RASC-AL/NASA Mars Ascent Vehicle

Assembly and Operation Manual

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1. Introduction

This manual provides the assembly, operation and maintenance of the Minimum Mars Ascent Vehicle (MAV). The MAV is designed to carry a crew of two from the surface of Mars to low Mars orbit. The following manual will cover how each part of the vehicle will attach to another, along with the necessary tools to achieve the final assembly. Lastly, this manual will include maintenance information regarding the upkeep of the MAV.

2. Background

This MAV was designed according to the requirements of the RASC-AL competition rules and guidelines. The vehicle is required to carry two passengers to low Mars orbit with a mass constraint. It is limited to a dry mass limit of 5,000 kg and a wet mass limit of 20,000 kg.

3. Assembly

Assembly of the rocket is to be completed at the NASA Vehicle Assembly Building(VAB), as it is fully equipped with the tools needed for rockets. The tools required are as listed under Tools.

3.1 Tools

Enhanced Robotic Weld Tool [1]- has two special tools used in dome welding, most notably is needed for the nose cone

- The Circumferential Dome Weld Tool- performs circumferential friction welding
- The Gore Weld Tool- performs vertical friction welds

Vertical Weld Center- friction-stir-welding for panels and making barrels. The weld Center can be used in wet and dry conditions.
The Segmented Ring Tool- friction-stir-welds the connector rings together
Vertical Assembly Center (VAC)- Assembly tool for the nose cone, rings, fuselage, and inner ribbs.

3.2.1 Full Assembly

Full body assembly views are shown in Figures 1 and 2.

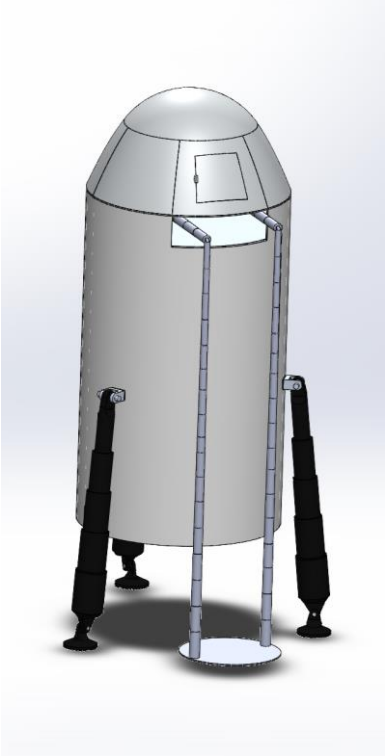

Figure 1: Full Body Rocket

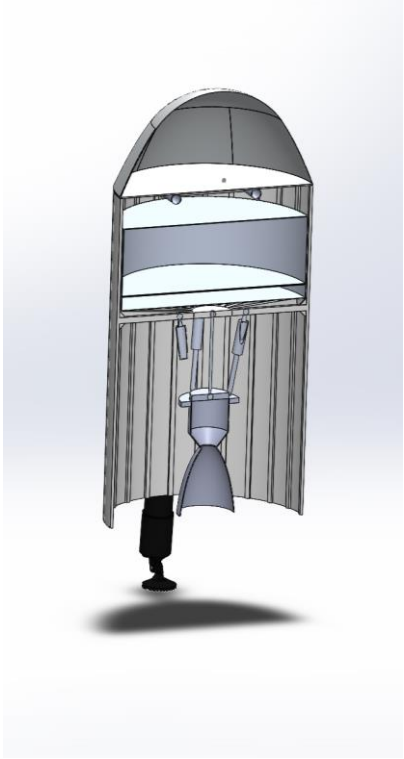

Figure 2. Full Body Rocket Section View

RASC-AL Minimum Mars Ascent Vehicle									
#	Content		Quantity	Weight (kg)	Material		Labor costs (per day)	Time Consuming (day)	Total
					Type	Unit Price			
1	Ribbed Body		1	2268.83	6061 Aluminium Alloy	$13.27	$219	20	$34,487.37
2	Engine Gimbal	Engine to Gimbal Ring	1	66.75	6061 Aluminium Alloy	$13.27	$219	10	$3,075.77
		Nozzle	1	509.58	Copper	$8.79	$219	10	$6,669.21
3	Center Gimbal Restraint		1	5.52	6061 Aluminium Alloy	$13.27	$219	15	$3,358.25
4	Gimbal Lags	Upper Gimbal Lag	4	6.68	6061 Aluminium Alloy	$13.27	$219	5	$1,183.64
		Lower Gimbal Lag	4	8.99	6061 Aluminium Alloy	$13.27	$219	5	$1,214.30
5	Metallic Cylinder		1	399.71	6061 Aluminium Alloy	$13.27	$219	5	$6,399.15
6	Liquid Cylinder		1	597.65	6061 Aluminium Alloy	$13.27	$219	5	$9,025.82
7	Landing Legs	Cylinder 1	3	72.9	Carbon Fiber	$140.00	$219	5	$11,301.00
		Cylinder 2	3	9.79	Carbon Fiber	$140.00	$219	5	$2,465.60
		Cylinder 3	3	13.14	Carbon Fiber	$140.00	$219	5	$2,934.60
		Cylinder 4	3	14.99	Carbon Fiber	$140.00	$219	5	$3,193.60
		Cylinder 5	3	33.61	Carbon Fiber	$140.00	$219	5	$5,800.40
		Attachment	3	9.41	Carbon Fiber	$140.00	$219	5	$2,412.40
		Feet	3	31.99	Carbon Fiber	$140.00	$219	5	$5,573.60
		Pin 1	3	2.21	Carbon Fiber	$140.00	$219	1	$528.40
		Pin 2	3	0.6	Carbon Fiber	$140.00	$219	1	$303.00
8	Nose Panel	Nose Panel Testing 1	1	12.74	6061 Aluminium Alloy	$13.27	$219	10	$2,359.06
		Nose Panel Testing 2	1	12.74	6061 Aluminium Alloy	$13.27	$219	10	$2,359.06
		Nose Panel Testing 3	1	12.74	6061 Aluminium Alloy	$13.27	$219	10	$2,359.06
		Nose Panel Testing 4	1	12.74	6061 Aluminium Alloy	$13.27	$219	10	$2,359.06
		Nose Panel Testing 5	1	12.74	6061 Aluminium Alloy	$13.27	$219	10	$2,359.06
		Nose Panel Testing 6	1	12.74	6061 Aluminium Alloy	$13.27	$219	10	$2,359.06
		Nose Top	1	32.51	6061 Aluminium Alloy	$13.27	$219	10	$2,621.41
					Total cost of manufacturing the cabin:				$116,701.88

Table 1. MAV Manufacturing Costs

3.2.2 Assembly Instructions - Elevate the Ribbed Body

The first step in constructing the MAV is to elevate the ribbed body several meters off the ground. This will allow for the insertion of the engine from the bottom.

Figure 3: Step 1

3.2.3 Insert the Engine-Gimbal-Thrust Adapter Subassembly

The second step is to insert the engine-gimbal-thrust adapter into the bottom of the ribbed body and weld in place the thrust adapter bars to the ribs of the body.

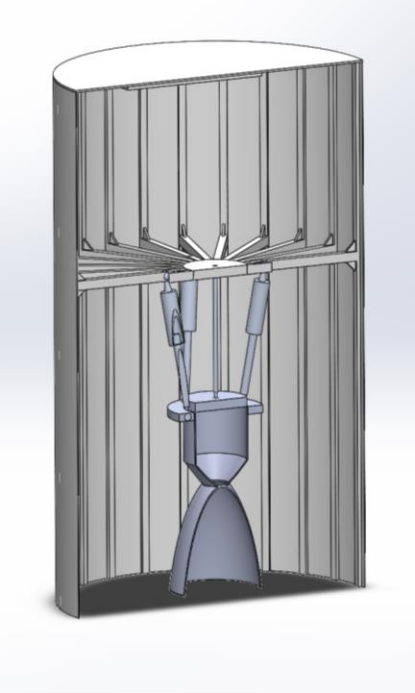

Figure 4: Step 2

3.2.4 Insert the Liquid and Solid Fuel Tanks

The third step is to insert the liquid and solid fuel tanks into the ribbed body from the top, making sure to weld all contact points between the tanks and the ribs on the body.

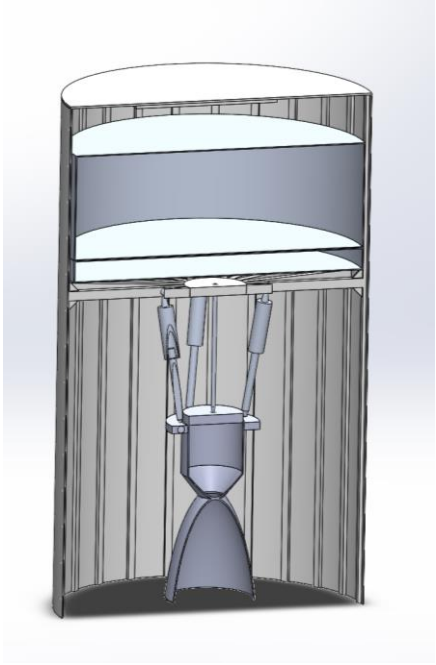

Figure 5: Step 3

3.2.5 Attach Landing Legs to the Ribbed Body

The fourth step is to attach the landing legs to the ribbed body. This will also be done with friction welding to the 3 flat plates located roughly half way up the body.

Figure 6: Step 4

3.2.6 Attach the Top Plate of the Ribbed Body and Attach Elevator System

The fifth step is to first weld the top plate covering the top of the ribbed body to the top of the ribbed body, and then weld the elevator system to the bar located on the bottom of the top plate.

Figure 7: Step 5

3.2.7 Attach the Nose Cone to the Top Plate

The sixth and final step is to weld and bolt the nose cone to the top plate that was installed in step five. This will complete the MAV's important external and internal structures. Below can be found steps for constructing the subassemblies used in these 6 steps, such as the engine-gimbal-thrust adapter and landing legs.

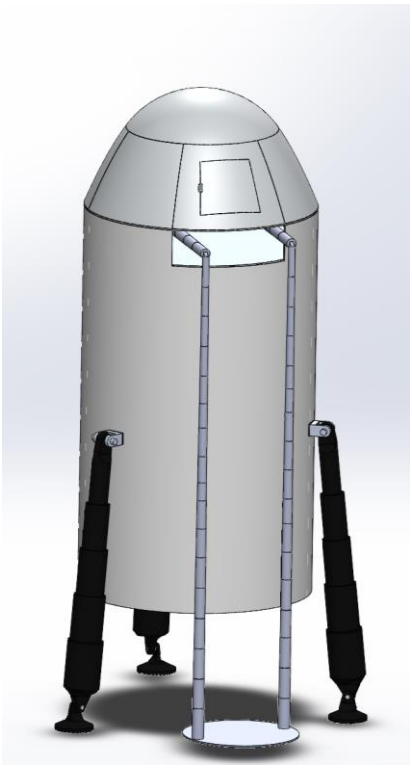

Figure 8: Step 6

Nose cone consists of six side panels, one that includes the crew hatch, and one nose top. Each panel is friction welded together using the special tooling on the Enhanced Robotic Weld Tool located within NASA's VAB. The welded panels are then friction welded using the Circumferential Dome Weld Tool, completing the nose cone hull.

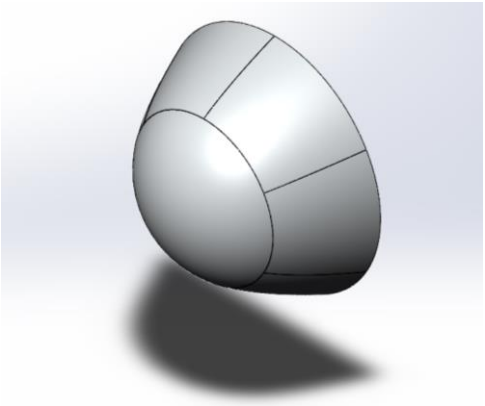

Figure 9. Nose Cone

3.2.8 Gimbal System to Thrust Adapter

Affix the upper gimbal leg knob to the bored holes on the Thrust Adapter arms. At the center, affix the center gimbal restraint knob to the center of the Thrust Adapter.

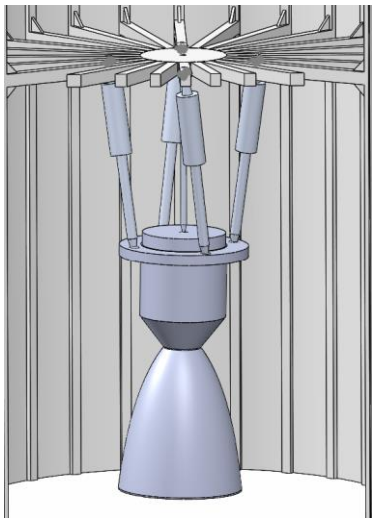

Figure 10. Thrust Adapter with Engine

3.2.9 Gimbals to Engine and Nozzle

Affix the opposite ends of the gimbal legs and the center restraint to the Thruster at their corresponding holes. See Figure 11 for reference.

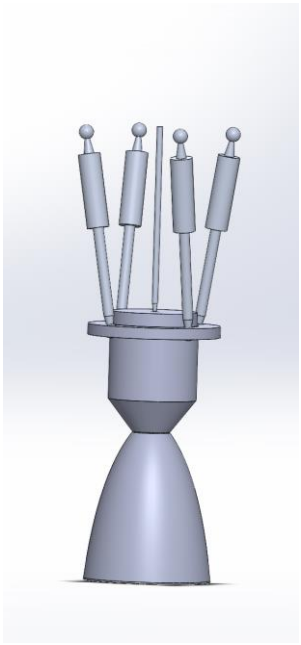

Figure 11. Engine and Nozzle with Gimbals

3.2.10 Legs to MAV Body

All three legs have a curved hinge that will be welded to the outside of the MAV. The legs and feet will be attached via pin.

Figure 12. Landing Leg

4. Operation

Operation of this vehicle begins with a crew member using the lift and hatch to enter the vehicle. The crew member must then sit in the cabin of the vehicle and secure themselves to one of the seats and engage the vehicle's main power. The crew member must then select a toggle that heats the engine to the proper temperature so that the fuel begins to combust. The crew member must stay fastened in their seat during the entire duration of the flight.

5. Maintenance

5.1 Maintenance Schedule

If any issues were to occur during the assembly of the MAV or testing of certain parts that will impact the vehicle's operation, maintenance will have to be done as soon as possible. Because of this, there is no set schedule for maintenance.

5.2 Inspection

As each part of the MAV is assembled, they will need to be inspected to ensure that they fit and are stable. It needs to be verified that each part can be used and will work upon launch.

5.3 Repairs

Repairs required by the vehicle after use are out of the scope of this project and have not been considered.

6. Safety

Because the MAV will be assembled at the VAC, all the safety protocols will align with the protocols issued when using the tools there. Hard hats and safety glasses must be worn at all times when dealing with the assemblage. While welding the parts, proper protection must be worn to prevent any injuries. Since the tools being used are huge in size, it is important to operate them correctly and safely, following all safety guidelines for each machine.

7. Troubleshooting

In the event of the hull or parts failing either from a failed friction weld or accident, reevaluating and machining a new part is necessary to preserve the safety and integrity. If the parts and weldments are in working order, disassemble removable parts for inspection and cleaning, then attempt the assembly afterwards.

8. References

[1] N. C. Administrator, "Space Launch System: Tooling Up to Build the World's Largest Rocket," 7 August 2017. [Online]. Available: https://www.nasa.gov/centers/marshall/news/news/releases/2013/13-080.html. [Accessed 15 April 2021].