1.4 Targets and Metrics

1.4.1 Targets Discussion

To define targets and metrics for this project, our team first had to define what aspects of the project are the most important to our project sponsor. Utilizing the customer needs assignment, we were able to define targets and metrics for the in-space cryogenic fuel storage. These targets and metrics can be found in Appendix C.

For the project to be usable by NASA, there are specific metrics that our product must meet. A target or metric is a measurable value for a function of the product. For this project, the metrics were set by looking at the needs of the customer and the most important functions of the product.

1.4.2 Critical Targets and Metrics

The most important critical functions for our design are to hold cryogenic fluid, maintain pressure, and reduce heat transfer. Our critical targets and metrics will reflect these functions as seen in the table below.

Function	Target
Hold cryogenic fuel without failure	• Withstand 6 G's of force on takeoff • Maintain structural integrity for two weeks
Maintain pressure	• Keep pressure between 80 and 90 psi for entire mission

Reduce heat transfer	• Inner tank will be subject to less than 10 KJ of energy per day

Table 3: Critical Targets

1.4.3 Method of Validation

The method of validation for our function of holding the cryogenic fluid can be found by testing the tank being filled with cryogenics at the proper temperature. We are testing with liquid nitrogen which in a liquid state is stored between 63 – 77 K. We must also ensure that the tank does not fail when emptied and refilled. We expect the material of the tank to expand and contract to some degree when filled and emptied due to the cryogenic being at such a low temperature. To avoid failure of the tank, we must choose a material that has the needed properties for this to occur.

We need to ensure that the tank is able to withstand six G's of force that it will experience during lift off. We will determine the best material based on the conclusions of scientists performing similar tests, since we will not be able to do adequate material testing with the time and resources available to us. Finally, we need to test the tank in zero gravity conditions as well as conditions on the moon by the same methods as G forces. This is also not possible given our resources, therefore we will validate some of our design choices with relevant calculations.

Our second critical target is maintaining the pressure, which can be tested by filling the container with cryogenic fuel and measuring the change in pressure over time with a sensor inside the tank. As heat transfer occurs, the pressure in the tank will increase and need to be released. The pressure relief valve will then be used to relieve the pressure until it reaches the desired pressure, which is between 80 and 90 psi for liquid nitrogen.

Our final critical target is reducing the heat transfer into the system. Once again, the fluid will be held in the container and the temperature and pressure will be measured over time with a sensor inside the tank. Our heat transfer target will be reached by utilizing multi-layer insulation (MLI) and an outer reflective shield. The MLI is effective at reducing conduction and convection from outside the tank. The reflective surface on the outside of the tank will reflect radiation back into the environment, reducing the heat transfer into the tank.

1.4.4 Arriving at Targets and Metrics

To arrive at these targets and metrics, background research was conducted into each function. To define the target for fuel storage, we investigated the conditions and the time frame that the tank would have to be in use. Upon takeoff the ship will experience up to six Gs of force, or three times the force of Earth's gravity. This is the most G forces that we need to design for in a lunar mission, so if it can maintain integrity through takeoff, it will keep its structural integrity throughout the mission. In order to determine the amount of time the storage tank must hold cryogenic fuel we defined a hypothetical mission to design for that will last two weeks travelling to the moon and back.

Our second key function is to maintain pressure within the tank. The target for this function is to maintain an internal pressure of 80 to 90 psi for the entirety of the mission. This pressure will allow for the liquid nitrogen we are designing for to remain in a liquid state at the desired temperature.

The third key function of our project is to reduce heat transfer in the system. We arrived at this target by looking at the specific heat of liquid nitrogen and the size of the tank. Our target of 10 KJ of energy entering the system per day was chosen, so that there will be a smaller amount of fuel will boil off over the course of the mission.

1.4.4 Targets Beyond Functions

Targets outside of the main functions of the project can be found in Appendix C. One of our targets is to make the tank useable for up to five missions. Since this tank at full scale will cost millions of dollars, it will be more efficient if the tank can be reused. This is especially true since the tanks will be used to get back to Earth, so they will return with the rocket instead of being left in space. The tank should be refillable and then placed in another ship.

The second target that is beyond the functions of the project is to alert the user if the tank leaks. 80 decibels will be used to ensure that the problem is recognized by the crew and attended to. This is critical for the mission because if the tank leaks a substantial amount there may not be enough fuel to complete the mission.

The third major target beyond the scope is to alert the user if the material properties of the tank are outside the acceptable range; mainly if the tank becomes brittle. If this occurs the system should alert the user with an 80-decibel alarm to ensure that the user is aware.

1.4.5 Discussion of Measurement

The tools needed to measure our targets include a temperature and pressure sensor, which will be placed inside the tank. The sensor needs to be able to communicate the readings to an outside display for the user. When the temperature increases, the fluid will go through a phase change from liquid to gas. The gas created is fuel that is no longer usable for propulsion and causes the pressure inside the tank to increase. Once the pressure exceeds the acceptable value, the user will know that the pressure relief valve will release the gas.

1.4.6 Summary

We will be performing tests to validate that the material we choose for the tank will operate under the various conditions that the tank will be subject to. For the conditions in space and during lift off, we will have to do calculations and simulations to test. We also need to maintain the pressure and temperature to avoid boil off and fuel loss. This will be tested by determining the temperature and pressure inside the tank over time using a sensor inside the tank. The sensor will be able to communicate the measurements to the user so that they can use the pressure relief valve to relieve pressure when needed.