutions were drawn and 3-D modeled, but after decision matrices were created, it was clear that the simple is sometimes the best
- The final design is to create a locking mechanism that is shaped as a T that holds the plates together and pops off when plates contact the lunar surface
- Spring-loaded hinges push against the locking T to ensure plates don’t move till T is pushed off the plates releasing them



Peter: Systems Engineer

6.4.1 System Design- Membrane

- The membrane is responsible for maintaining pressure within the structure and providing additional structural support
- The membrane is critical for a habitable environment

Previously:

- Hemispherical shape to reside within the arms. Pressurization to .2 atm.

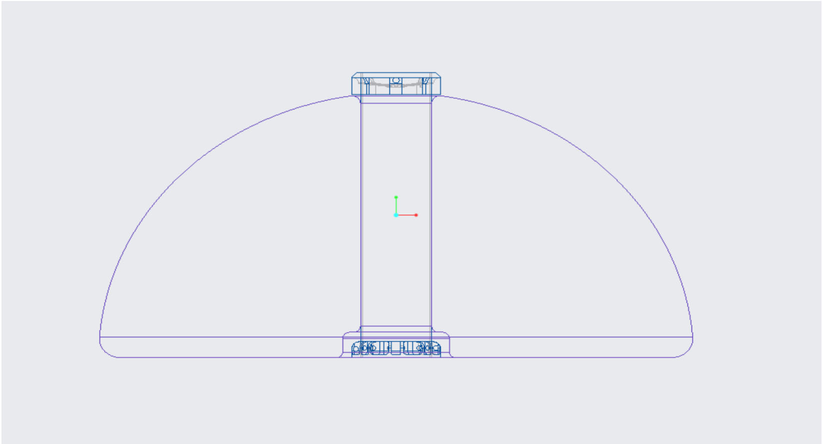
Currently:

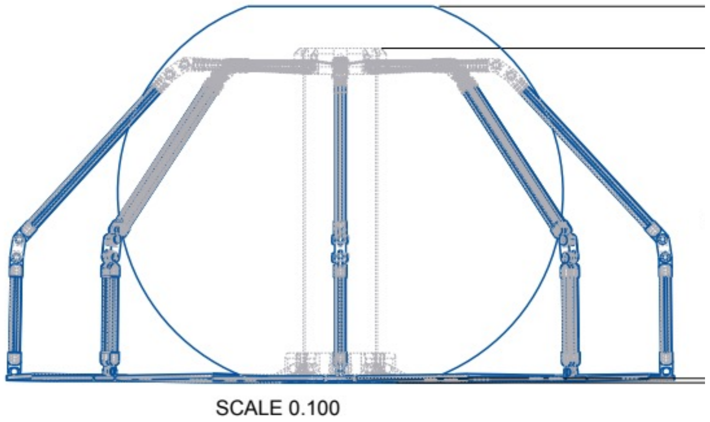
- Spherical design to reside within the arms. No pressurization requirement.

Pros:

- Effectively demonstrates the pressurization system while providing structural support to the arms.
- Significantly reduces expenses (factor of 10)

Xavier: Membrane Lead





6.4 Subsystem Requirements - Membrane

Examples shown below

Number	Requirement	Requirements Rationale	Verification Method	Verification Strategy, other notes	Expected Status
MEM-01	The membrane shall maintain an internal pressure of .2 atmosphere within a vacuum.	Minimum atmospheric requirement for a habitable environment.	Analysis	After complete deployment, internal pressure reading will be measured	Only partial compliance is expected because the design has been modified
MEM-02	The membrane shall be air-tight.	Leaks in membrane will result in failure of entire system	Test	Vacuum chamber testing will verifiy that the membrane is airtight.	Full compliance expected
MEM-03	The membrane shall be autonomously inflated after the deployment sequence.	Autonomous deployment is necessary for the final lunar model.	Demonstration	Full deployment sequence will be demonstrated at showcase.	Full compliance expected

Xavier: Membrane Lead

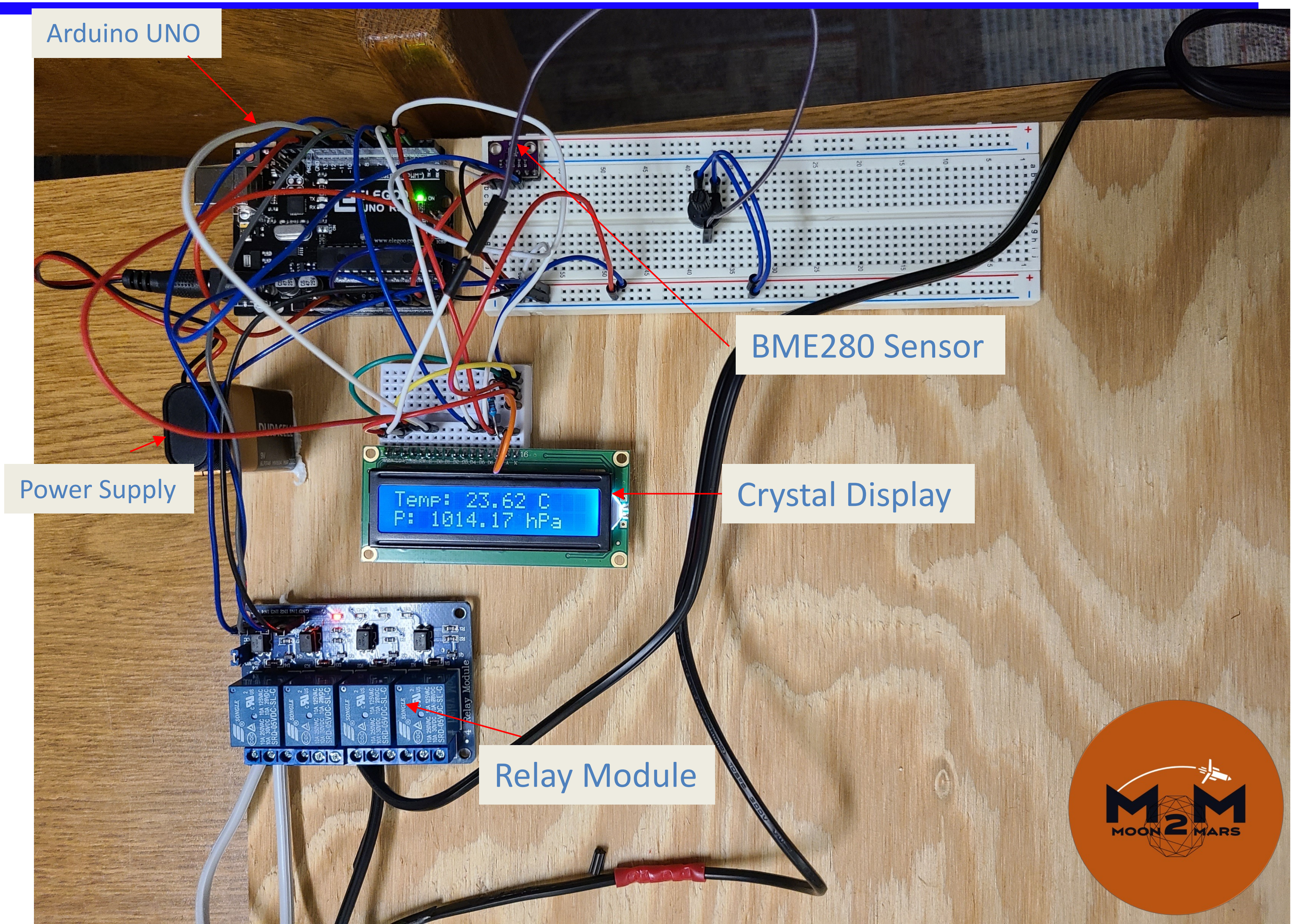
6.5.1 System Design - Electrical

Our model will mainly consist of 2 Arduino UNOs, a crystal display, BME280 sensor, Relay Module, Power Supplies, and a motor.

We are using a BME280 sensor, with this sensor we will be able to monitor and keep all values in a controlled range.

In addition to the BME280 we will be using a relay module that will be able to control the heat and AC. Once the parts arrive, we will have a solenoid valve hooked up to Relay 3 that will maintain a constant 0.2atm in the membrane.

All the environmental controls are running off one Arduino, and all the systems for deployment will be connected to a second Arduino.



Thomas: Electrical Subsystem Lead

6.5 Subsystem Requirements - Electrical

Electrical

Number	Requirement	Requirements Rationale	Verification Method	Verification Strategy, other notes	Expected Status
ELE-01	To create a self-supported environment, that has the ability to maintain life during the mission.	Note: This is a functional requirement- it tells what is required but does not specify details.	Analysis Vacuum Testing Demonstration	We will place our system in different environments to simulate a change in temperature and make sure the system is able to correct the temperature to the specified range.	Full compliance expected
ELE-02	To be able to fully deploy and inflate our structure, with a press of button.	Note: This is a functional requirement- it tells what is required but does not specify details.	Analysis Demonstration	Will do tests with all the induvial components and then test the deployment sequence once the structure is completed.	Full compliance expected

Thomas: Electrical Subsystem Lead

7.1 Mass Budget

Subsystem ID	Scale Model Material	Scale Model Material Density (kg/m^3)	Part Volume (m^3)	Scale Model Mass (kg)	Scale Model Weight (lb.)	Quantity	Total Mass (kg)	Total Weight (lb.)
Baseplate	White Ash Plywood	750	0.0039	2.9250	6.4350	8	23.40	51.48
Arm (short)	Aluminum 6060	2710	0.0001	0.3577	0.7870	16	5.72	12.59
Arm (long)	Aluminum 6060	2710	0.0002	0.6369	1.4011	8	5.09	11.21
Center Column	Poly-Vinyl Chloride (PVC)	1380	0.0037	5.1597	11.3513	1	5.16	11.35
Double Pinned Joints	Aluminum 6060	2710	0.00004	0.1114	0.2450	16	1.78	3.92
Deployment Assemblies	Miscellaneous	Miscellaneous	Miscellaneous	10.0000	22.0000	2	20.00	44.00
Totals:	-	-	0.0080	9.1906	20.2194	51	61.16	134.55

Scaled Model Mass Budget

SLS Block 2 Cargo Payload Volume:	988	Allocated SLS Block 2 Cargo Payload Mass:	4173
Habitat Full-Scale Volume (m^3) [Collapsed]	48	Habitat Full-Scale Mass (kg)	1428.63
Volume Consumption %	4.8482	Mass Consumption %	34.2351
Volume Remaining %	95.1518	Mass Remaining %	65.7649

Mass/Volume Consumption

Subsystem ID	Idealized Material	Idealized Material Density (kg/m^3)	Part Volume (m^3)	Idealized Mass (kg)	Expected Weight (lb.)	Quantity	Total Mass (kg)	Total Weight (lb.)
Baseplate	Carbon Fiber/Aramid Honeycomb Composite	176.09	0.0949	16.7087	36.7590	8	133.67	294.07
Arm (short)	Titanium	4540	0.0032	14.5805	32.0771	16	233.29	513.23
Arm (long)	Titanium	4540	0.0057	25.9577	57.1069	8	207.66	456.86
Center Column	Stainless Steel	7930	0.0910	721.3718	1587.0179	1	721.37	1587.02
Double Pinned Joints	Titanium	4540	0.0010	4.5400	9.9880	16	72.64	159.81
Deployment Assemblies	Miscellaneous	Miscellaneous	Miscellaneous	30.0000	66.0000	2	60.00	132.00
Totals:	-	-	0.1948	778.6186	1712.9609	51	1428.63	3142.99

Full-Scale Model Mass Budget

*Expanded-Collapsed Volume Ratio: 2.2:1

Anthony: Arms Subsystem Lead

7.2 Electrical Power Budgets

Power Usage

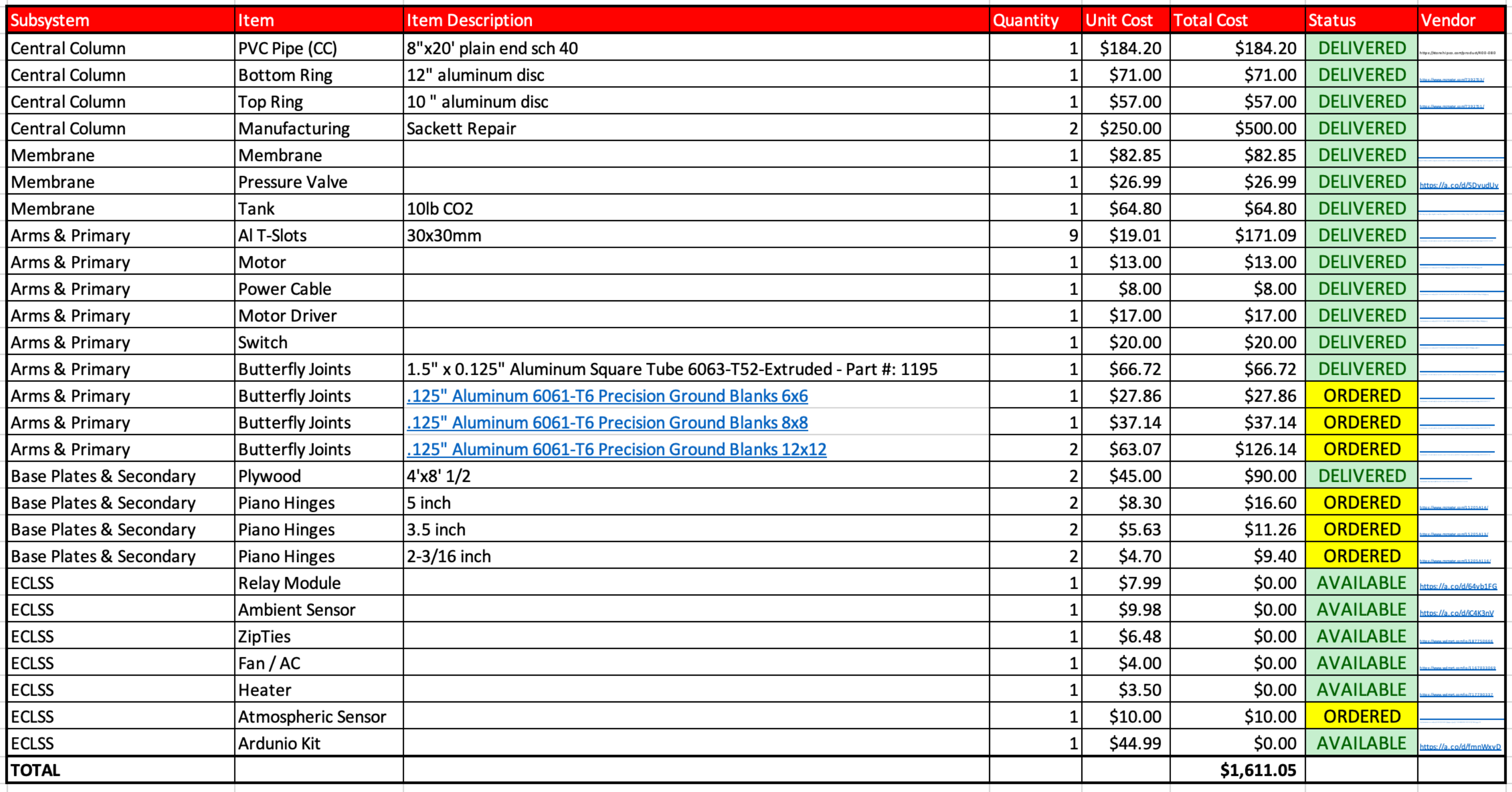
Subsystem	Avg Power Usage per day (Watts)	Avg Power Usage per rotation of moon (Watts)
AC (12 hr Usage)	21600	604800
Heat (12 hr Usage)	18000	504000
Fan/Blower	12000	336000
Oxygen Scrubber	72000	2016000
Computers	240	6720
Lights	240	6720
Communications	480	13440
Misc.	480	13440
Total	**125038.6**	**3501080**

Power Usage	Watt-hour	kWh
Daily Power	5,209.94	5.21
Rotation Power	153,693.23	153.69

Power Needed	Daily Operation	Rotation Operation
Batteries kWh's	5.21	153.69
Solar panels (m^2)	12(16.44kWh) required to fully charge	

Thomas: Electrical Subsystem Lead

8 Financial Budget

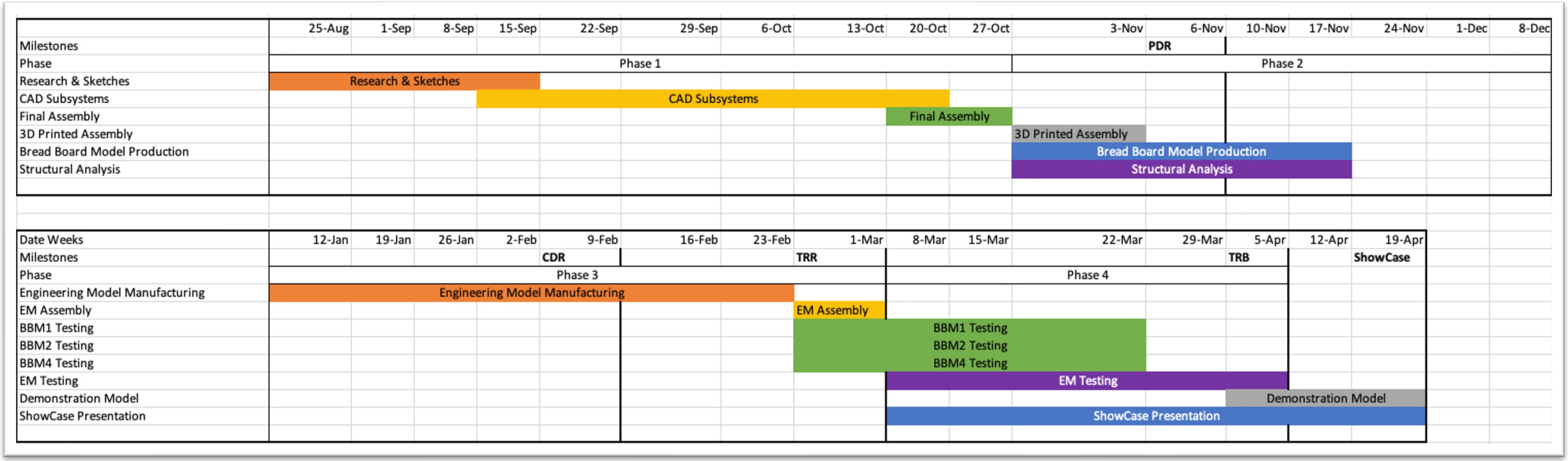


Subsystem	Item	Item Description	Quantity	Unit Cost	Total Cost	Status	Vendor
Central Column	PVC Pipe (CC)	8"x20' plain end sch 40	1	$184.20	$184.20	DELIVERED	https://storehipco.com/product/400-080
Central Column	Bottom Ring	12" aluminum disc	1	$71.00	$71.00	DELIVERED	https://www.mcmaster.com/7392T53/
Central Column	Top Ring	10 " aluminum disc	1	$57.00	$57.00	DELIVERED	https://www.mcmaster.com/7392T51/
Central Column	Manufacturing	Sackett Repair	2	$250.00	$500.00	DELIVERED	
Membrane	Membrane		1	$82.85	$82.85	DELIVERED	
Membrane	Pressure Valve		1	$26.99	$26.99	DELIVERED	https://a.co/d/5DyudUy
Membrane	Tank	10lb CO2	1	$64.80	$64.80	DELIVERED	
Arms & Primary	Al T-Slots	30x30mm	9	$19.01	$171.09	DELIVERED	
Arms & Primary	Motor		1	$13.00	$13.00	DELIVERED	
Arms & Primary	Power Cable		1	$8.00	$8.00	DELIVERED	
Arms & Primary	Motor Driver		1	$17.00	$17.00	DELIVERED	
Arms & Primary	Switch		1	$20.00	$20.00	DELIVERED	
Arms & Primary	Butterfly Joints	1.5" x 0.125" Aluminum Square Tube 6063-T52-Extruded - Part #: 1195	1	$66.72	$66.72	DELIVERED	
Arms & Primary	Butterfly Joints	.125" Aluminum 6061-T6 Precision Ground Blanks 6x6	1	$27.86	$27.86	ORDERED	
Arms & Primary	Butterfly Joints	.125" Aluminum 6061-T6 Precision Ground Blanks 8x8	1	$37.14	$37.14	ORDERED	
Arms & Primary	Butterfly Joints	.125" Aluminum 6061-T6 Precision Ground Blanks 12x12	2	$63.07	$126.14	ORDERED	
Base Plates & Secondary	Plywood	4'x8' 1/2	2	$45.00	$90.00	DELIVERED	
Base Plates & Secondary	Piano Hinges	5 inch	2	$8.30	$16.60	ORDERED	https://www.mcmaster.com/15205A14/
Base Plates & Secondary	Piano Hinges	3.5 inch	2	$5.63	$11.26	ORDERED	https://www.mcmaster.com/15205A13/
Base Plates & Secondary	Piano Hinges	2-3/16 inch	2	$4.70	$9.40	ORDERED	https://www.mcmaster.com/15205A116/
ECLSS		Relay Module	1	$7.99	$0.00	AVAILABLE	https://a.co/d/64vb1FG
ECLSS		Ambient Sensor	1	$9.98	$0.00	AVAILABLE	https://a.co/d/iC4K3nV
ECLSS		ZipTies	1	$6.48	$0.00	AVAILABLE	https://www.walmart.com/ip/187750666
ECLSS		Fan / AC	1	$4.00	$0.00	AVAILABLE	https://www.walmart.com/ip/1167033069
ECLSS		Heater	1	$3.50	$0.00	AVAILABLE	https://www.walmart.com/ip/717790337
ECLSS		Atmospheric Sensor	1	$10.00	$10.00	ORDERED	
ECLSS		Ardunio Kit	1	$44.99	$0.00	AVAILABLE	https://a.co/d/fmnWxyD
TOTAL					**$1,611.05**		

Total Budget	Current Amount Spent	Current Remaining	Expected Remaining Expenditures at Completion	Expected Total at Completion	Expected Remaining Funds
$2,000	$1611.05	$388.95	$300	$1911.05	$88.95

Adam: Project Manager

8.1 Schedule



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<tr><th></th><th>25-Aug</th><th>1-Sep</th><th>8-Sep</th><th>15-Sep</th><th>22-Sep</th><th>29-Sep</th><th>6-Oct</th><th>13-Oct</th><th>20-Oct</th><th>27-Oct</th><th>3-Nov</th><th>6-Nov</th><th>10-Nov</th><th>17-Nov</th><th>24-Nov</th><th>1-Dec</th><th>8-Dec</th></tr>
<tr><td>Milestones</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>PDR</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Phase</td><td colspan="10">Phase 1</td><td colspan="7">Phase 2</td></tr>
<tr><td>Research & Sketches</td><td colspan="4">Research & Sketches</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>Structural Analysis</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">Structural Analysis</td><td></td><td></td><td></td></tr>
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<tr><th>Date Weeks</th><th>12-Jan</th><th>19-Jan</th><th>26-Jan</th><th>2-Feb</th><th>9-Feb</th><th>16-Feb</th><th>23-Feb</th><th>1-Mar</th><th>8-Mar</th><th>15-Mar</th><th>22-Mar</th><th>29-Mar</th><th>5-Apr</th><th>12-Apr</th><th>19-Apr</th></tr>
<tr><td>Milestones</td><td></td><td></td><td></td><td></td><td>CDR</td><td></td><td></td><td>TRR</td><td></td><td></td><td></td><td></td><td>TRB</td><td></td><td>ShowCase</td></tr>
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<tr><td>Engineering Model Manufacturing</td><td colspan="7">Engineering Model Manufacturing</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>BBM1 Testing</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">BBM1 Testing</td><td></td><td></td><td></td><td></td></tr>
<tr><td>BBM2 Testing</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">BBM2 Testing</td><td></td><td></td><td></td><td></td></tr>
<tr><td>BBM4 Testing</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">BBM4 Testing</td><td></td><td></td><td></td><td></td></tr>
<tr><td>EM Testing</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="5">EM Testing</td><td></td><td></td></tr>
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<tr><td>ShowCase Presentation</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="7">ShowCase Presentation</td></tr>
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Currently on track, with possibility to extend EM Assembly one week into EM Testing.

Manufacturing hinges and joints is the biggest schedule risk.

The critical path is to start manufacturing hinges and butterfly joints.

Adam: Project Manager

9 Fabrication Plan - Arms

- Materials used:
  - 30x30mm T-Slot Aluminum Extrusions
  - 35x35mm Square Aluminum Tubing
  - 50x40x20mm Aluminum Panels
  - 10mm Diameter Aluminum Round Stock

Fabrication Plans

- Arm T-Slot: measure and cut them to length
- Female joints: cut the aluminum tubing to length and weld a top cap to the end of the tubing
- Butterfly joint: cut the aluminum panels to size
- Locking pins: cut round stock to length

Materials	Obtained	Manufactured
T-Slot Aluminum	Yes	In process
Square Aluminum	En route	No
Aluminum Panels	En route	No
Round Stock	No	No

Peter: Systems Engineer

9 Fabrication Plan - Base Plates

- Materials used:
    - 4x8ft MDF
    - Spring-loaded Hinges
    - .5x1in Bolts
    - 30x20x5mm Aluminum Flat Panel

Fabrication Plans

- Base plates are made from MDF that are cut out using the CNC router machine
- Hinges are then cut to size and bolted to each MDF base plate
- The secondary deployment mechanism is made from the aluminum flat panel by welding to prior cut material from the flat panel

Materials	**Obtained**	**Manufactured**
MDF	Yes	In Process
Spring-Loaded Hinges	En route	No
Bolts	Obtained	In process
Aluminum Flat Panel	No	No

Peter: Systems Engineer

9 Fabrication Plan - Center Column

- Materials used:
  - 8inx3ft PVC Pipe
  - 10x3in round Aluminum Stock
  - 12x3in Round Aluminum Stock
  - 12x12x.25in Aluminum Sheet

Fabrication Plans

- The center column is cut from the PVC stock material to size
- The bottom center column plate is milled down, and then pre-cut aluminum sheet material is welded onto the plate, allowing for high points
- The top center column plate is milled down from stock material, and then holes are drilled, allowing cables to run through it

Materials	Obtained	Manufactured
PVC	Obtained	Yes
10x3in Round Stock	In route	No
12x3in Round Stock	In route	No
Aluminum Sheet	Obtained	In progress

Peter: Systems Engineer

10.1 Test Plans Overview

Test Name & Number	Description of Test (test objectives and what physical item will be tested)	Requirements to be verified by this test	Test Location and Other Notes (Test plan status, special hardware, etc)	Status/Readiness
BBM1	Test arms folding geometry and butterfly joint stability.	M2M-01, M2M-02	HSDC	Expect to be ready and complete test before Showcase
BBM2	Test secondary deployment and baseplate unfolding.	M2M-01, M2M-02	HSDC	Expect to be ready and complete test before Showcase
BBM3	Membrane	M2M-01, M2M-03	HSDC, Vac Chamber	No membrane due to financial reasons
BBM4	Balloon	M2M-01, M2M-03	HSDC	Expect to be ready and complete test before Showcase
EM	System level test. Test primary deployment, tension cables, and arms folding geometry. Secondary deployment. Inflation.	M2M-01, M2M-02, M2M-03	HSDC	Expect to be ready and complete test before Showcase

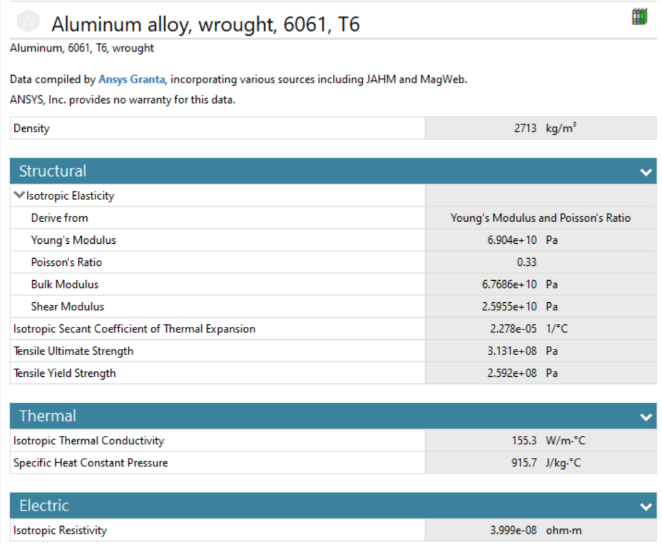
Adam: Project Manager
Peter: Systems Engineer

10.2 Structural Analysis - Arms

Utilized Ansys software to create finite element models of the aluminum arm segments.

Conducted static structural analysis to evaluate stress, shear, deformation, and potential failure points.

It was concluded that there were no failure points in the design and that they withstood analysis of stress and strain



Aluminum alloy, wrought, 6061, T6

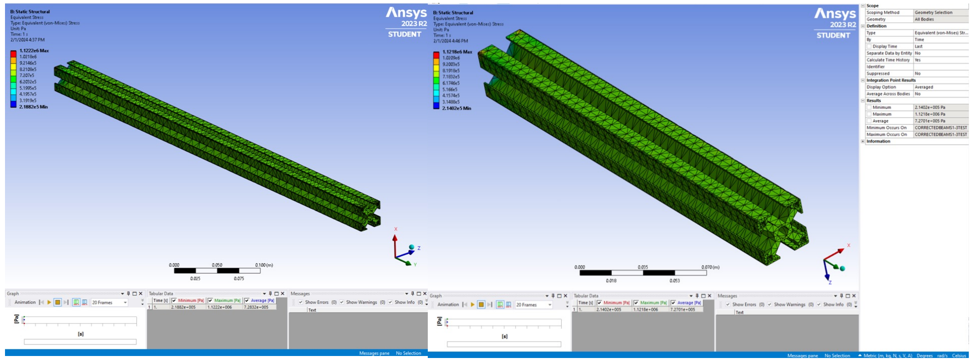
Aluminum, 6061, T6, wrought

Data compiled by Ansys Granta, incorporating various sources including JAHM and MagWeb.

ANSYS, Inc. provides no warranty for this data.

Density	2713 kg/m³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	6.904e+10 Pa
Poisson's Ratio	0.33
Bulk Modulus	6.7686e+10 Pa
Shear Modulus	2.5955e+10 Pa
Isotropic Secant Coefficient of Thermal Expansion	2.278e-05 1/°C
Tensile Ultimate Strength	3.131e+08 Pa
Tensile Yield Strength	2.592e+08 Pa
Thermal	
Isotropic Thermal Conductivity	155.3 W/m·°C
Specific Heat Constant Pressure	915.7 J/kg·°C
Electric	
Isotropic Resistivity	3.999e-08 ohm·m

Arms

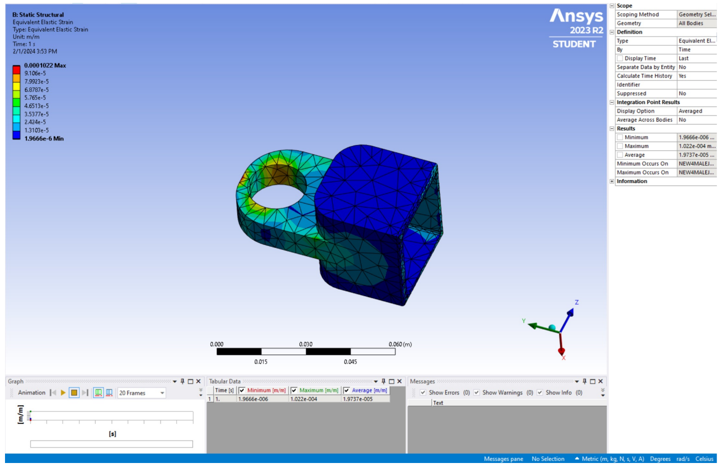


B: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: Pa
Time: 1 s
2/1/2024 4:37 PM

B: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: Pa
Time: 1 s
2/1/2024 4:46 PM

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Equivalent (von-Mises) Str...
By	Time
Display Time	Last
Separate Data by Entity	No
Calculate Time History	Yes
Identifier	
Suppressed	No
Integration Point Results	
Display Option	Averaged
Average Across Bodies	No
Results	
Minimum	2.1402e+005 Pa
Maximum	1.1218e+006 Pa
Average	7.2701e+005 Pa
Minimum Occurs On	CORRECTEDBEAMS1-3TEST
Maximum Occurs On	CORRECTEDBEAMS1-3TEST
Information	

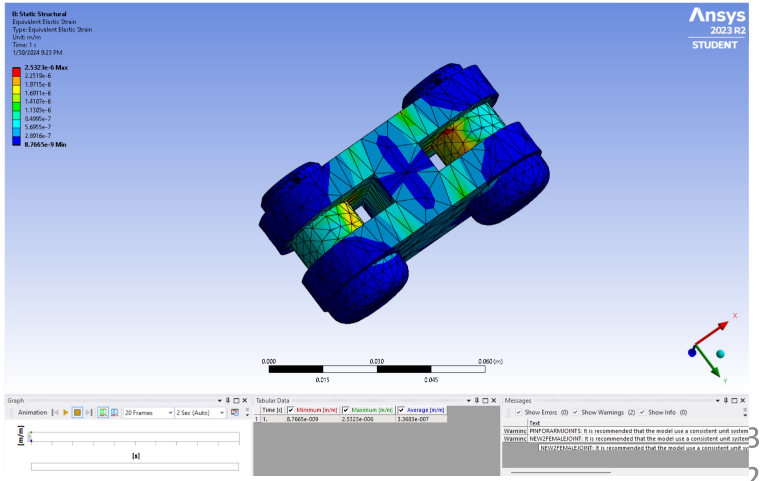
Male Joint



B: Static Structural
Equivalent Elastic Strain
Type: Equivalent Elastic Strain
Unit: m/m
Time: 1 s
2/1/2024 3:53 PM

Scope	
Scoping Method	Geometry Sel...
Geometry	All Bodies
Definition	
Type	Equivalent El...
By	Time
Display Time	Last
Separate Data by Entity	No
Calculate Time History	Yes
Identifier	
Suppressed	No
Integration Point Results	
Display Option	Averaged
Average Across Bodies	No
Results	
Minimum	1.9666e-006 ...
Maximum	1.022e-004 m...
Average	1.9737e-005 ...
Minimum Occurs On	NEW4MALEJ...
Maximum Occurs On	NEW4MALEJ...
Information	

Female Joint



B: Static Structural
Equivalent Elastic Strain
Type: Equivalent Elastic Strain
Unit: m/m
Time: 1 s
1/30/2024 9:23 PM

Avery & Anthony: Arms & Deployment

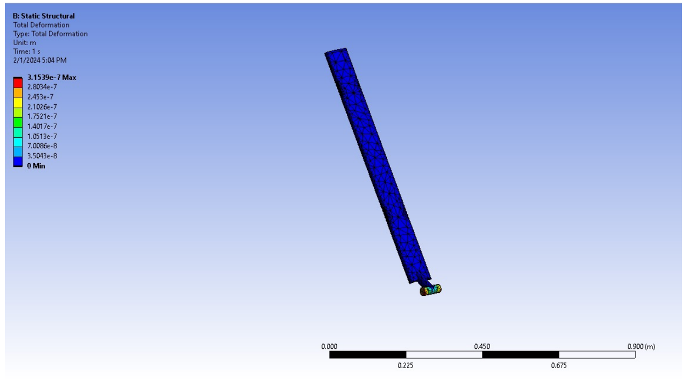
10.3 Structural Analysis – Base Plates

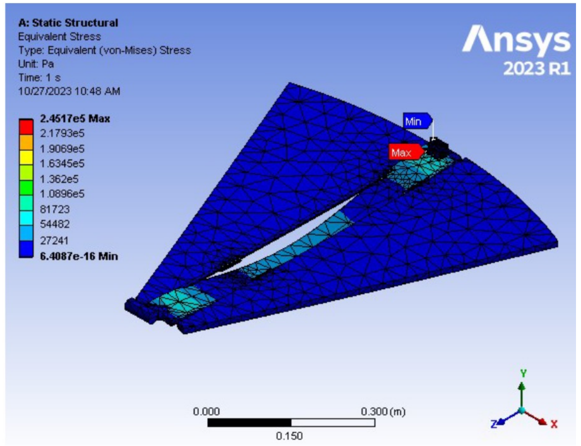
Testing was performed using Ansys Workbench software.

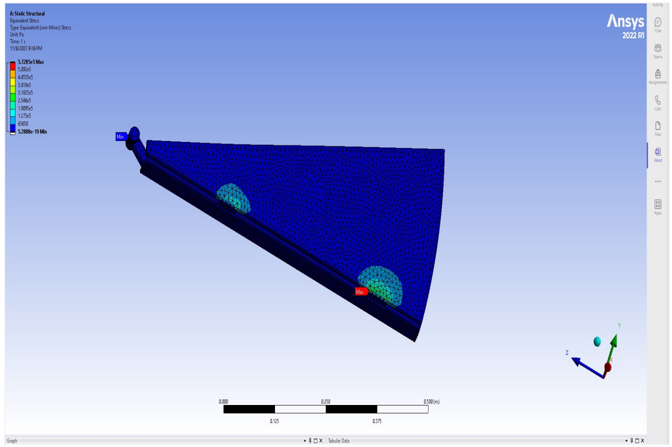
Applying static structural analysis on base plates to test the stress, deformation, factor of safety, and failure points.

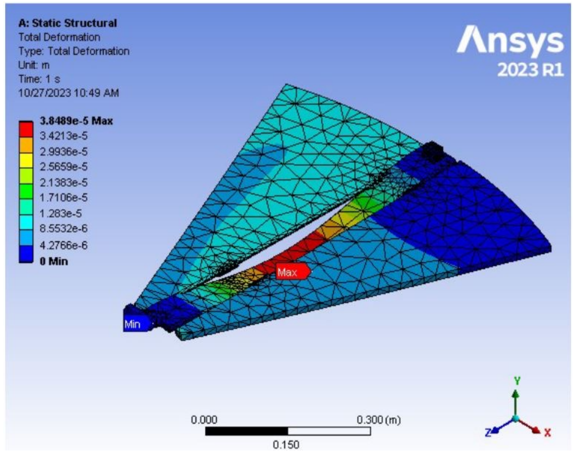
Results meet our standard requirements.

Material used: Plywood









11 Risk Management

Rank	Type	Risk Statement	Mitigation Approach	Risk Criticality	Risk Likelihood
1	Schedule	If any of the ordered parts do not arrive on time, then there will be a delay in our fabrication plans.	Use the materials provided in the machine shop to create our own parts. Order in time.	Medium	Low
2	Financial	If the membrane cost exceed our budget, then we cannot include it in our complete project.	We will find a cheap off-the-shelf alternative to demonstrate inflation system.	High	High
3	Technical	If the power supply (battery) fails, then it will result in computer system shutdown risking the habitat stability.	Provide a backup batteries for such cases, with ensuring regular maintenance and monitoring the power supply.	High	Low
4	Technical	If applying excessive overloads on the joints, then it will lead to joints failure and structural collapse.	Thoroughly test the joints load under lunar environmental conditions.	Medium	Low
5	Technical	If a sensor failure occurs causing a misreading, then that will lead to over or under regulation of temperature and pressure.	Employ redundancy in critical sensors.	Medium	Low
6	Schedule	If the fabrication plans execution faced any form of delay, then the physical design will not be ready for showcase.	Provide weekly report during team meeting to ensure everything is going as planned.	Low	Low
7	Technical	If a mechanical failure occur during the process of deployment, then it may lead to inability to set up the habitat.	Thoroughly test the deployment mechanism under lunar environmental conditions.	High	Low

Ahmad: Baseplates

Conclusions

The design process is complete, and we don’t foresee any big changes needed during manufacturing.

The team is ready for production and is already working on individual components.

As a team, we don’t see any concern to stop funding the project and expect to be ready for showcase.

We believe we should pass CDR.

Risks are negligible now due to extensive design and testing practices.

Peter: Systems Engineer

12 Conclusions

	Design	Fabrication	Testing	Schedule	Mass/Volume Budget	Power Budget	Financial Budget
Status	Compliant	Compliant	Full Compliance Expected	Full Compliance Expected	Compliant	Compliant	Full Compliance Expected
Comments	Complete	In progress	Expected to begin in March	Possibility to extend EM assembly one week into EM Testing	Fits in SLS Block 2 Cargo		5 % margin

We recommend to pass CDR and continue the project as planned.

Adam: Project Manager