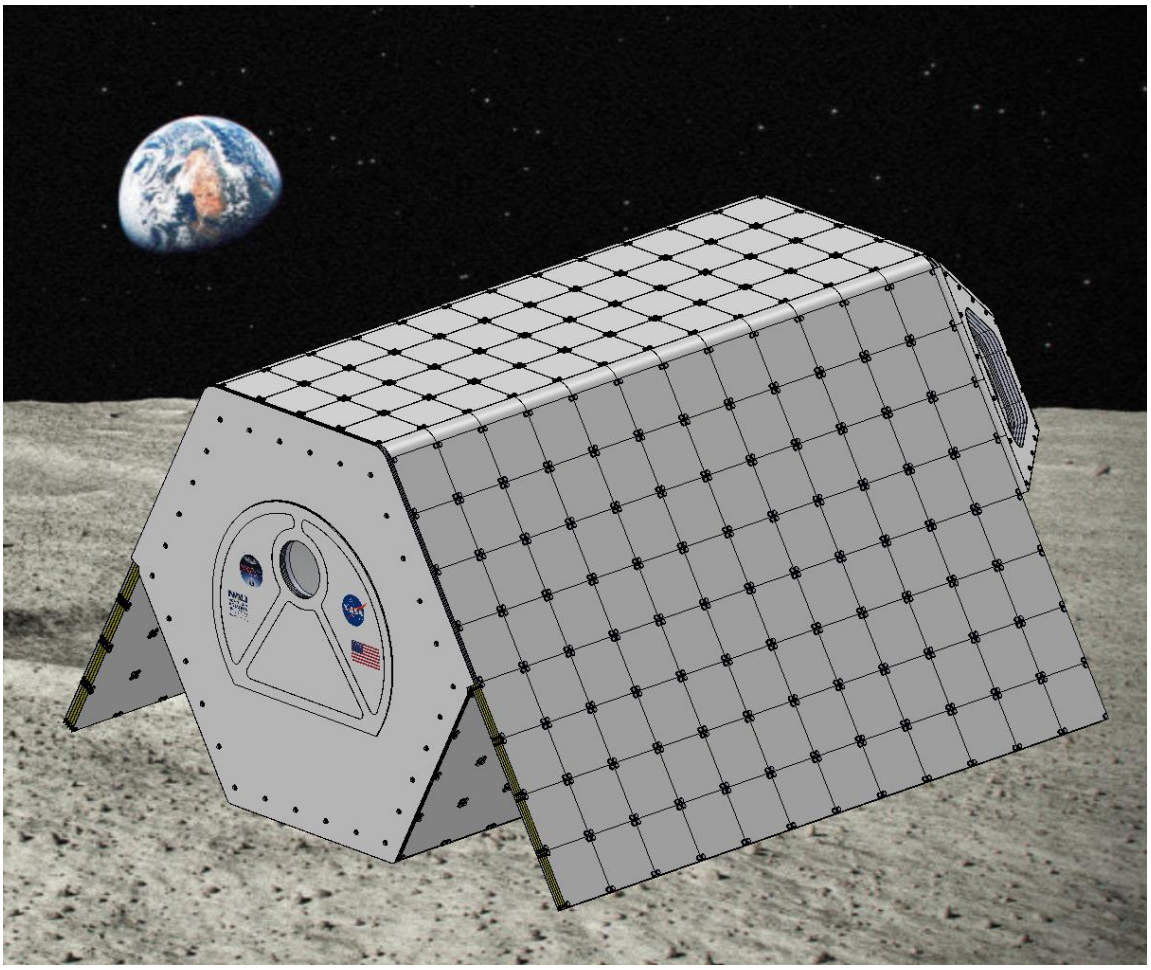
NASA Lunar Habitat
Operation and Assembly Manual



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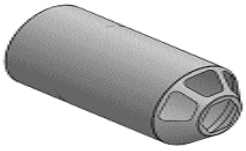
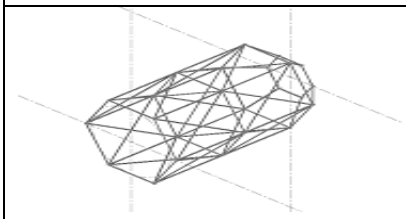
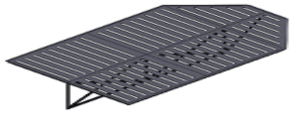
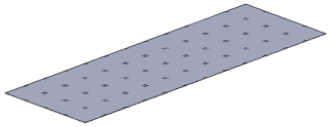
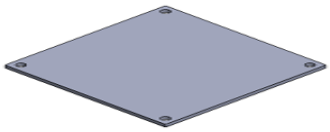
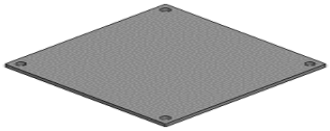
1 Assembly / Disassembly and Storage

The lunar habitat module is designed to require little assembly once transported to the surface of the moon, but there are still a few tasks to complete to get the habitat fully operational. This section will cover the assembly, disassembly, and storage for future use.

1.1 Bill of Materials

DOCUMENT PREVIEW	ITEM NO.	PART NAME	QUANTITY
	1	NASA RASC-AL Pressure Wall with Window	1
	2	NASA RASC-AL Bone Structure Window Weldment-Pipe	1
	3	NASA RASC-AL Airlock Floor Weldments-SquareTube	1
	4	NASA RASC-AL Cabin Floor Weldments-SquareTube	1
	5	NASA RASC-AL Base Shielding	11

	6	NASA RASC-AL MLI Layer 1	288
	7	NASA RASC-AL MLI Layer 2	288
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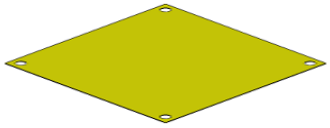
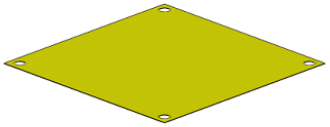
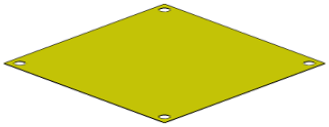
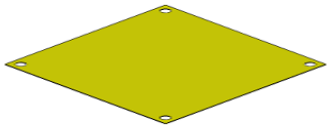
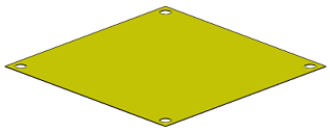
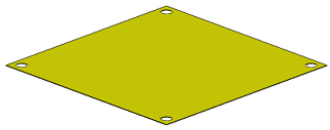
	10	NASA RASC-AL Whipple Shield Layer 2	240
	11	NASA RASC-AL Whipple Shield Layer 3	240
	12	NASA RASC-AL Whipple Shield Layer 4	240

	13	NASA RASC-AL Whipple Shield Layer 5	240
	14	NASA RASC-AL Whipple Shield Layer 6	240
	15	NASA RASC-AL Whipple Shield Layer 7	240
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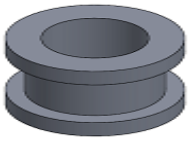	18	NASA RASC-AL Whipple Shield Cylindrical Fastener Component	4224
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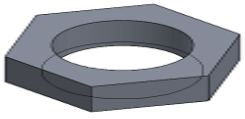	20	NASA RASC-AL Whipple Shield M24 Nut	1686

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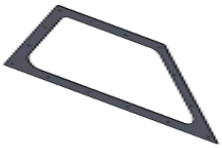
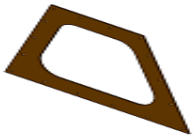
	22	NASA RASC-AL Window Base Shielding (Window)	3
	23	NASA RASC-AL Window MLI Layer 1 (Window)	3
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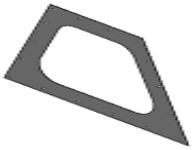	26	NASA RASC-AL Window Whipple Shield Layer 1 (Window)	3
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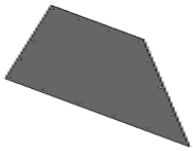
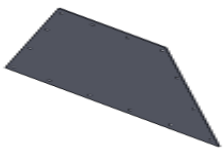
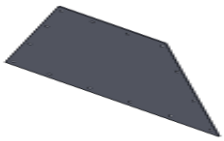
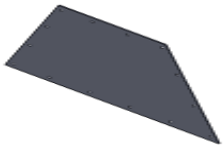
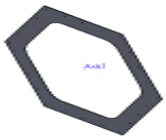
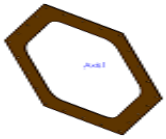
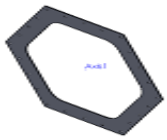
	34	NASA RASC-AL Window Base Shielding	6
	35	NASA RASC-AL Window MLI Layer 1	3

	36	NASA RASC-AL Window MLI Layer 2	3
	37	NASA RASC-AL Window MLI Layer 3	3
	38	NASA RASC-AL Window Hex Base Shielding	1
	39	NASA RASC-AL Window Hex MLI Layer 1	1
	40	NASA RASC-AL Window Hex MLI Layer 2	1
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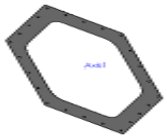	42	NASA RASC-AL Window Hex Whipple Shield Layer 1	1
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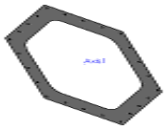
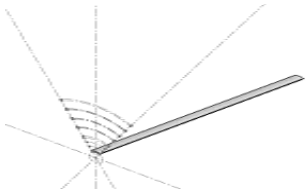
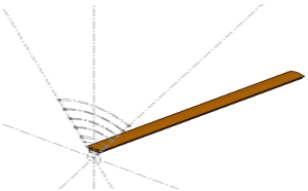
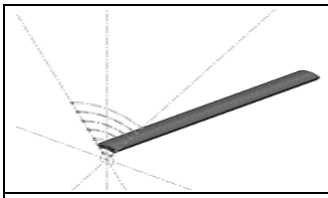
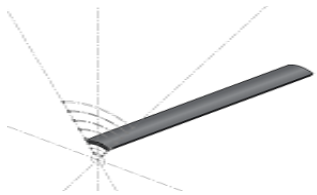
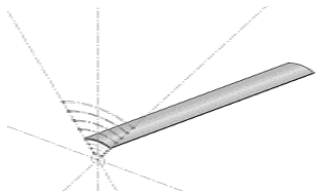
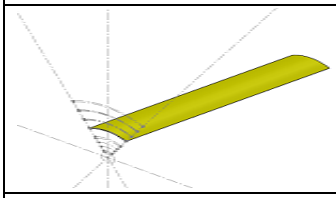
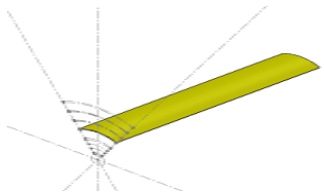
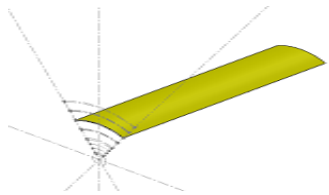
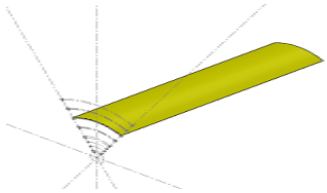
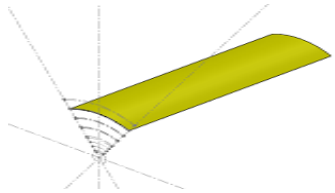
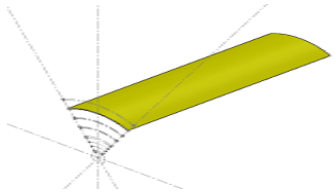
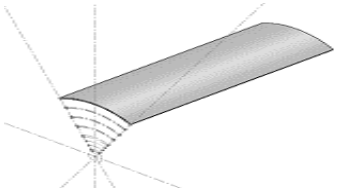
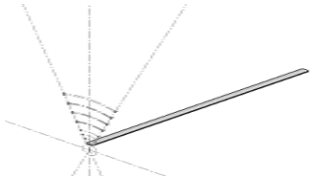
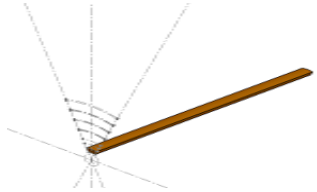
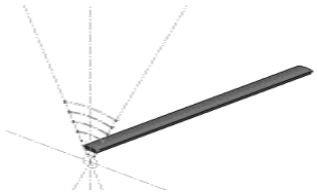
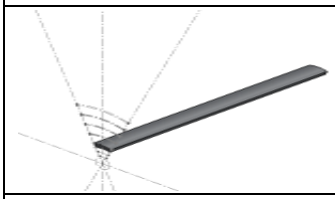
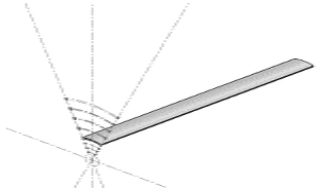
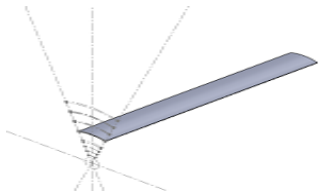
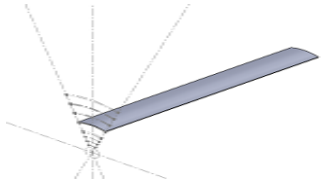
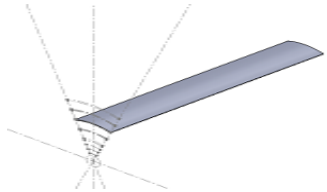
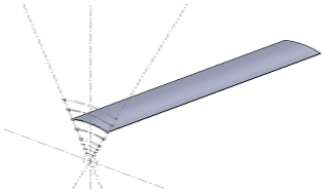
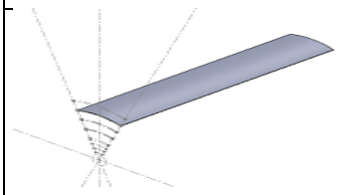
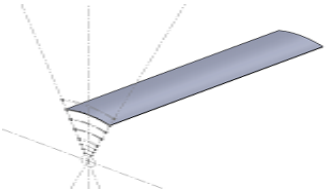
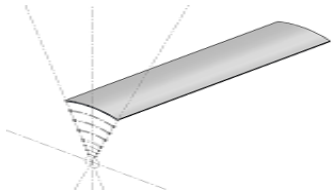
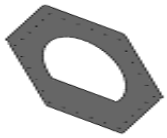
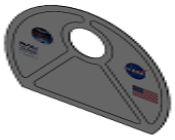
	49	NASA RASC-AL Window Hex Whipple Shield Layer 8	1
	50	NASA RASC-AL Base Shielding (connection)	84
	51	NASA RASC-AL MLI Layer 1 (connection)	84

	52	NASA RASC-AL MLI Layer 2 (connection)	84
	53	NASA RASC-AL MLI Layer 3 (connection)	84
	54	NASA RASC-AL Whipple Shield Layer 1 (connection)	84
	55	NASA RASC-AL Whipple Shield Layer 2 (connection)	24
	56	NASA RASC-AL Whipple Shield Layer 3 (connection)	24
	57	NASA RASC-AL Whipple Shield Layer 4 (connection)	24
	58	NASA RASC-AL Whipple Shield Layer 5 (connection)	24
	59	NASA RASC-AL Whipple Shield Layer 6 (connection)	24

	60	NASA RASC-AL Whipple Shield Layer 7 (connection)	24
	61	NASA RASC-AL Whipple Shield Layer 8 (connection)	24
	62	NASA RASC-AL Window-40deg Base Shielding (connection)	24
	63	NASA RASC-AL Window-40deg MLI Layer 1 (connection)	24
	64	NASA RASC-AL Window-40deg MLI Layer 2 (connection)	24
	65	NASA RASC-AL Window-40deg MLI Layer 3 (connection)	24
	66	NASA RASC-AL Window-40deg Whipple Shield Layer 1 (connection)	24
	67	NASA RASC-AL Window-40deg Whipple Shield Layer 2 (connection)	12

	68	NASA RASC-AL Window-40deg Whipple Shield Layer 3 (connection)	12
	69	NASA RASC-AL Window-40deg Whipple Shield Layer 4 (connection)	12
	70	NASA RASC-AL Window-40deg Whipple Shield Layer 5 (connection)	12
	71	NASA RASC-AL Window-40deg Whipple Shield Layer 6 (connection)	12
	72	NASA RASC-AL Window-40deg Whipple Shield Layer 7 (connection)	12
	73	NASA RASC-AL Window-40deg Whipple Shield Layer 8 (connection)	12
	74	NASA RASC-AL Front Base Shielding	2
	75	NASA RASC-AL Front MLI Layer 1	1

	76	NASA RASC-AL Front MLI Layer 2	1
	77	NASA RASC-AL Front MLI Layer 3	1
	78	NASA RASC-AL Airlock Front Door	1
	79	NASA RASC-AL Airlock Front Base Shielding	2
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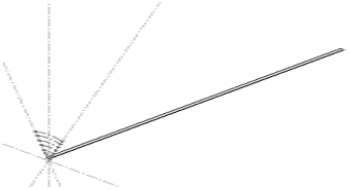
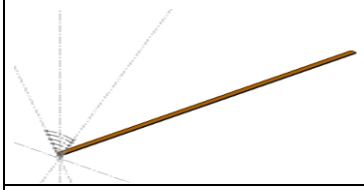
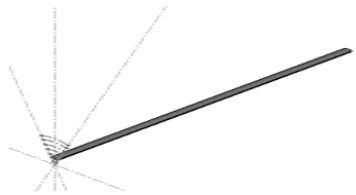
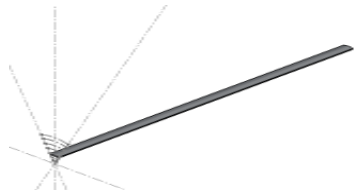
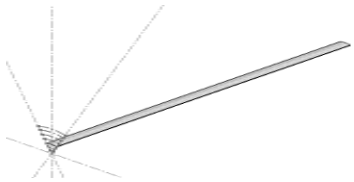
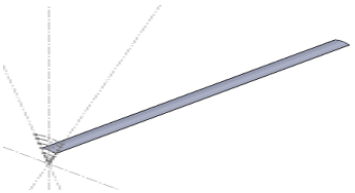
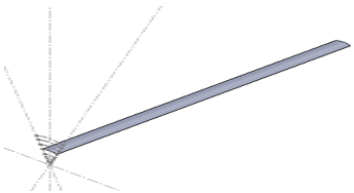
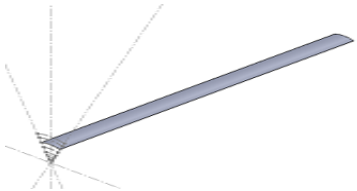
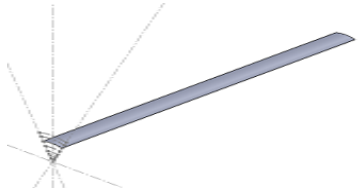
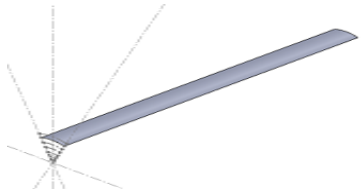
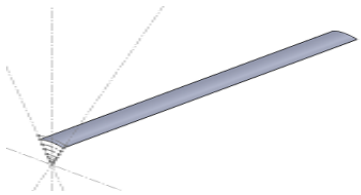
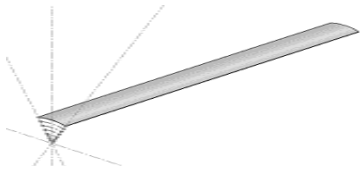
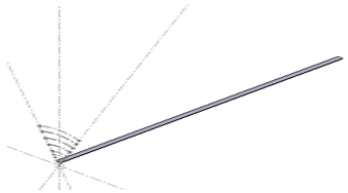
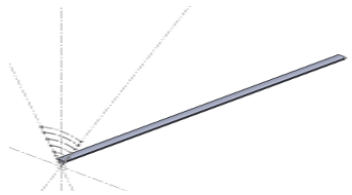
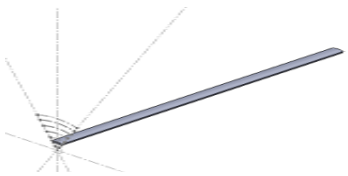
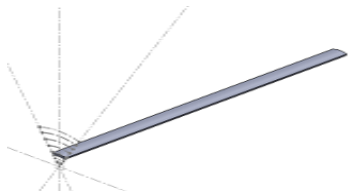
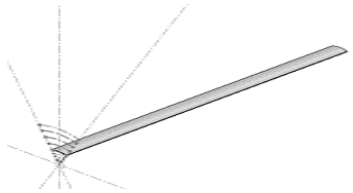
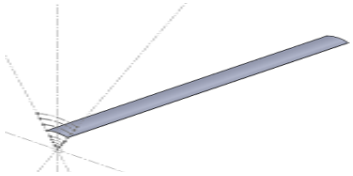
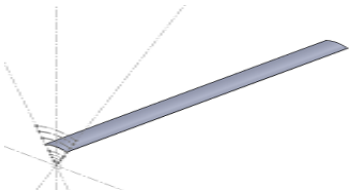
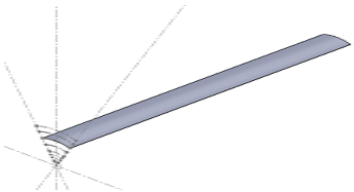
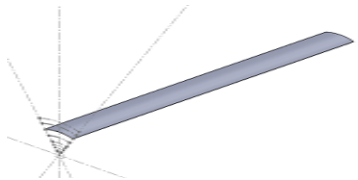
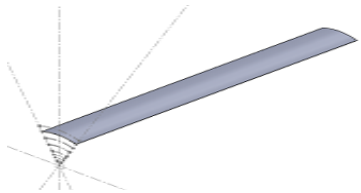
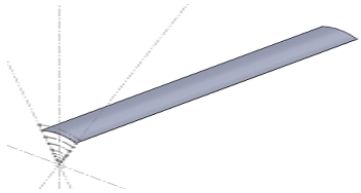
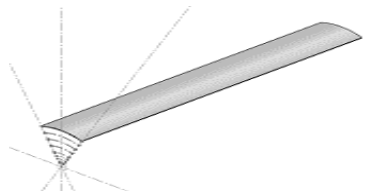
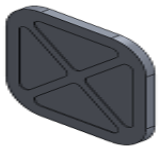
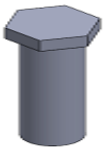
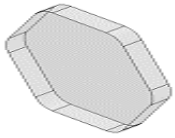
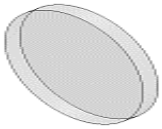
	83	NASA RASC-AL Window-44deg Base Shielding (connection)	8

	84	NASA RASC-AL Window-44deg MLI Layer 1 (connection)	8
	85	NASA RASC-AL Window-44deg MLI Layer 2 (connection)	8
	86	NASA RASC-AL Window-44deg MLI Layer 3 (connection)	8
	87	NASA RASC-AL Window-44deg Whipple Shield Layer 1 (connection)	8
	88	NASA RASC-AL Window-44deg Whipple Shield Layer 2 (connection)	2
	89	NASA RASC-AL Window-44deg Whipple Shield Layer 3 (connection)	2
	90	NASA RASC-AL Window-44deg Whipple Shield Layer 4 (connection)	2
	91	NASA RASC-AL Window-44deg Whipple Shield Layer 5 (connection)	2

	92	NASA RASC-AL Window-44deg Whipple Shield Layer 6 (connection)	2
	93	NASA RASC-AL Window-44deg Whipple Shield Layer 7 (connection)	2
	94	NASA RASC-AL Window-44deg Whipple Shield Layer 8 (connection)	2
	95	NASA RASC-AL Window-49deg Base Shielding (connection)	6
	96	NASA RASC-AL Window-49deg MLI Layer 1 (connection)	6
	97	NASA RASC-AL Window-49deg MLI Layer 2 (connection)	6
	98	NASA RASC-AL Window-49deg MLI Layer 3 (connection)	6
	99	NASA RASC-AL Window-49deg Whipple Shield Layer 1 (connection)	6

	100	NASA RASC-AL Window-49deg Whipple Shield Layer 2 (connection)	3
	101	NASA RASC-AL Window-49deg Whipple Shield Layer 3 (connection)	3
	102	NASA RASC-AL Window-49deg Whipple Shield Layer 4 (connection)	3
	103	NASA RASC-AL Window-49deg Whipple Shield Layer 5 (connection)	3
	104	NASA RASC-AL Window-49deg Whipple Shield Layer 6 (connection)	3
	105	NASA RASC-AL Window-49deg Whipple Shield Layer 7 (connection)	3
	106	NASA RASC-AL Window-49deg Whipple Shield Layer 8 (connection)	3
	107	NASA RASC-AL Pressure Wall Internal Door	1

	108	NASA RASC-AL Pressure Wall Suit Hatch Door	2
	109	NASA RASC-AL Base Shielding and Whipple Shield M24 Bolt	384
	110	NASA RASC-AL Glass Window	3
	111	NASA RASC-AL HEX-Glass Window	1
	112	NASA RASC-AL Airlock Glass Window	1
	113	NASA RASC-AL Supports	6

1.2 Assembly on Earth

The majority of the NASA RASC-AL Lunar Habitat will need to be assembled on Earth in one of NASAS's many available building laboratories, NASA's Jet Propulsion Laboratory (JPL) is a great place to assemble this lunar habitat.

Assembling on earth keeps the cost of assembly down and limits some of the problems that result from assembling in space. The initial phase of the assembly begins with the pressure wall as the pressure wall is designed to handle all the internal pressures. This way, the testing process on the most crucial part of the structure can begin right away.
Once the pressure wall and the testing is complete, the manufacturing and assembling process moves on to the bone structure. At 174Kg, the bone structure is the lightest component on the structure. However, the Bone structure welded on the Pressure wall will provide a platform for the multi-layer insulation (MLI) and the Whipple shield to bind to the structure. In addition, the bone structure is designed to alleviate some of the extreme stresses experienced by the entire system during an emergency.
The bone structure will be followed by the MLI and Whipple shield assembly. Once the final testing for structural analysis is complete, the windows and the corner structures will be installed. Followed by the floor, internal hatch, and doors. Finishing this part would allow the final phase to be assembling Front airlock, bulkhead, suit access port hatch. Testing for percentage of air leakage, thermal and structural rigidity will be performed at every phase. In the following section, the assembly process will illustrate to convey the idea better.

1.2.1 Pressure Wall

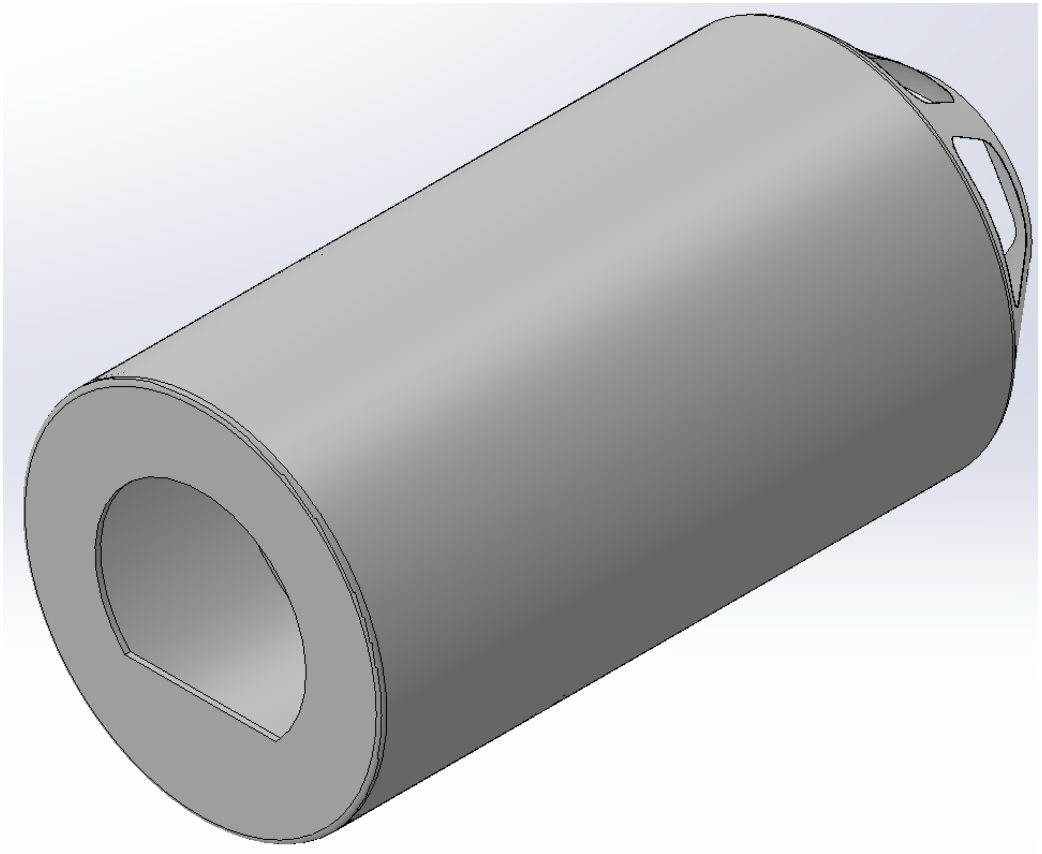


Figure 1: Pressure Wall

Start with the Aluminum 6061-T6 fabricated pressure wall for everything else to be attached to.

1.2.2 Bone Structure

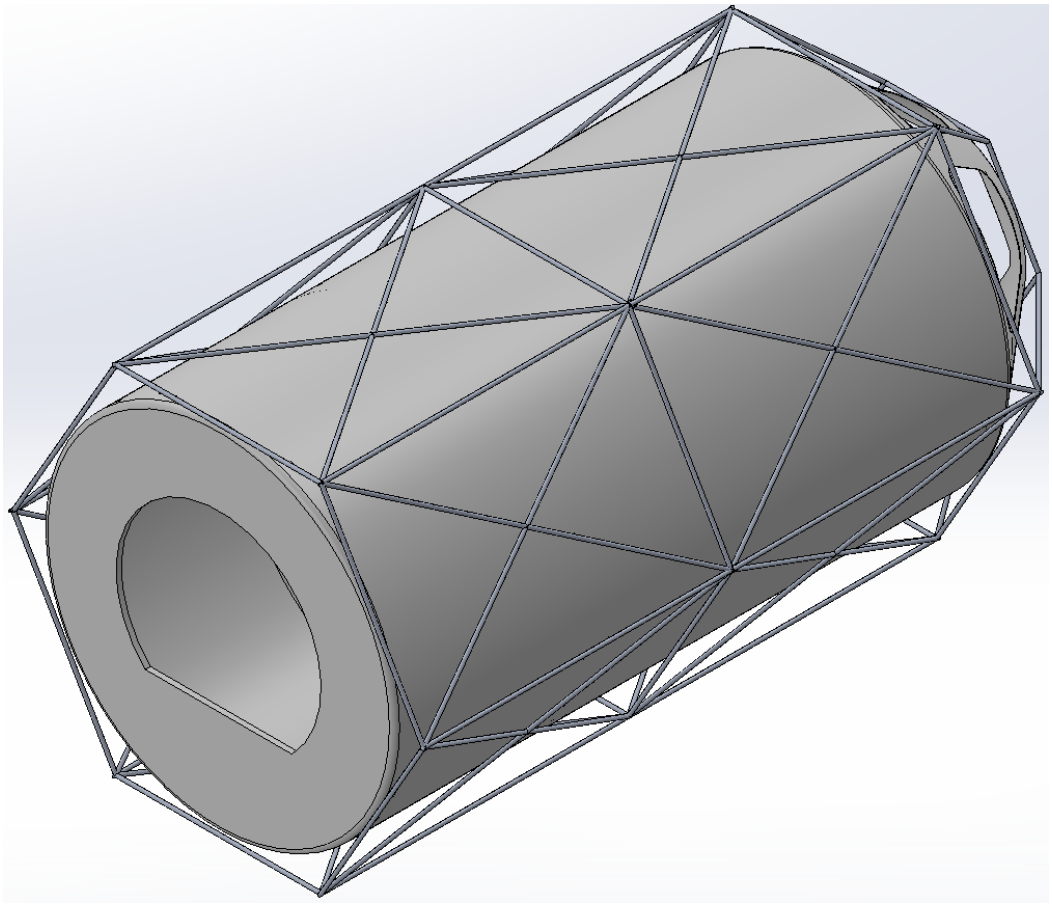


Figure 2: Bone Structure attached to Pressure Wall

Using Aluminum 6061-T6 pipes, construct the bone structure from 33.7 X 4.0 mm [diameter X thickness] pipe. The bone structure pipe pieces are to be welded together and then fastened to the pressure wall via weldments.

1.2.3 Shielding (Frame and Windows)

This is where base shielding will be added all over the bone structure to then build up layers of MLI wraps and Whipple Shielding where needed. The habitat will need to be lifted by a crane to allow access to all sides of the lunar habitat.

1.2.3.1 Base Shielding

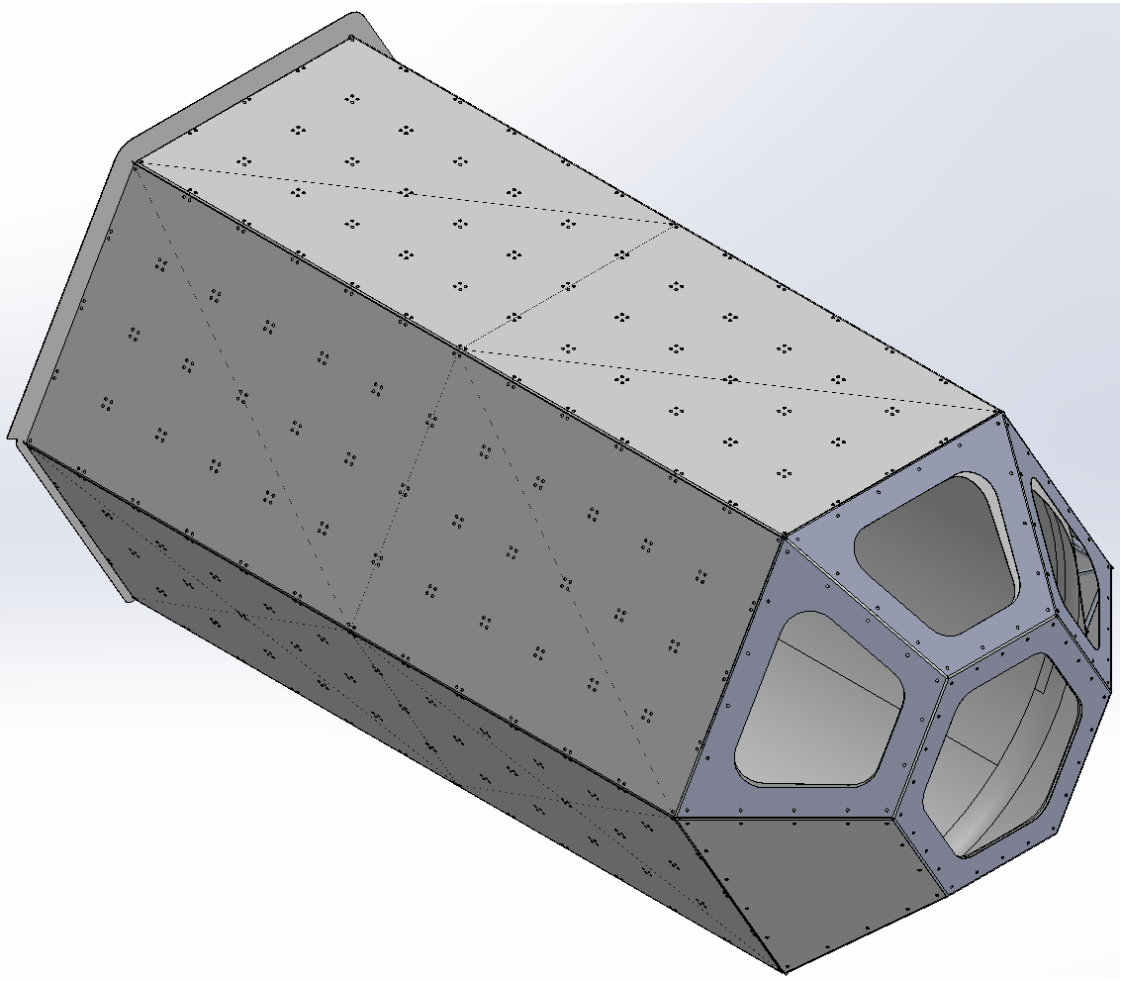


Figure 3: Base Shielding placed atop the bone structure

The base shielding, constructed out of Aluminum 6061-T6, will be welded to the bone structure to allow a platform to have the rest of the external component to be easily attached to the lunar habitat.

1.2.3.2 Multi-Layer Insulation (MIL) Wrapping

Multi-Layer Insulation, or MLI for short, is to be wrapped around the base shielding with three different MLI layers to allow proper insulation of the lunar habitat. The MLI layers will mirror the Whipple shield dimensions and will be installed on the structure in sections as the bolts are welded on to the bone structure. The following Figures 4, 5 and 6 illustrate the individual layering thermal shield.

1.2.3.2.1 Layer 1 (Kapton)

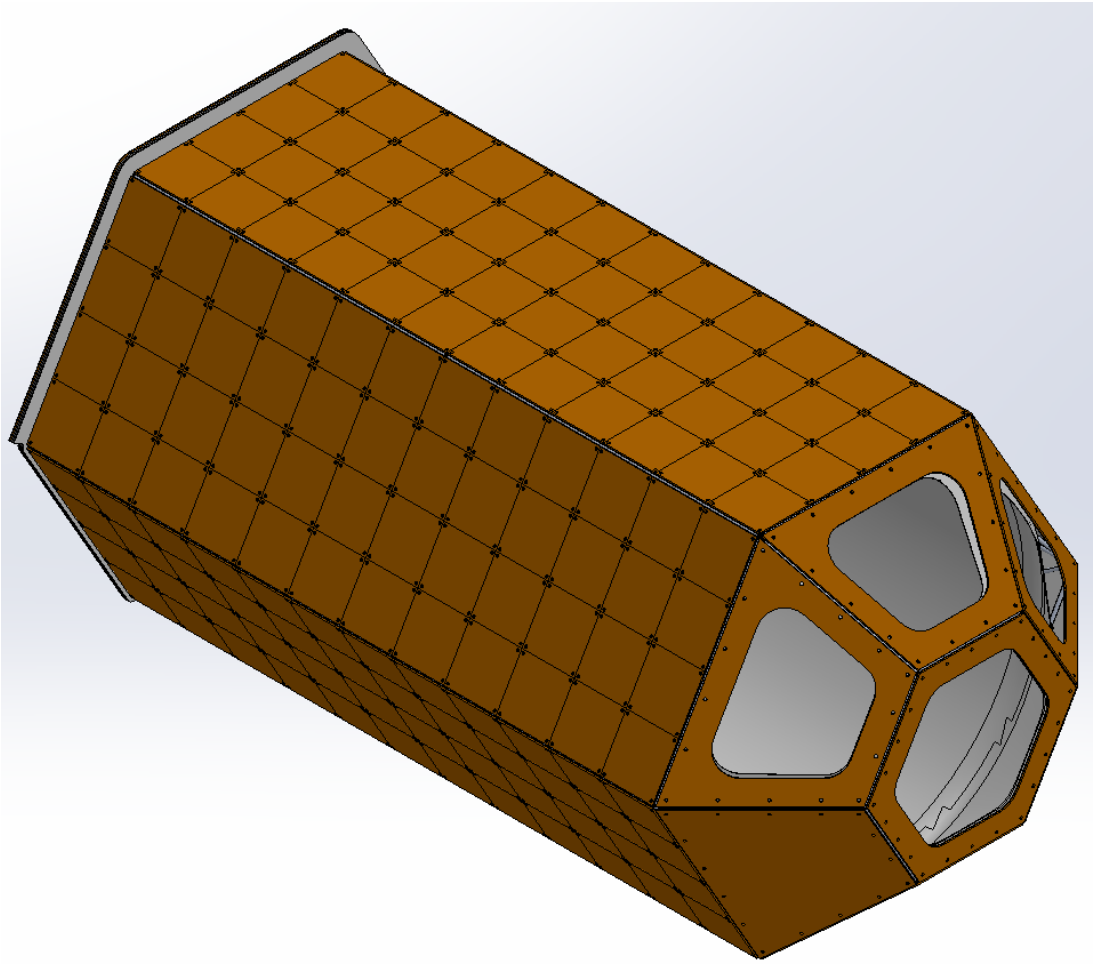


Figure 4: Layer 1 of MLI (Kapton) Wrap

1.2.3.2.2 Layer 2 (Polyethylene)

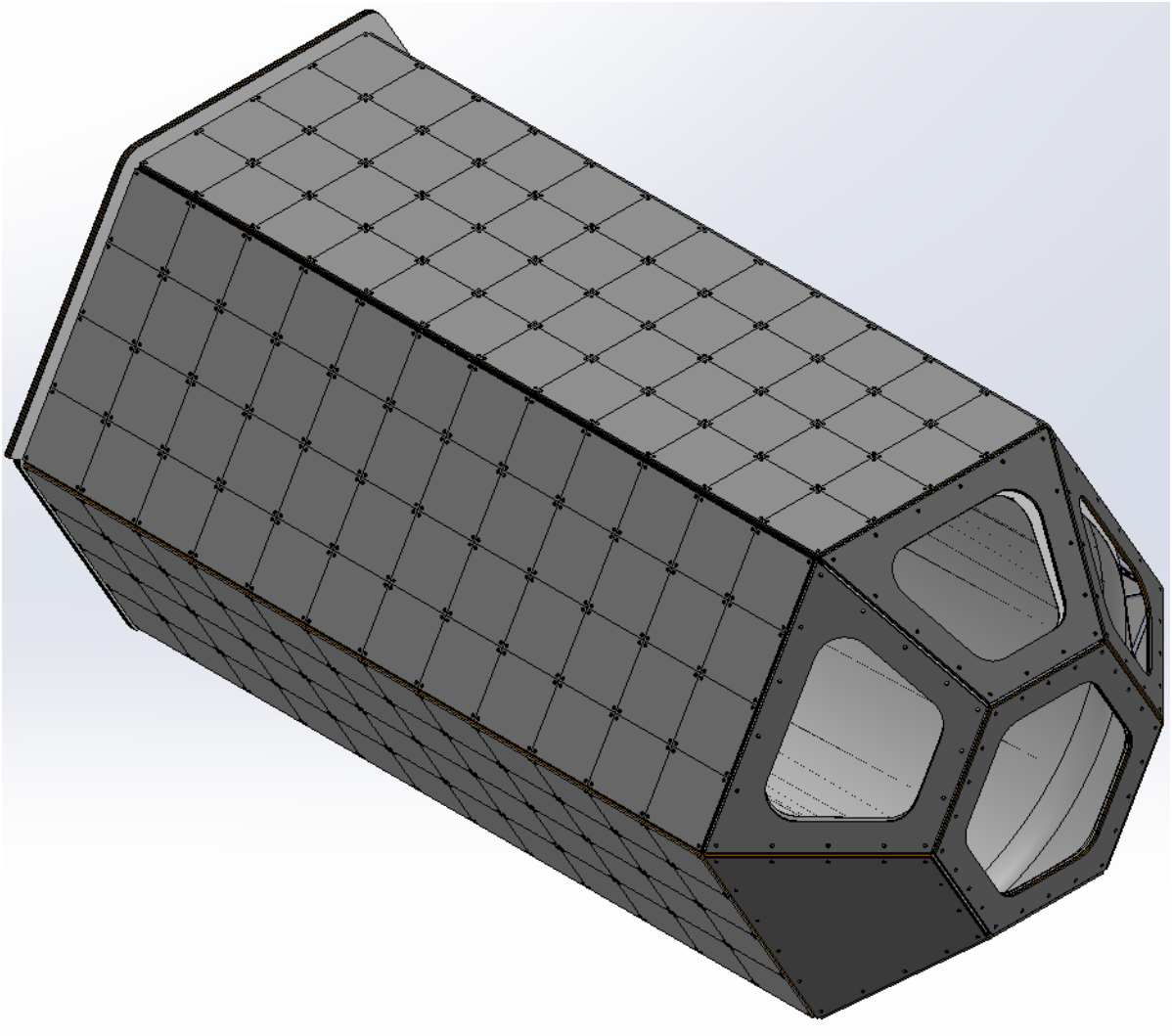


Figure 5: Layer 2 of MLI (Polyethylene) Wrap

1.2.3.2.3 Layer 3 (Mylar)

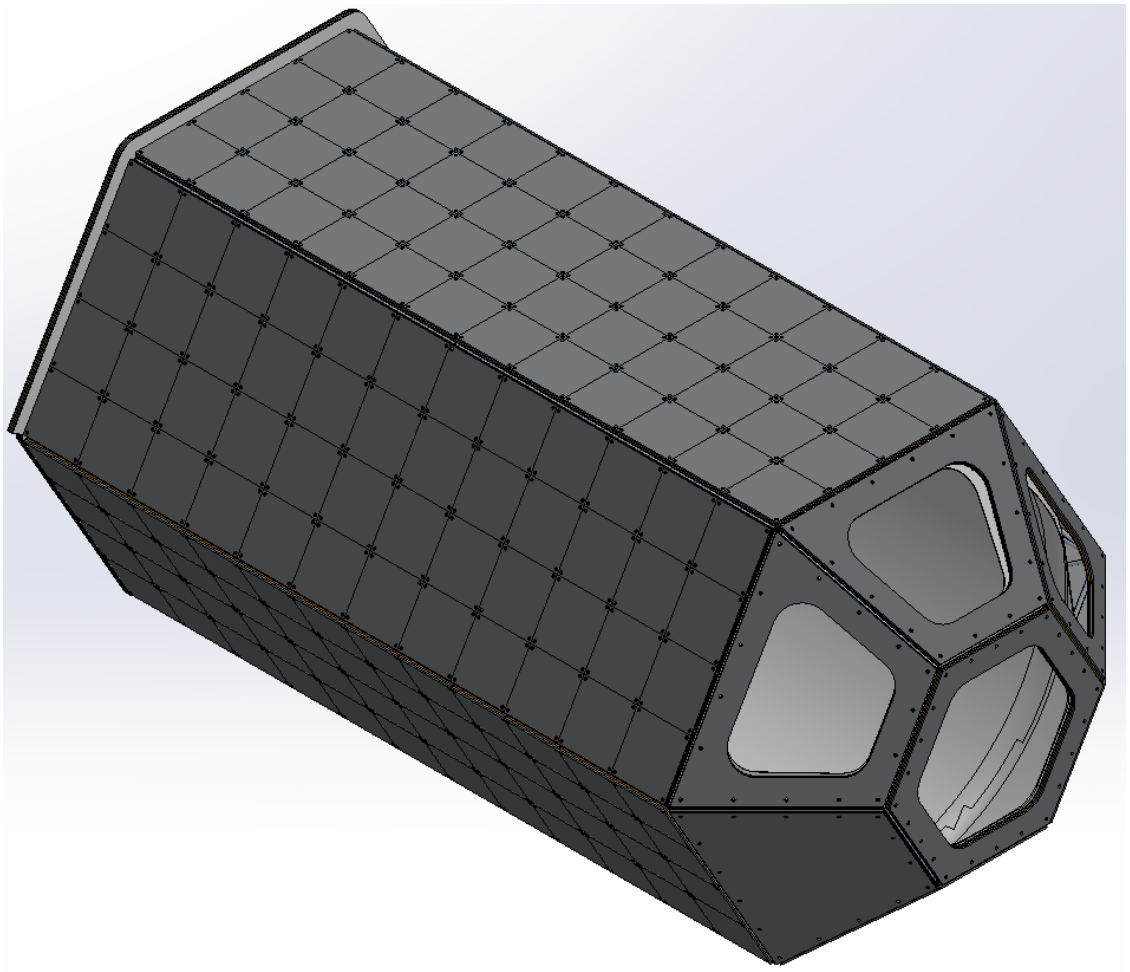


Figure 6: Layer 3 MLI (Mylar) Wrap

1.2.3.3 Whipple Shield Layers

The Whipple Shield serves to protect the lunar habit from micrometeorite impacts. As two other sections of the Whipple shield will be attached dot the structure upon landing on the moon, the Whipple shield was designed to keep protect the areas that will face micrometeorite impacts. Therefore, the Whipple Shield will only cover the top portion of the lunar habitat. The Whipple Shield is constructed from 8 layers, two Aluminum 6061-T6 plates and three alternating layers of double Kevlar between the two aluminum plates. The Whipple Shield is held together by four M24 bolts at each corner. Figures 7, 8, 9, and 10 show the layers and stack up of the Whipple Shield.

1.2.3.3.1 Layer 1 (Aluminum 6061-T6)

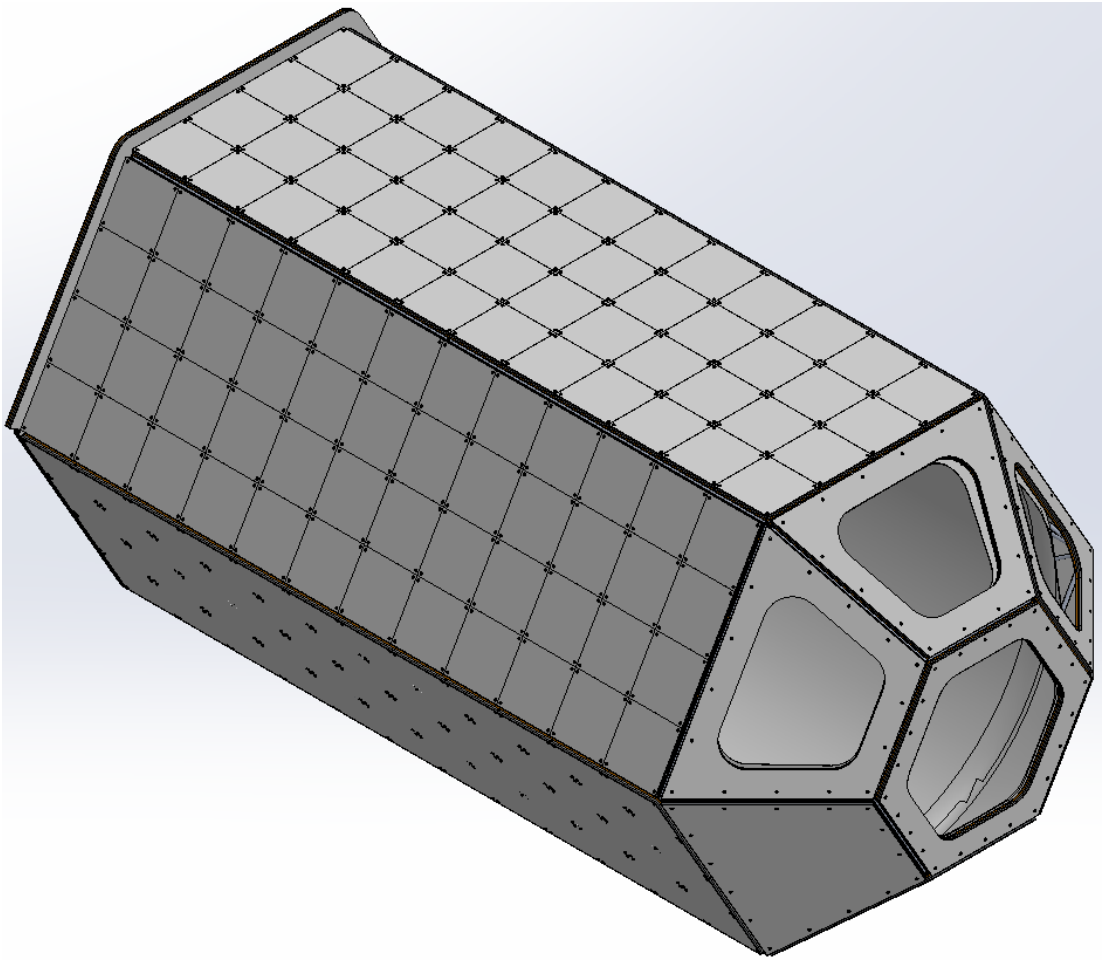


Figure 7: Layer 1 of the (Aluminum 6061-T6) Whipple Shield attached to the structure.

1.2.3.3.2 Layers 2 to 7 (Kevlar)

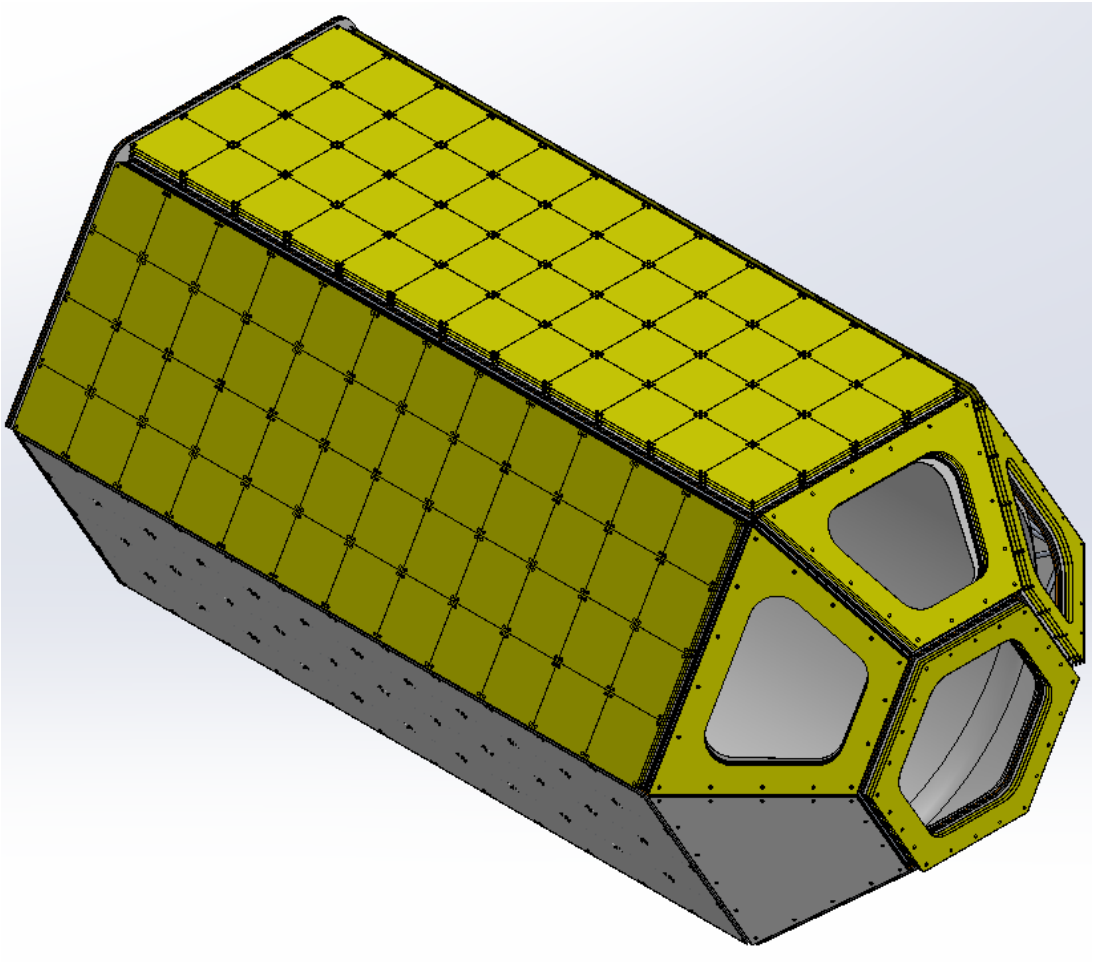


Figure 8: Layers 2 to 7 (Kevlar) of the Whipple Shield attached to the structure.

1.2.3.3.3 Layer 8 (Aluminum 6061-T6)

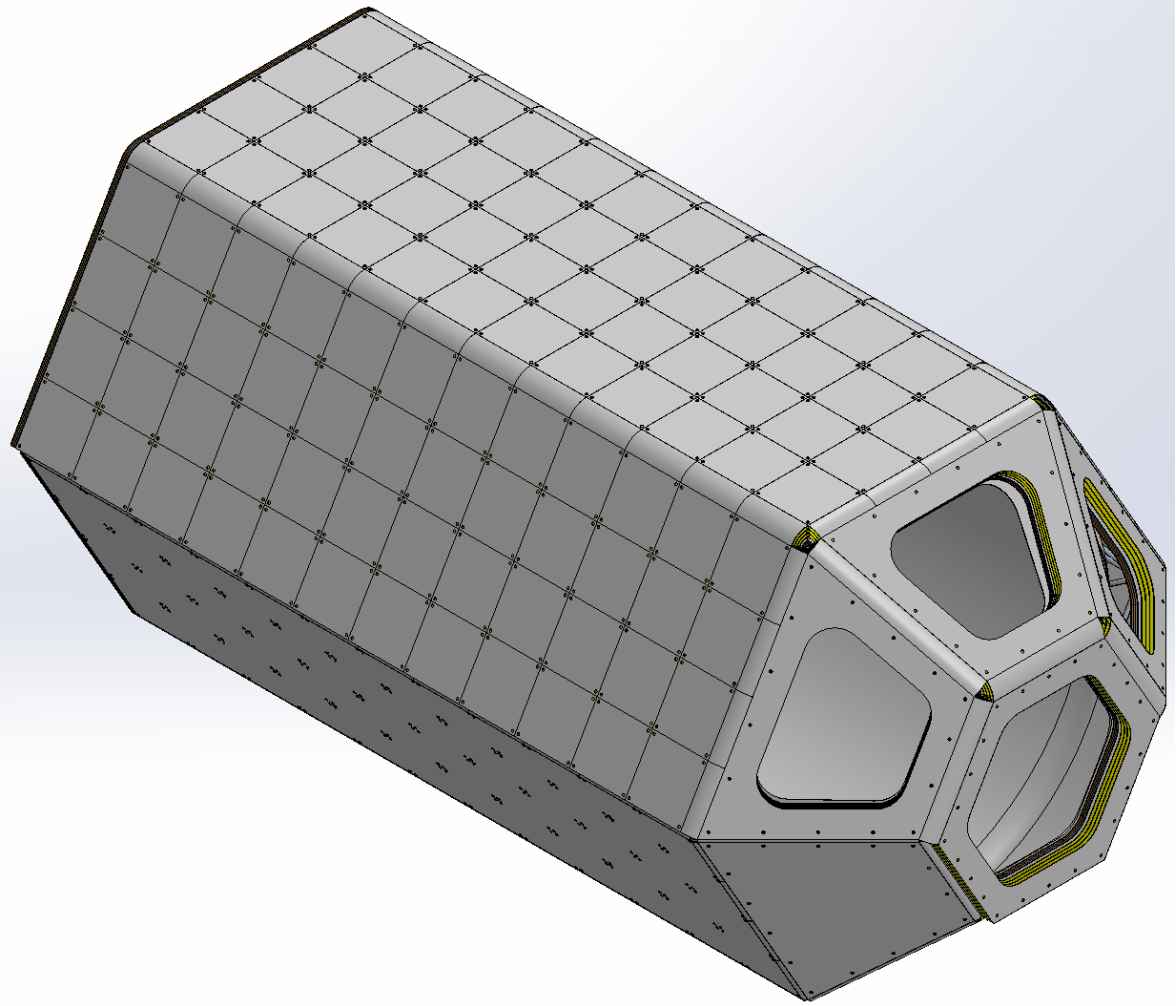


Figure 9: Layer 8 (Aluminum 6061-T6) of the Whipple Shield attached to the structure.

1.2.3.4 Whipple Shield Fasteners

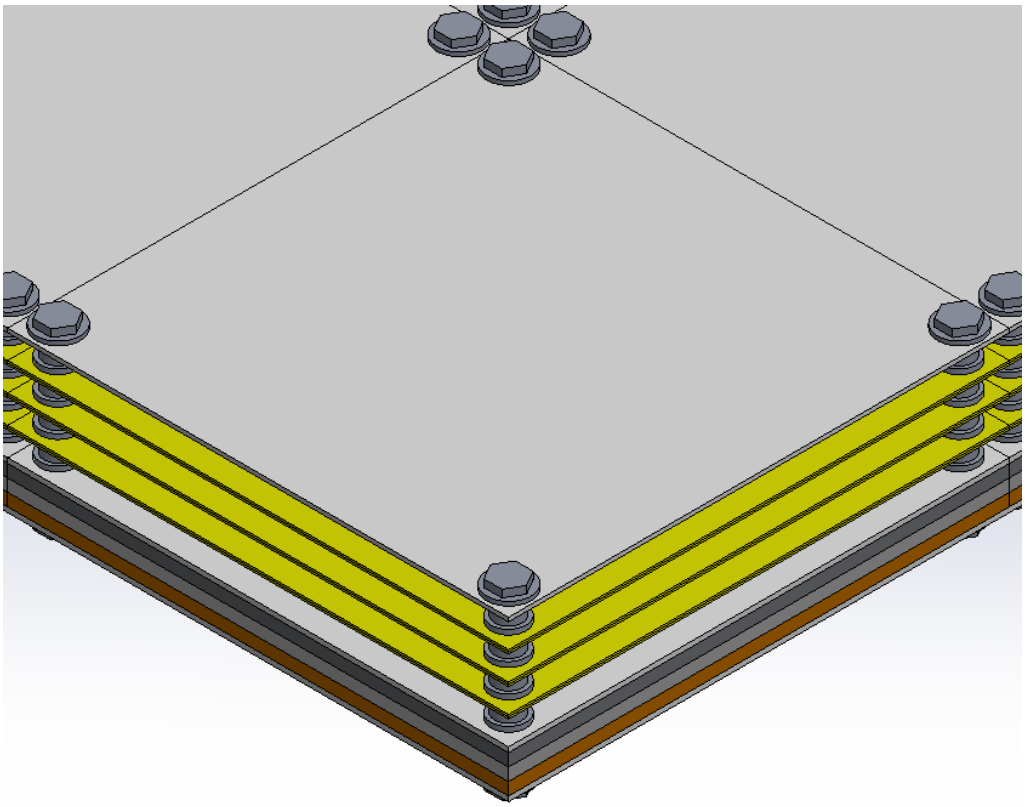


Figure 10: Whipple Shield Stack up with fastener components

The Whipple Shield is held in place by M24 bolts with washers on each end and an M24 nut to apply a proper clamping force. This will also allow the astronaut earlier access to replacing any damaged section of the Whipple shield.

1.2.4 Pressure Wall Internal Components

The pressure wall has some internal components, aside from the life-support systems and the ECLSS, that need to be assembled internally. Figures 11 to 17 show all the components that will need to be attached to the pressure wall.

1.2.4.1 Floors (Cabin and Airlock)

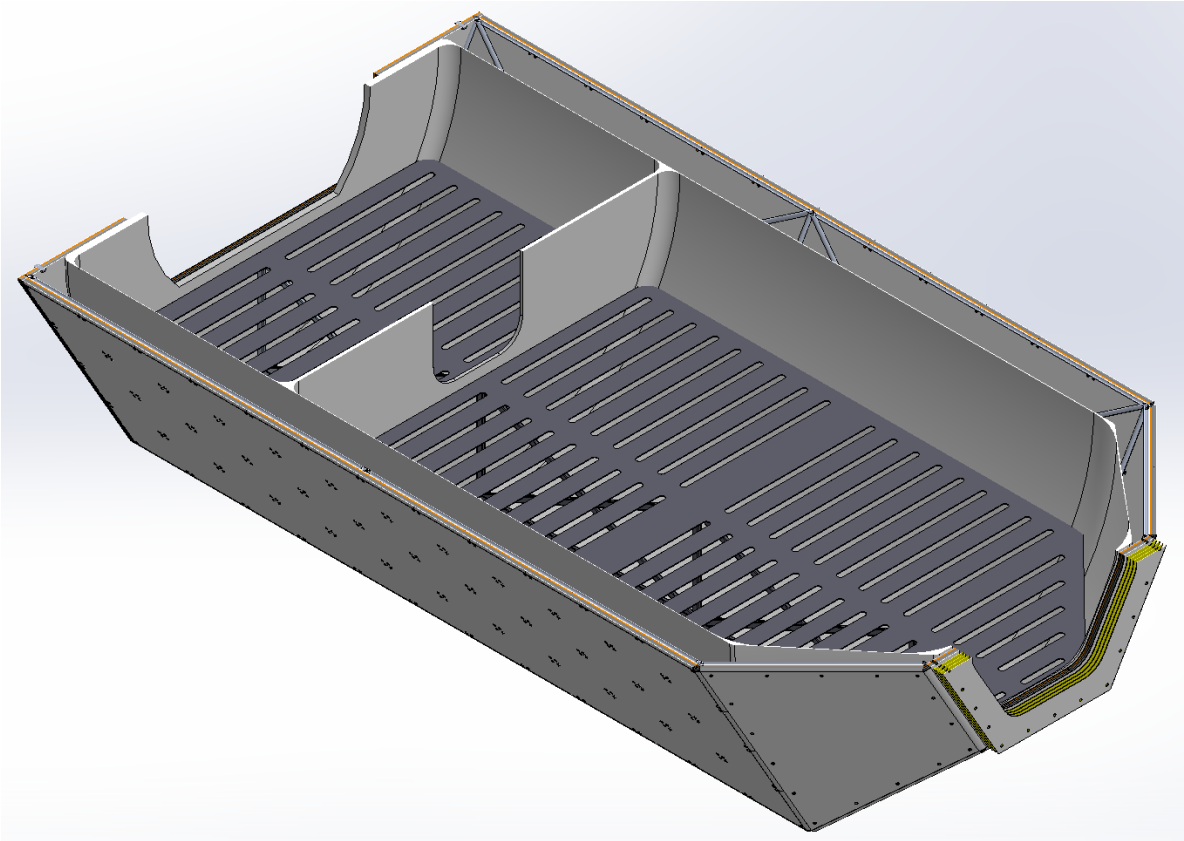


Figure 11: Floor assembled inside the pressure wall.

The floor is held up by 50 X 30 X 2.6 mm (length X width X thickness) square tubing and is entirely constricted out of Aluminum 6061-T6.

1.2.4.2 Hatches and Doors

1.2.4.3 Airlock Door

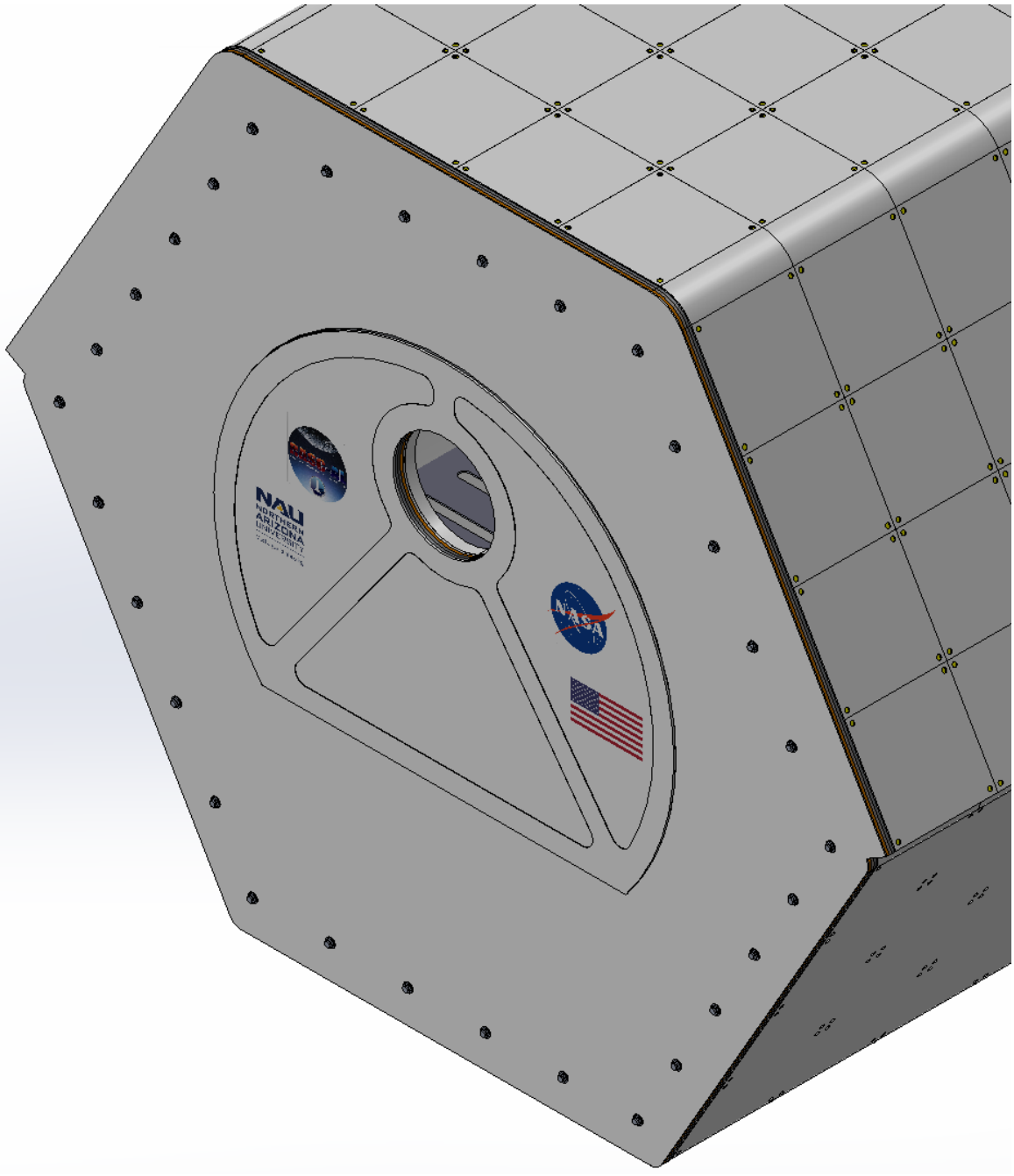


Figure 12: Front airlock door added to the front of the pressure wall.

This front airlock is construed out of Aluminum 6061-T6 and is layered with the same MLI configuration as the rest of the lunar habitat.

1.2.4.4 Bulkhead Door

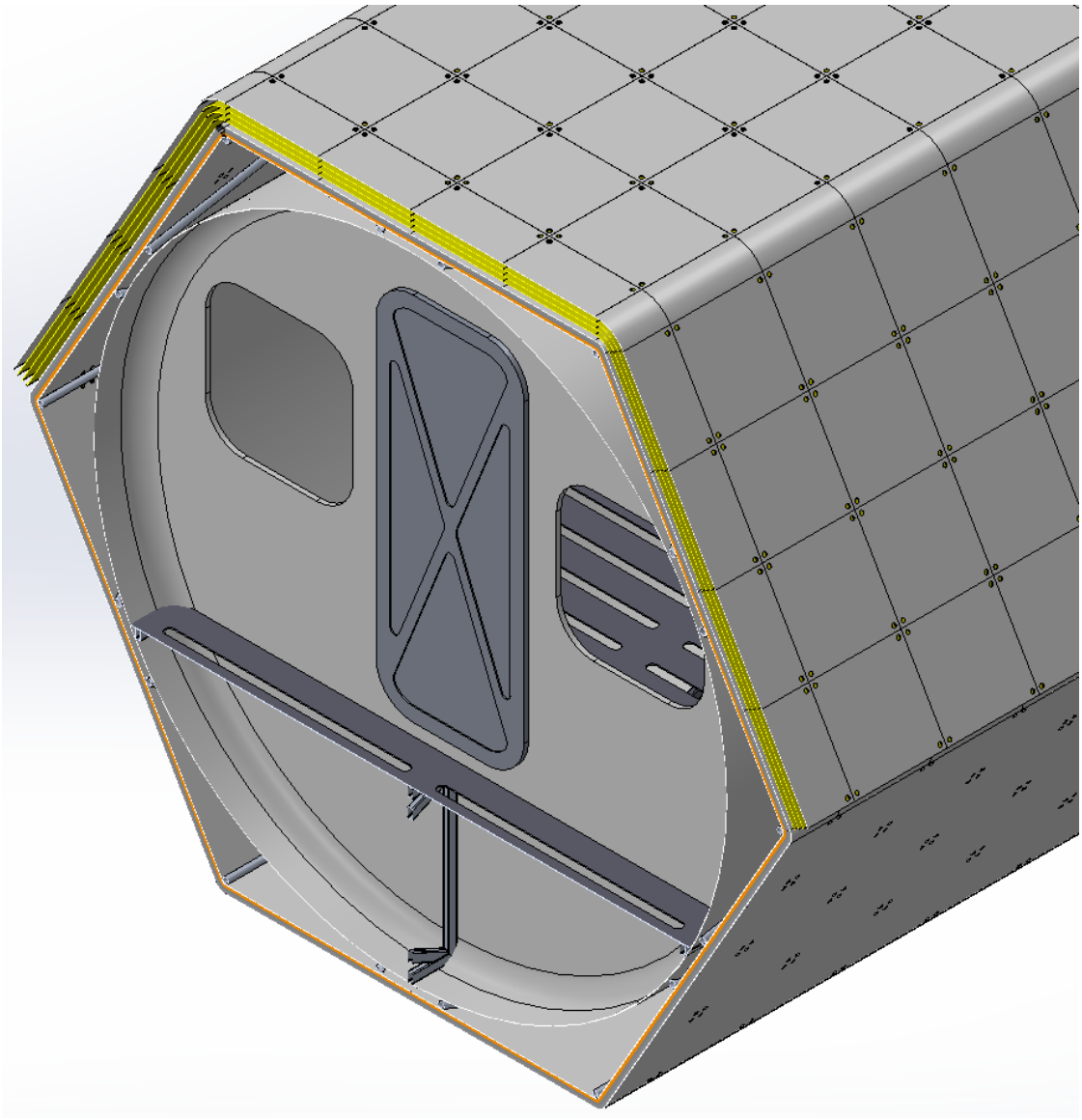


Figure 13: Bulkhead door attached inside of the pressure wall.

1.2.4.5 Suit-Access Port Hatch

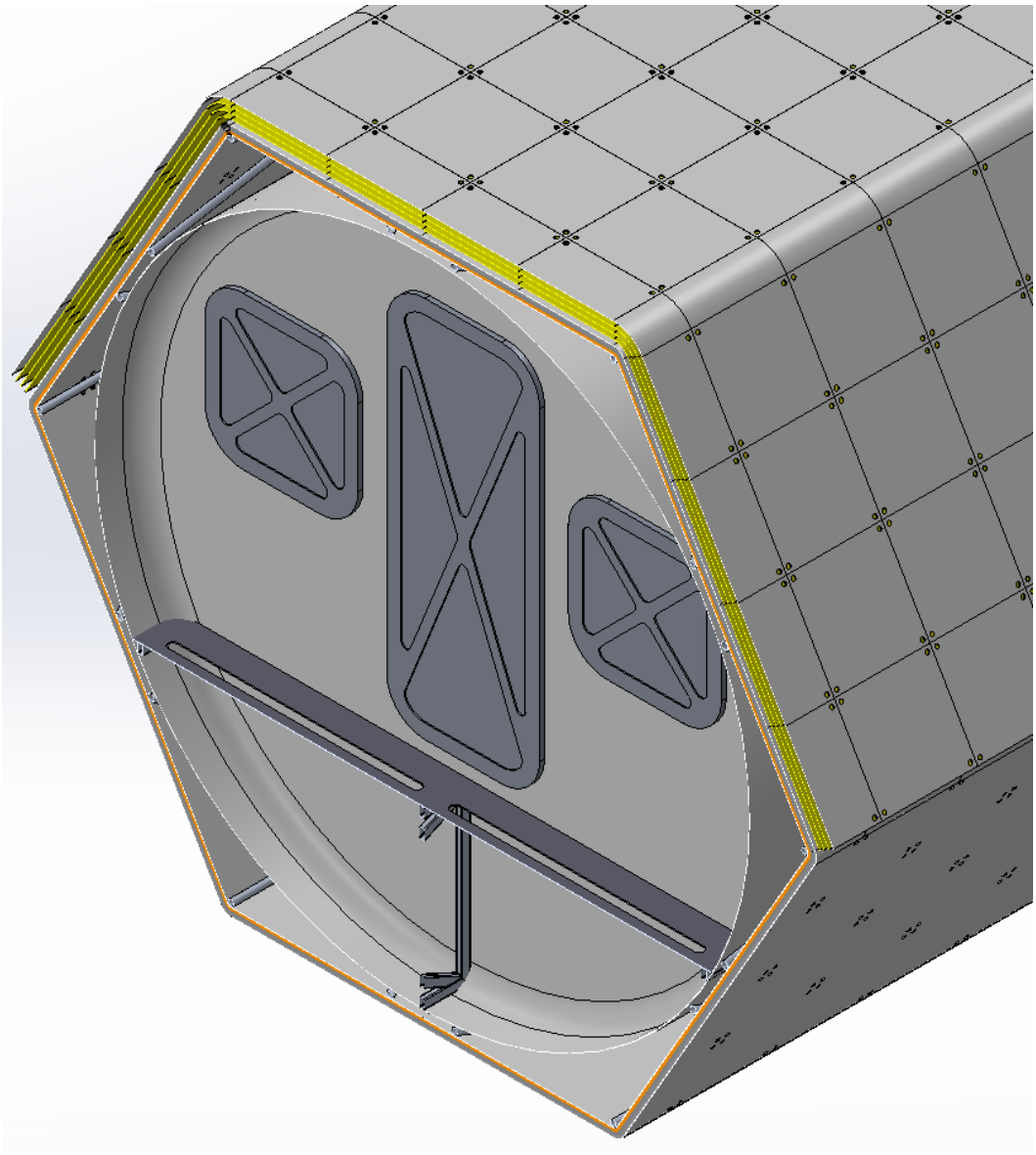


Figure 14: Suit Access Hatch Doors attached to the inside of the pressure wall

1.2.5 Glass Windows

The glass windows used on the lunar habitat are made from fused silica and borosilicate glass panes to ensure that the windows are structurally sound. Figures 15 and 16 show the placement of these panes.

1.2.5.1 Front Airlock View Port

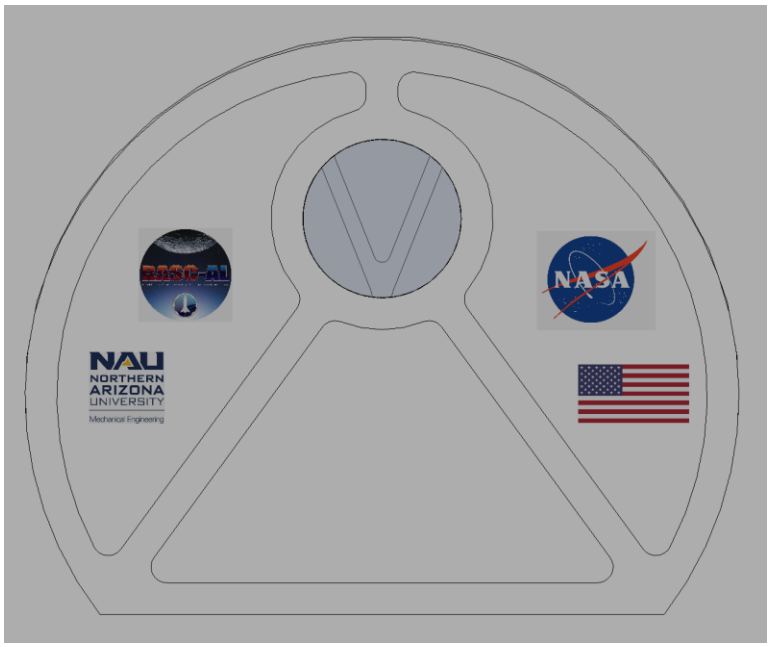


Figure 15: Front Airlock View Port attached to the airlock door

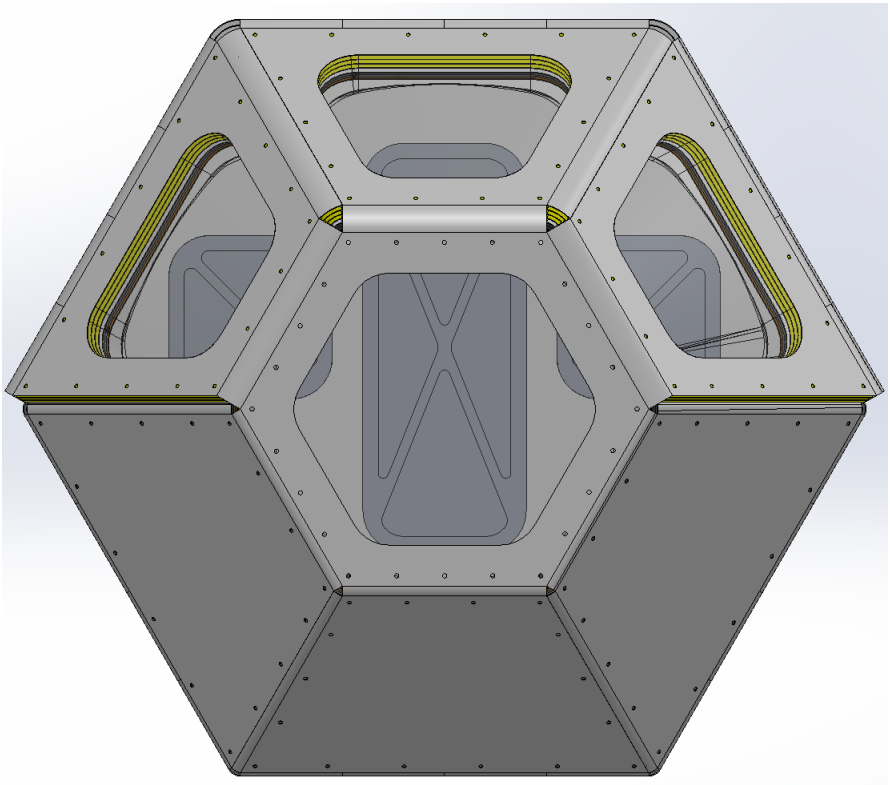


Figure 16: Rear viewing ports attached to the shielding

1.2.6 Fully Assembled on Earth

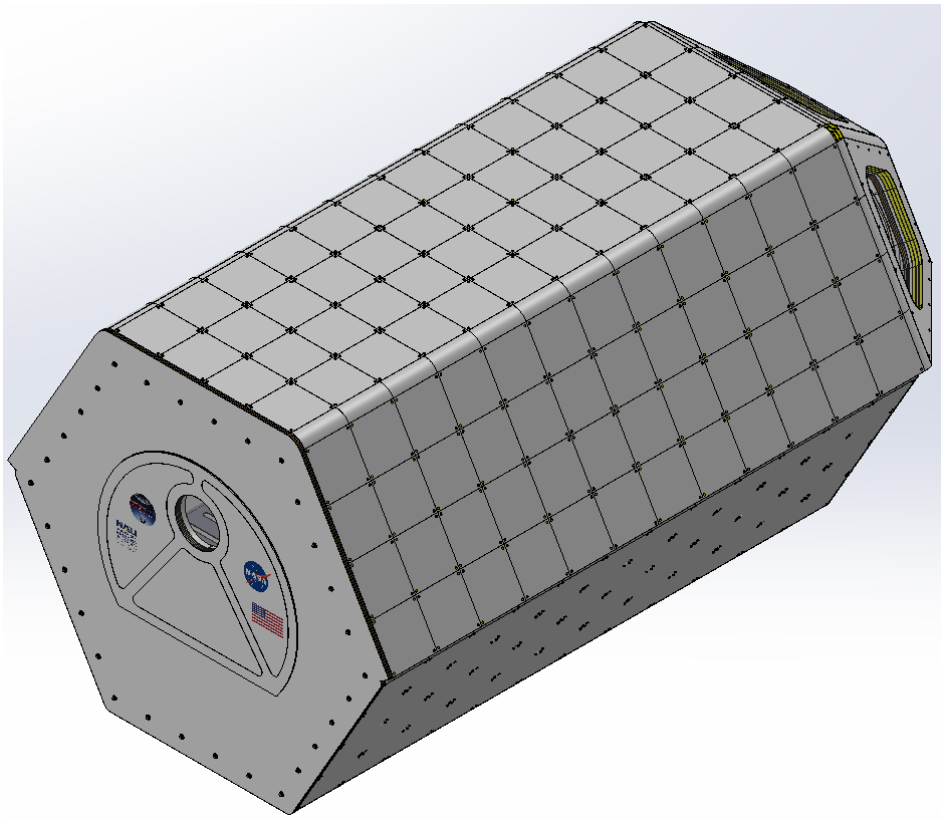


Figure 17: Fully assembled lunar habitat on earth ready for launch to the lunar surface.

1.3 Assembly in Space

Upon arrival to the lunar surface, the lunar habitat module will need to be lifted into the desired location via a crane. The lunar habitat will be loaded vertically into the payload carrying device window side up. The crane will need to be sent to the moon prior to the arrival of the habitat, and must have a carrying capacity of 10,000kg or greater.

1.3.1 Whipple Shield and Support Setup

Once the habitat is in position, two extra panels of Whipple shields and 6 supports must be installed. Figures 18 and 19 show this assembly.

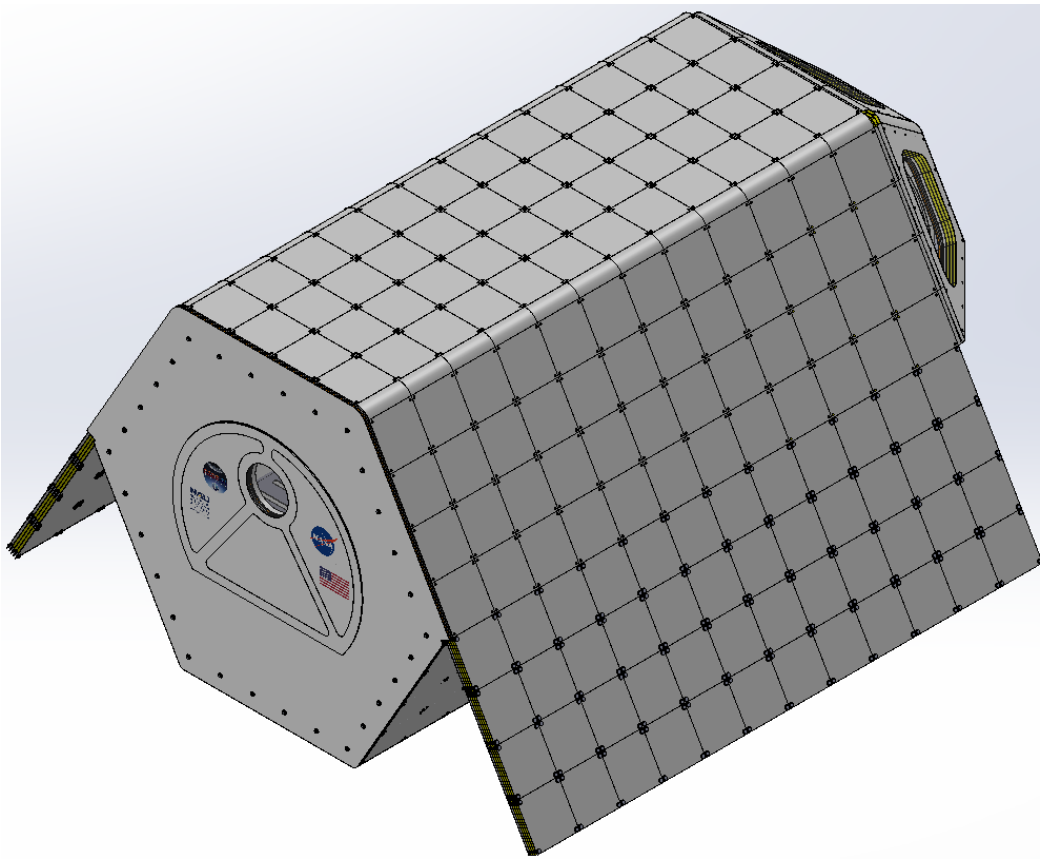


Figure 18: External Whipple Shield sections attached to the sides of the lunar habitat.

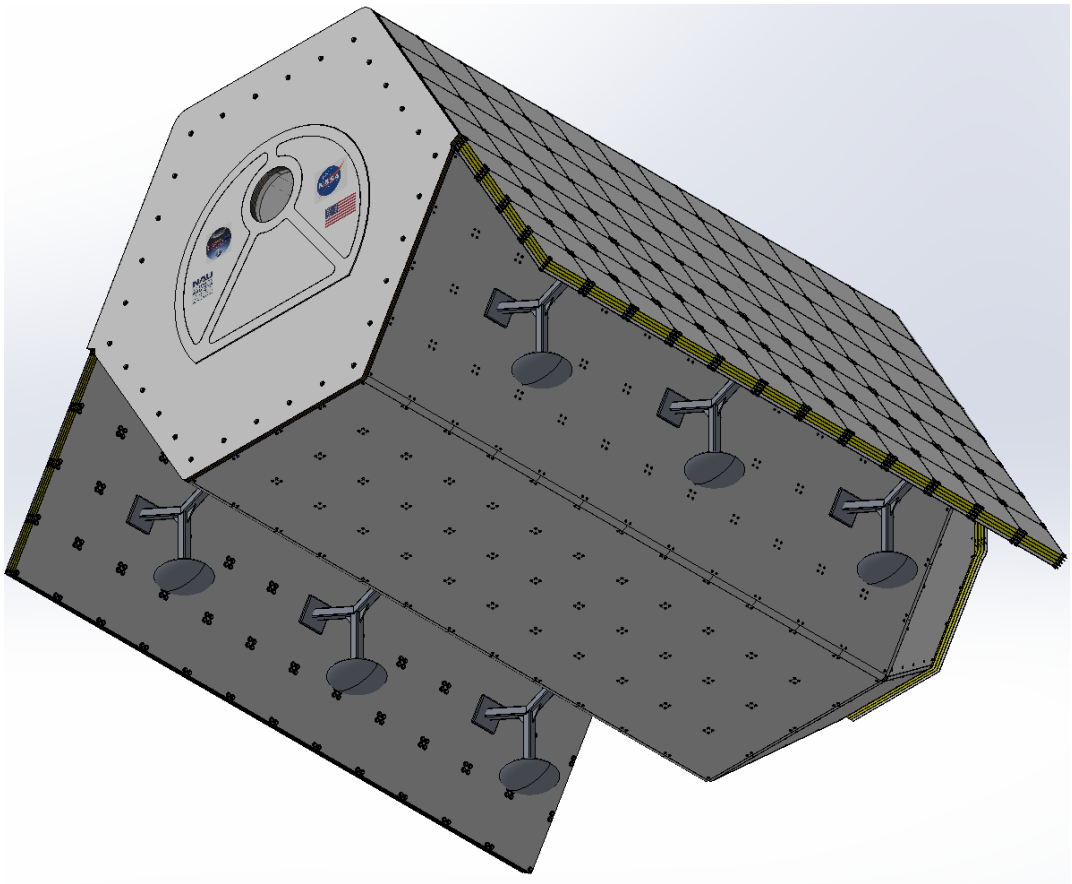


Figure 19: Structural supports attached to the structure and the external Whipple shield.

1.3.2 ECLSS Setup

The Life Support System will require a manual valve opening for certain gasses and properties to operate as they should. Initially, the Oxygen and Nitrogen tanks will be released and will fill the nozzle up to 200 psi N2. The manifold within the configure will then force the O2 valve to release as well.

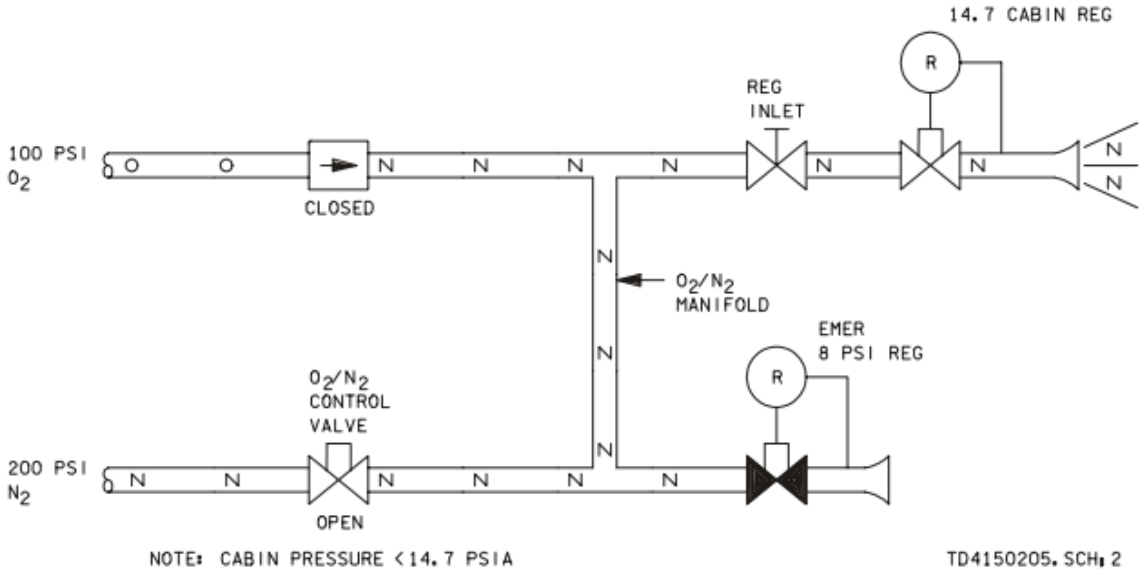


Figure 20: O2 and N2 control valve [1]

When the habitat initially lands and is set up, the O2 and N2 systems will be on controlled by the computer system automatically. The integrated automatic system will control the air pressure and gas levels throughout the habitat.

The water refinery systems will all be setup on ground and will be set to go once the habitat touches down on the lunar surface. All that will need to be done is connect the provided supply of initial water to the internal drain tank and fill the water supply tank with the water. Once filled up, close the tank and the integrated system will cycle the required water to all the appropriate properties.

Once the assembly has been completed, the system will provide the crew with a “GO” once all the tests and requirements have been processed. If there is something lacking or that needs to be completed, the digital monitor screen will guide the user to step by step instruction sin order to trouble shoot the problem.

1.3.3 Climate Control Setup

The internal climate control system will be preinstalled within the habitat. The only section that will require assembly is the external system. First locate the interface heat exchanger located within the habitat. It is located beneath the floor where the life support systems are located close to the airlock side of the habitat. The exit port facing the wall of the habitat will require a connection for an ammonia line. These metal lines will come separately bagged and stored beneath the habitat. The connection setup is as follows:

1. Unwrap the ammonia line.
2. Connect the fitting to the fitting connection on the interface heat exchanger marked “Ammonia.”
3. Feed the line though the airtight fitting beneath the floor which leads to the surface of the moon. Upon habitat pressurization be sure to check this fitting for air leaks.
4. Connect all the ammonia lines together outside of the habitat and bring the last fitting back through the habitat airtight fitting.

5. Connect the final fitting to the heat exchanger on the same side below the first Ammonia connection. This will also be labeled “Ammonia”.

16 4m x 1m radiators will need to be carried out onto the lunar surface and placed perpendicular to the ammonia loop. Each radiator will need to be connected to the loop with the quick two quick connects located on either side of the short side. The flow direction is counterclockwise for the fluid, so the first connection should be attached on the left, and the second on the right. The black arrows indicate this on the diagram. Figure **20** below shows the diagram for the radiator and heat exchanger connections and loop setup.

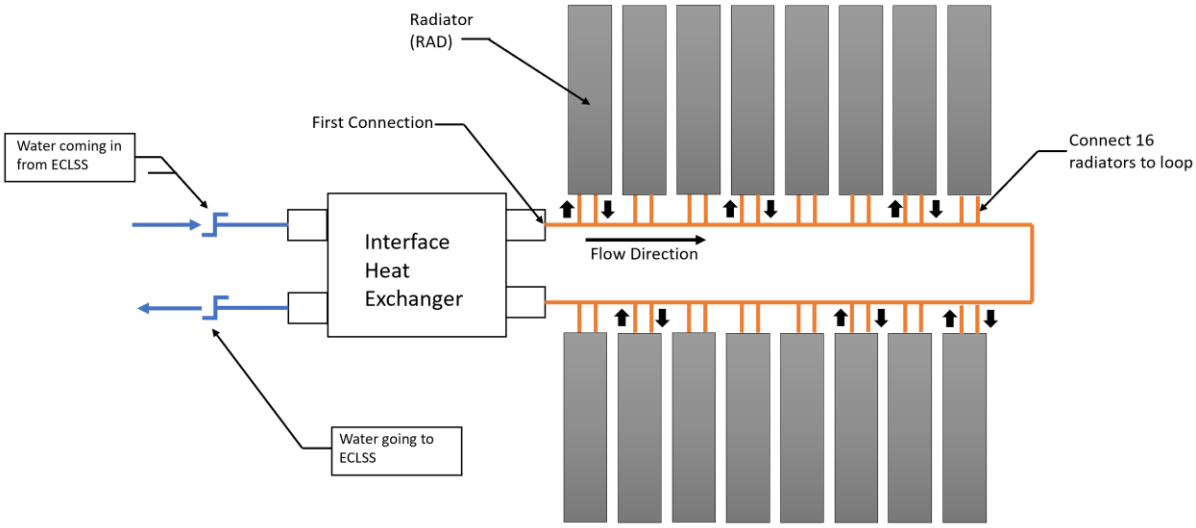


Figure 21: Ammonia Loop and Radiator Setup

Once the radiator setup is complete it is time to add the ammonia to the system and power it on. The interface heat exchanger will have a cap on the top of it on the ammonia side. Add 3-gallon jugs of ammonia to this heat exchanger for best operation conditions. Show extreme caution when handling ammonia as it is very toxic. Be sure to only power on the system after habitat pressurization has occurred.

1.3.4 Fully Assembled in Space

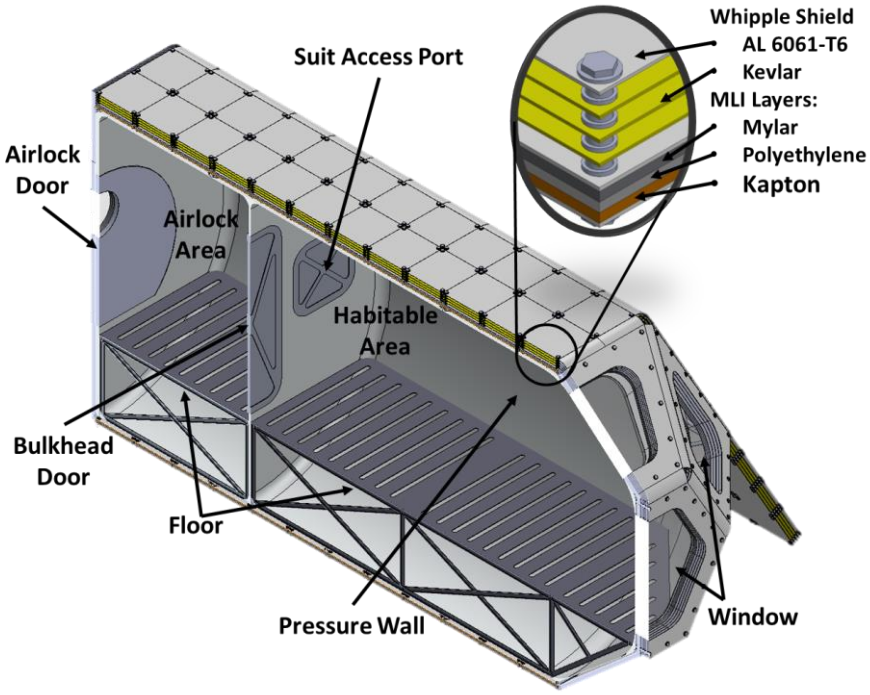


Figure 22: Section Cut of the fully assembled lunar habitat.

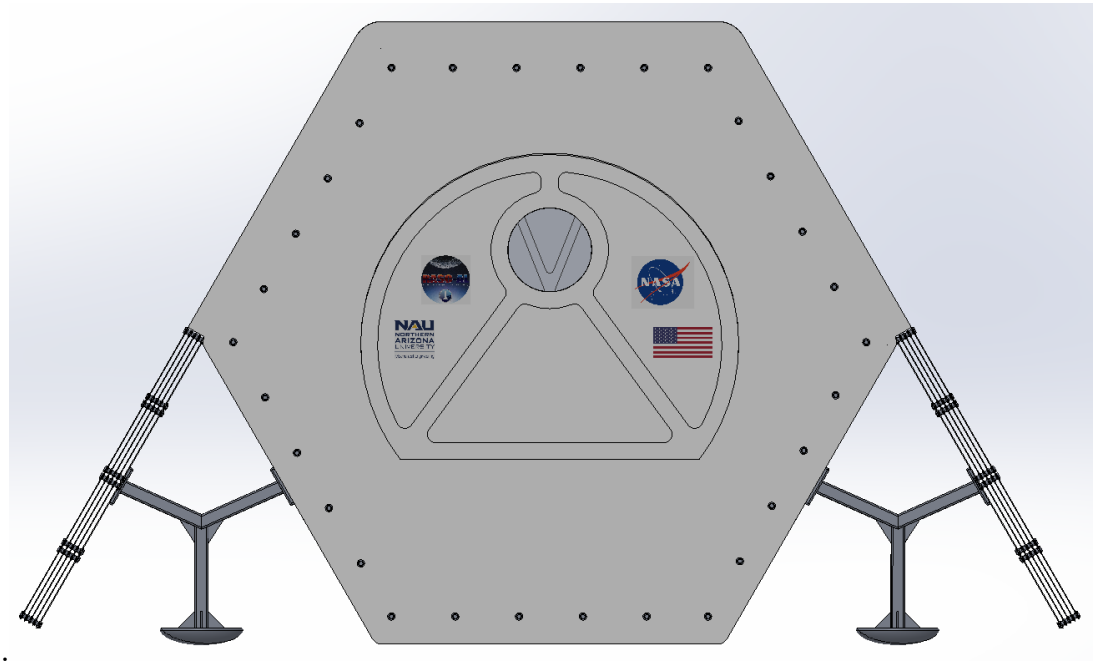


Figure 23: Front view of the fully assembled lunar habitat.

1.4 Disassembly and Storage for Future Use

The NASA RASC-AL Lunar Habitat is designed to be used longer than the minimum requirement of 30 days. This habitat will be left abandoned once the duration of the mission is completed. There is a

possibility of rescuing this habitat for future missions or used of spare parts as NASA sees fit.

2 Maintenance

As two astronauts will be living on this lunar habitat for 30 days minimum, it is unlikely for everything to function without flaw for the full duration. The two astronauts must have the knowledge to fix and maintain the various subsystems and components that comprise the major life-support systems.

2.1 ECLSS Maintenance

The water refinery system will refine excess water than what the astronauts will be able to use. Thus, the excess will dump overboard in order to make room for the newly refined and better filtered water that is coming into the storage tanks. This process must be performed manually by the astronauts on board. This will be done periodically at random based on when the system defines it is necessary. The water dump nozzles are turned on to warm up the water from the freezing temperatures. Next, the dump isolation valve and the dump valve are opened to let go of the excess water overboard. [1] Once the required excess water is has been dumped, the isol valve is closed then the dump valve is cycled to remove the excess water in the lines then finally left closed and the dump isol is opened once again. Pictured below is the configuration of the water supply and refinery system.

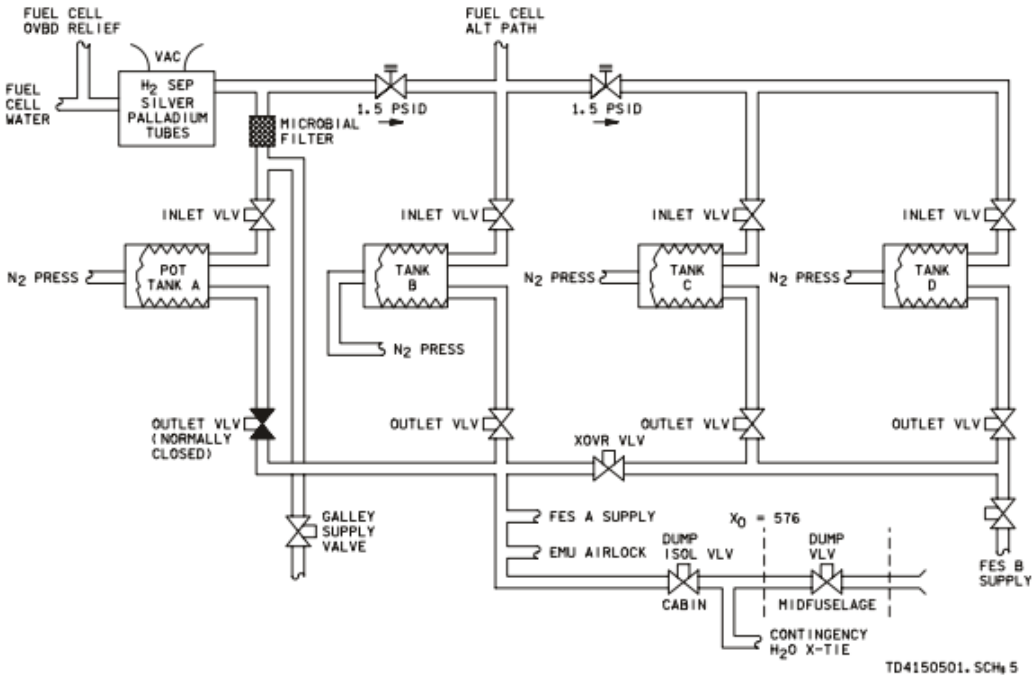


Figure 24: Water Supply Storage System

The wastewater storage tank is a separate compartment that will maintain the crew's urine and humidity condensation in a sanitary manner until it can be disposed. Although a majority of will refined and reused, certain parameters must be simply discarded. The normal plan for this system is to dump the tank via the wastewater dump line whenever it reaches 80% capacity. Similar to the water refinery system, this assembly must be thermostatically controlled to ensure a dump line that is not within freezing temperatures.

2.2 Climate Control Maintenance

The climate control system will require regular maintenance to ensure proper operation. **On a**

daily basis, be sure to:

1. Moon dust will accumulate on the radiators outside of the habitat. Be sure to clean these radiators thoroughly as this will reduce the radiation heat transfer rate.
2. Inspect the level cold plate connections that interface with the life support systems. If there are any fractures or imperfections in the fitting or line, turn off the system, drain the water, and replace the part.
3. Check any and all ammonia fittings for leaks. If a leak is present, do not replace the part without proper chemical protection. Contact experts at NASA for advice.

3 Potential Failures and Troubleshooting

There are likely to be design oversights and flaws in the lunar habit design that may potentially contribute to values of certain subsystems. Below is a list of some work-around and troubleshooting methods to aid the two astronauts on the lunar surface.

3.1 Whipple Shield

Depending on the severity and frequency of micrometeorite impacts, the Whipple Shield on the outside of the lunar habitat may need portions to be replaced. The Whipple Shield is designed to be taken apart by individual sections if the damage seen to one section warrants the need for replacing.

1. Visually inspect the Whipple Shield to locate any severely damaged portions or portions beyond repair and in need of replacement.
2. Disassemble the section of the Whipple Shield that needs to be replaced by removing the section of M24 bolts fastened to the section.
3. Use the additional materials and equipment present to cut a section of the Whipple shield to the desired dimensions. Prefabricated parts will be sent to the lunar surface as well.
4. Replace the section of the Whipple Shield and replace any damaged fasteners while reassembling the repaired section.

As a last resort, if there is not enough extra material to replace the Lunar Regolith is a viable alternative to dissipate micrometeorite impacts while the two astronauts contact NASA and ask for additional materials to make the necessary repairs.

3.2 Climate Control

The most likely failure scenario for failure is a quick connection failure. In the event of a connection failure for the water loop follow the following steps:

1. Turn off power to the climate control system.
2. Using a 12mm socket and wrench, Drain the water from the heat exchanger into a catch basin, do not unscrew the ammonia drain plug.
3. Disconnect the connection from the line and the life support system or heat exchanger. Replace the connection with a spare. No tools should be necessary to do this.

If there is a failure in a quick connection in the ammonia loop, do **NOT** attempt to replace this connection without assistance. Ammonia is a toxic chemical that requires cautious handling. Contact NASA mission control for advice.

3.3 Life Support Systems

If the cabin pressure drops below 14.7 psia, the gasses within the O2 and N2 manifold will flow into the cabin and the N2 will replenish the levels within the cabin and the manifolds.

There have also been security measurements installed in for the tanks in order to account for the water pressures cracking through the tanks. If tank A inlet valve is closed for some reason, eventually the water pressure will increase so much that it will crack through the 1.5 psid check valve. If so, the water will overflow and enter Tank B. If tank B is filled, the next 1.5 psid check valve will also blow through and the cycle will overflow into tank C and potentially into tank D as well. This is visually relayed in the Figure 24, which translates the map of the water storage tanks.

The water refinery system, storage tanks and urine refinery system and tanks have all been installed with

four safety tanks to ensure there is never a spillage or leak outside of the tank. If potentially, one fails there will be four extra backups.

References

[1] M. Sadowski, “Environmental control and life support system - NASA,” *NASA.GOV*, 23-Oct-2006. [Online]. Available: https://www.nasa.gov/centers/johnson/pdf/383445main_eclss_21002.pdf. [Accessed: 06-Dec-2021].