Multi-Use Lunar Transport (M.U.L.T.)
2022 RASC-AL Proposal
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Brigham Young University

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Quad Chart:

Brigham Young University MULT

Theme: Suitport Logistics Carrier

Objectives & Technical Approach:

•SPLC will:

•Shield goods from vacuum of space, radiation hazards, and temperature hazards.

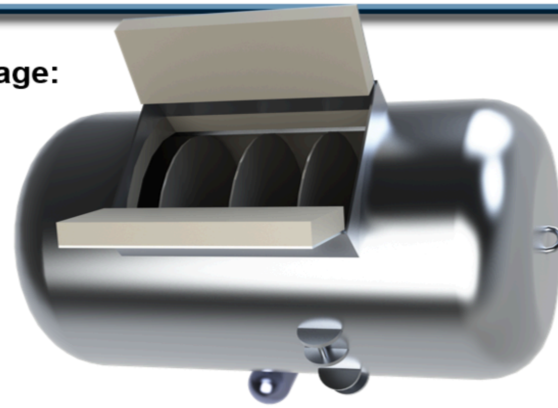
•Have goods be easily accessed.

•Cast Aluminum outer shell will protect inside.

•Aluminized Mylar, Kevlar, and ammonia cooling will limit radiation and temperature.

•Internal rail box system will allow goods to be easily stored/ retrieved.

Image:



Key Design Details & Innovations:

- Integration of Kevlar shielding will limit radiation exposure internally.
- Ammonia cooling will maintain control of temperature.
- Rail system will manage storage.
- Total mass estimate is 900 kg empty.
- Total usable volume is 1.27 m^3
- Total volume is 2.60 m^3
- Total power estimate is 400 Watts.

Schedule: Start Date: 5/3/2022

- Concept Studies: 60 days
- Concept/ Tech Development: 93 days
- Preliminary Design: 62 days
- Final Design: 60 days
- System Assembly: 139 days
- Completion date: 6/26/2023

Expected Cost: $2,830.49

Figure 1: Rendering of the MULT exterior

Abstract:
Future planned lunar missions will require astronauts to spend extended time on the lunar surface. To facilitate this, supply drops will need to deliver both technical and perishable goods to the astronauts below. The logistical requirements of these tasks means that a container capable of long-term storage on the lunar surface will be required. We propose a carrier of cast aluminum with multi-layered insulation capable of temperature control and radiation shielding. An internal rails and box storage systems will manage internal spacing.

Theme Requirements
We will have handles on our container that will allow two astronauts to lift it together and move it, and there will also be an anchor point on the top that a crane system can hook onto and use to lift and move the container.

A sheath surrounding the suitport will be used to stave off dust, while a mix of kevlar, aluminized mylar, and ammonia-based cooling to keep temperature, pressure and radiation at manageable levels.

Instead of several smaller carriers for our carriers, we are implementing one larger carrier for several reasons, the most prominent of which being the radiation protection. The amount of mass needed to get equivalent radiation protection for multiple containers is much higher, and considering that these containers will have food supplies, radiation protection is essential for the integrity of the payload. While diversification of containers has its benefits, some of those benefits of the security of the contents are compromised by lesser radiation protection.

The MULT will be able to carry 800 kg of dry goods and 90 kg in the tanks on the outside.

The pod will have a mass around 900 kg, a usable volume of 1.27 m^3 and a total volume of 2.60 m^3. It will need a battery to provide close to 400 Watts.

The MULT has handles on the side for movement by astronauts, but using the crane and rover for longer trips would be recommended.

Innovative Approaches/ Capabilities/ Technology

1 Inner Storage

The inside of the suitport logistics carrier will hold supplies on shelves. The shelves will be held on a rail and bolt-locking system that can be moved to optimize usable space inside the carrier while in use by the astronauts. The shelves can be locked in place by resting dips and bolt locks. The supplies will be secured to the shelves by ratchet straps secured to each shelf. The rail system will go from the top to the bottom of the cylindrical section, and the only parts that move or have any mechanical parts are the shelves.

1.1 Rail System

The carrier will be a cylinder with caps on either end. The cylinder section will provide the majority of the storage space with a 1 meter diameter and height of 1.6 meters. This storage space will contain the rail system, which will contain three rails that run from the roof to the floor. These will be secured to the wall by bolts every 8cm with insulated bolts to provide additional structural support for the rails.

The arrangement of the 3 rails will be one directly opposite the suitport entrance and the other two 120° to the right and left. The shelves will be able to pivot counter clockwise and then go down into the "L" shaped resting dips. On the rails on the left and right of the suitport side, there will be bolt holes every 16 cm that allow bolts from the shelves to latch into. This will lock the shelf in place at a certain level and prevent it from moving around.

Aluminum bolts will be screwed in flush against the rail system, pushing it against the insulation. The bolts will connect the rails to the inner surface of the chassis. The bolts will have insulated (rubber) covers and washers to minimize heat transfer and loss between layers of the MULT.

1.2 Shelf Design

The shelves will be made out of polycarbonate. The shelf will be a cylinder that is 2cm thick and 1 meter in diameter. The shelf will have 3 pegs sticking out into each rail system. The pegs will have a rectangularly shape in order to fit into the rail system. These pegs will always be in either the rail system or the resting dips to hold up the shelves. In addition to these pegs there will be a retractable dead bolt that can be manually removed or activated. These will be by the two pegs closest to the door.

Since the shelves will be holding the supplies, we want to strap them down to the shelves so they do not move or get damaged. 4 ratchet straps will be screwed into the shelves using 2 aluminum screws each. To lift the shelves, the crew can grab the straps and pull it to the desired level, and lock it into place with the resting dips and bolts

2 Chassis

The shell of the MULT will be the body that contains the cargo, as well as the insulation and cooling system. It will be composed of 3 main pieces: the main cylindrical shell, and two end caps. The main cylindrical shell will provide the main source of storage space for the carrier. It will have the suitport entrance attached on one of its sides to allow for unloading the cargo. The caps will be connected to the main cylinder body, and will gradually curve in from where they meet the main cylinder to form a flattened surface that the MULT can rest on. The end caps will be identical to each other except for an anchor point on the top cap to allow for convenient lifting. Additionally, we will mount the gas canisters to the outside of the shell in positions to help balance the weight of the suitport.

2.1 Material Selection

The main cylinder with the suitport entrance, and the end caps will be individually cast from Aluminum 2219[1] and then welded together. We have selected aluminum 2219 for the shell because of its strength combined with low density. Additionally, this alloy will retain its desirable properties at the high and low temperatures experienced on the moon. The dimensions will be discussed in detail in the mass and size estimates section.

3 Environmental Hazard Deterrent

In order to protect the contents of the MULT we need to account for the various natural environmental hazards of the lunar surface. The primary hazards include a large range in temperature, -179°C to 115°C, and exposure to cosmic radiation and other high energy particles. A secondary hazard includes the rough nature of the lunar surface and the charged dust that covers it.

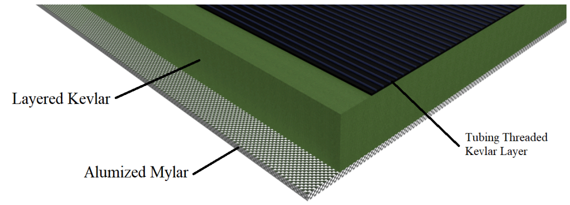


Figure 2: Diagram of Thermal Insulation and Radiation Protection Scheme

3.1 Thermal Management

To address the large changes in temperature, we have devised a mix of active cooling and thermal insulation that will allow us to maintain stable temperatures despite exposure to the energy of direct sunlight.

Insulation

The innermost layer of our thermal insulation component will be 2 cm and consist of a layering similar to the multilayered aluminized mylar that has been used in the Space Shuttle Extravehicular Mobility Unit (EMU).[2] Immediately following that layer will be a 7 cm section of layered Kevlar, acting as both additional insulation and radiation protection, which will also provide the structure for the active cooling system. These will be secured to the side using the anchors that secure the railing system.

Active Cooling

Following the passive insulation will be a layer of active cooling, flush with the aluminum chassis. It will be a liquid cooling system, based on the system from the ISS,[3] which will use liquid ammonia pumped through tubing spread across the interior of the chassis, held up by and woven through the first layer of Kevlar in the insulation system. Doing so will allow the ammonia to transfer the heat[4] gained from the side of the MULT that is exposed to solar radiation to its dark side for transfer into space, mitigating the amount of heat needed to insulate against. To implement this system, we will be using a system of 3mm outer diameter FEP Tubing[5] and a pump, using a coiling pattern that will loop back around and spiral in reverse down to the base, for the tubing in order to minimize time between gaining heat and releasing it. With respect to the suitport hatch the tubing will be run to the door using the hinges as entry/exit points. The coiling system will be interrupted at this point, switching to a snaking method to avoid blocking off the suitport hatch.

3.2 Radiation Shielding

To counteract the damaging effects of comics rays and other high energy particles our design incorporated, as an addition to its thermal insulation, a thick layer of Kevlar combined with our other layers of additional insulation and protection.

Inherent Shielding

The insulation and outer shell will provide basic radiation shielding capacity that will be supplemented with additional shielding. 1 cm of the aluminized mylar has been tested to block all but $1.4 \times 10^{-9}\ Sv/s$ in spacesuits on the surface of the moon[6]. The aluminum used for the outer shell will not block as much, but its main purpose is structural integrity.

Additional Shielding

The additional shielding will be constructed with multiple layers of Kevlar, totaling 8 cm in thickness, though this includes insulation tubing woven throughout the Kevlar. This provides around $10\ g/cm^2$ of Kevlar, reducing the dose equivalent radiation by 55 ± 4%. This reduction in addition to the minor shielding benefits of the inherent shielding of materials used for other purposes should protect the cargo from any dangerous levels of radiation that could cause the astronaut's harm.

Contamination Detection

To detect contamination due to unexpected increases in radiation or other variables, a passive radiation detector in the form of a dosimeter will be included inside the MULT, allowing the astronauts to check if radiation has surpassed maximum allowable levels.

3.3 Dust Management

We propose employing a cinching ortho-fabric cloth covering over the suitport to prevent dust from entering the capsule, which can be removed when the pod is going to be connected to the suitport. If dust is causing other problems, it can be swept off by hand, and dust on the outside of the logistic carrier should not become a problem.

3.4 Required Electronics

In order to provide control for the pump and indicator lights we are going to incorporate a custom integrated circuit, combined with a few additional components, to devise a low power system for regulating when the pump should be activated and which indicator lights should be turned on. This will include two indicator LEDs, located directly inside the suitport, one for battery failure, which will turn off if the battery fails, and one for pump failure, which will turn off if the load on the pump decreases due to loss of pressure in the tubing system.

Information about the Work Conducted in various Trades, Concept, and Mission constructs

To better understand how pressure considerations might affect our design, we decided to research SCUBA tanks to get a realistic comparison for a pressurized cylinder. We found that most SCUBA tanks are made of either steel or aluminum,[8] and aluminum SCUBA tanks with walls about 11 mm thick can handle pressures between 207 and 240 bar, or around 200 to 235 atmospheres of pressure.[9] We do not anticipate our containers experiencing anything more than three atmospheres of pressure difference, which is far below the maximum pressures that our comparison can contain, so we believe that our chosen design of aluminum 1 cm thick for our chassis will be more than sufficient to serve as a pressure vessel for our needs.

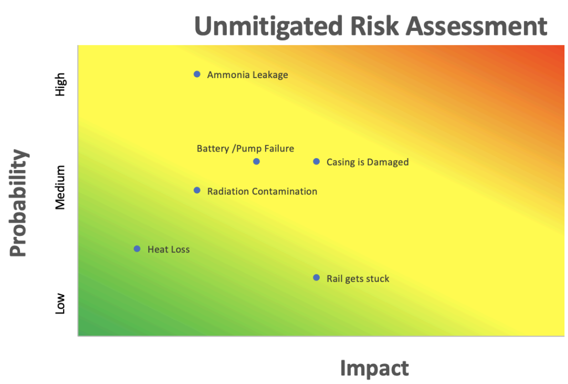
Concept Renders

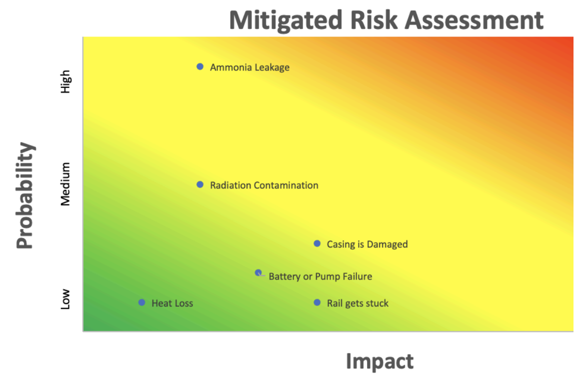
Figure 3: MULT Exterior with doors in the place of suitport

Figure 4: Cross Section of MULT interior

Figure 5: Exploded View

Risk Analysis





Risk	Proposed Mitigation
Casing is Damaged	Application of crack sealant
Rail gets stuck	Lubricant or extra force to unstick
Ammonia Leakage	Ammonia is sealed behind insulation, but it is a toxic gas. Remove materials from the MULT and seal it up
Battery or Pump Failure	Lower exposure to heat by placing the MULT in the shade or regulate temperature by attaching it to the suitport
Heat Loss	Cautiously increase exposure to heat by placing the MULT in the sun or increase internal heat by attaching it to the suitport
Radiation Contamina tion	Dosimeters indicate contamination, if radiation level is above acceptable values then materials stored in the MULT can be removed

Mass and Size estimates

Total Height	2.22 m
Total Diameter	1.22 m
Storage Volume	1.27 m^3
Estimated Mass Unloaded	900 kg

The shell will be expected to carry 900 kg of cargo, the mass of the insulation, cooling system, and radiation protection layers. The shell thickness will be 1 cm. The total height of the MULT will be 2.22 m, the total diameter will be 1.22 m. The caps will have a height of 30 cm, and the sides will gradually curve in from where they meet the main cylinder to the flattened surface. The caps will have the same thickness as the rest of the chassis, 1 cm, and the hollow space inside them will be used to hold batteries and components for the cooling and environmental systems.

The main part of the chassis will be an aluminum cylinder with walls 1 cm thick, a diameter of 1.22 m, and a height of 1.62 m. The suitport will be attached to one side of the main cylinder, and it will be 1 meter tall by 0.75 m wide. The depth of the suitport will vary from 5 cm in the center to 16.7 cm at the sides as the walls of the cylinder curve away from the front of the port (see CAD drawings for reference). One thing that we are unsure of is the exact mechanisms that will be used to seal the MULT and connect it to a suitport, but if necessary we can alter the depth to give more room for these mechanisms to fit on our carrier and be operable by astronauts.

Key Findings supporting the Envisioned approach

According to our research, SCUBA tanks with wall thicknesses similar to the wall thickness we chose to use can safely contain pressures of over 200 atm[9], which is far above the maximum pressure differential that the MULT might reasonably experience, so we are confident that our design will be able to maintain the desired pressure for extended periods without damage.

Based on our own analysis, the shelving and storage structures should be able to survive up to 6 g of acceleration with the specified loads without breaking.

According to our research into cost effective radiation shielding, a 10g/cm^2 shield made of Kevlar will block around 55 ± 4% of solar radiation.[7] Compared to other materials, we found that Kevlar provides the best shielding in terms of cost.

Also, ammonia and aluminized mylar were selected as the materials of choice for heat management because of their uses in both the International Space Station, and previous Extravehicular Movement Units.[2]

Realistic Technology Assumptions, including TRL and Justifications

1. Battery

To power the pump and control electronics we will require a rechargeable battery that will vary based on the expected period between charging. The rough estimate of battery capacity is comparable to commercially available 120V Lithium Ion batteries (citation needed) and so we are basing our battery assumption on them. An equivalent battery is about 2 kg and 8x5x5cm which will easily fit in the area allotted in the top and bottom of the MULT.

2. Shelving
The force on the rocket will be 5.9 kiloNewtons, so the shelf thickness was made 2 cm thick, with pegs 1.4cm long and 2cm thick. This appeared to be structurally strong enough based on the strength of polycarbonate, but this can change at extremely hot or cold temperatures. Additionally the expected force may be different than the actual force.

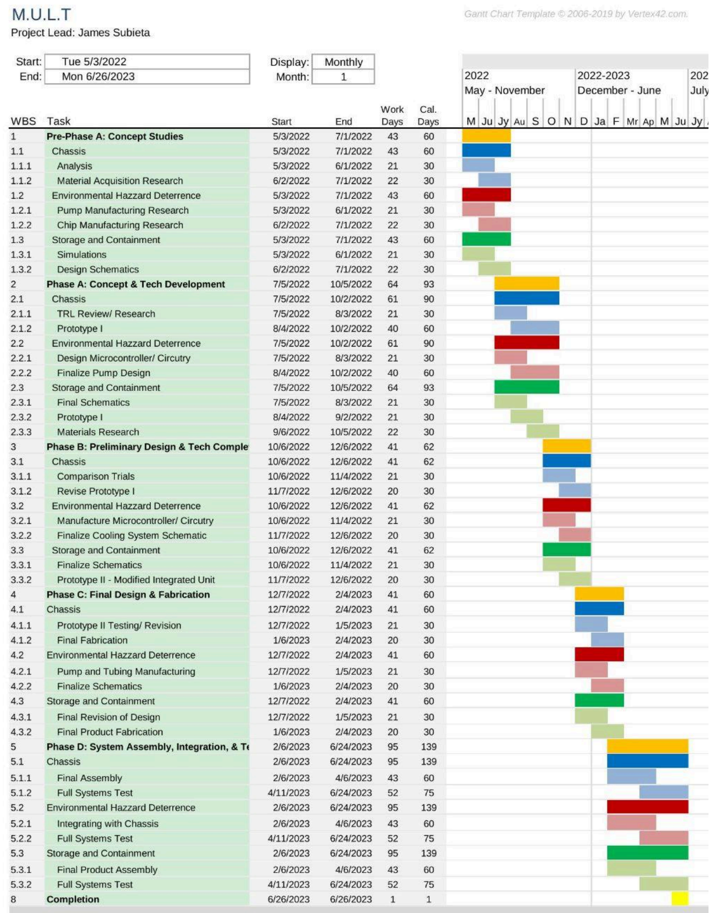
Readiness Levels for Incorporated Technologies (TRL)

Technology	RL	Justification
Aluminized Mylar	9	Same insulation that is used in the spacesuits
Ammonia Tubing System	6	Similar technology is used to cool the ISS
Kevlar Insulation	3	Material is well examined and tested
Control Systems	9	Systems have a history of space usage
Internal Structure	6	Uses materials and designs with proven durability and strength
External Structure	7	Uses similar manufacturing and design techniques to previous NASA projects

Budget

Parts:	Cost (USD):
Polycarbonate	188
Pegs	0.75
Latches	256
Aluminum	25.74
Aluminum Casting	1360
Insulation	1000
Total	2830.49

Timeline


M.U.L.T
Project Lead: James Subieta
Gantt Chart Template © 2006-2019 by Vertex42.com.
Start: Tue 5/3/2022
End: Mon 6/26/2023
Display: Monthly
Month: 1

WBS	Task	Start	End	Work Days	Cal. Days
1	**Pre-Phase A: Concept Studies**	5/3/2022	7/1/2022	43	60
1.1	Chassis	5/3/2022	7/1/2022	43	60
1.1.1	Analysis	5/3/2022	6/1/2022	21	30
1.1.2	Material Acquisition Research	6/2/2022	7/1/2022	22	30
1.2	Environmental Hazzard Deterrence	5/3/2022	7/1/2022	43	60
1.2.1	Pump Manufacturing Research	5/3/2022	6/1/2022	21	30
1.2.2	Chip Manufacturing Research	6/2/2022	7/1/2022	22	30
1.3	Storage and Containment	5/3/2022	7/1/2022	43	60
1.3.1	Simulations	5/3/2022	6/1/2022	21	30
1.3.2	Design Schematics	6/2/2022	7/1/2022	22	30
2	**Phase A: Concept & Tech Development**	7/5/2022	10/5/2022	64	93
2.1	Chassis	7/5/2022	10/2/2022	61	90
2.1.1	TRL Review/ Research	7/5/2022	8/3/2022	21	30
2.1.2	Prototype I	8/4/2022	10/2/2022	40	60
2.2	Environmental Hazzard Deterrence	7/5/2022	10/2/2022	61	90
2.2.1	Design Microcontroller/ Circutry	7/5/2022	8/3/2022	21	30
2.2.2	Finalize Pump Design	8/4/2022	10/2/2022	40	60
2.3	Storage and Containment	7/5/2022	10/5/2022	64	93
2.3.1	Final Schematics	7/5/2022	8/3/2022	21	30
2.3.2	Prototype I	8/4/2022	9/2/2022	21	30
2.3.3	Materials Research	9/6/2022	10/5/2022	22	30
3	**Phase B: Preliminary Design & Tech Comple**	10/6/2022	12/6/2022	41	62
3.1	Chassis	10/6/2022	12/6/2022	41	62
3.1.1	Comparison Trials	10/6/2022	11/4/2022	21	30
3.1.2	Revise Prototype I	11/7/2022	12/6/2022	20	30
3.2	Environmental Hazzard Deterrence	10/6/2022	12/6/2022	41	62
3.2.1	Manufacture Microcontroller/ Circutry	10/6/2022	11/4/2022	21	30
3.2.2	Finalize Cooling System Schematic	11/7/2022	12/6/2022	20	30
3.3	Storage and Containment	10/6/2022	12/6/2022	41	62
3.3.1	Finalize Schematics	10/6/2022	11/4/2022	21	30
3.3.2	Prototype II - Modified Integrated Unit	11/7/2022	12/6/2022	20	30
4	**Phase C: Final Design & Fabrication**	12/7/2022	2/4/2023	41	60
4.1	Chassis	12/7/2022	2/4/2023	41	60
4.1.1	Prototype II Testing/ Revision	12/7/2022	1/5/2023	21	30
4.1.2	Final Fabrication	1/6/2023	2/4/2023	20	30
4.2	Environmental Hazzard Deterrence	12/7/2022	2/4/2023	41	60
4.2.1	Pump and Tubing Manufacturing	12/7/2022	1/5/2023	21	30
4.2.2	Finalize Schematics	1/6/2023	2/4/2023	20	30
4.3	Storage and Containment	12/7/2022	2/4/2023	41	60
4.3.1	Final Revision of Design	12/7/2022	1/5/2023	21	30
4.3.2	Final Product Fabrication	1/6/2023	2/4/2023	20	30
5	**Phase D: System Assembly, Integration, & Te**	2/6/2023	6/24/2023	95	139
5.1	Chassis	2/6/2023	6/24/2023	95	139
5.1.1	Final Assembly	2/6/2023	4/6/2023	43	60
5.1.2	Full Systems Test	4/11/2023	6/24/2023	52	75
5.2	Environmental Hazzard Deterrence	2/6/2023	6/24/2023	95	139
5.2.1	Integrating with Chassis	2/6/2023	4/6/2023	43	60
5.2.2	Full Systems Test	4/11/2023	6/24/2023	52	75
5.3	Storage and Containment	2/6/2023	6/24/2023	95	139
5.3.1	Final Product Assembly	2/6/2023	4/6/2023	43	60
5.3.2	Full Systems Test	4/11/2023	6/24/2023	52	75
8	**Completion**	6/26/2023	6/26/2023	1	1

Appendix A: Works Cited

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