Target Summary

Introduction

After determining the functions for a system that uses a tribometer in spacelike conditions, each function was assigned a target and given metrics. Each function is given at least one metric that defines the function into either a quantitative or qualitative measurement and some functions have multiple metrics to further define its role. A target is given to each metric, so that a goal that the system must attain is defined. The fully developed target catalog is in Appendix C: Target Catalog in the evidence manual as well as linked in the content to date section of the webpage. The success of this project will be defined by the achievement of these individual targets.

Critical Targets and Metrics

We defined our critical targets and metrics by referencing our objective, customer needs, and functional cross reference chart in Table 3. Based on the objective and customer needs the most important functions are holding the samples and calculation of tribological quantities. From the cross functional reference chart, the most important functions are the regulation of temperature and the safety requirements. These functions are critical because they apply to all the columns in the table and therefore, are active at all times in the system. Additionally, we were able to further validate these critical targets and metrics using our advisor, Dr. Brandon Krick. Our critical targets and metrics are shown below in Table 4.

Table 4
Critical Targets and Metrics.

System	Function	Metric	Target	Unit
Inputs	Holds samples	Number of samples held	4-6	Count
		Types of samples held	2	Count
		Time to load samples	30	Minutes (min.)
Testing	Senses changes in temperature	Resolution of temperature	1	Celsius (°C)
		Ideal error for readjustment	±1	Celsius (°C)
		Marginal error for readjustment	±5	Celsius (°C)
		Readjustment while transient	±10	Celsius (°C)
		Max temperature	200	Celsius (°C)
		Min temperature	-100	Celsius (°C)
Testing	Calculates coefficient of friction	Calculates value	0 - 1	
		Error of calculation	10	Percent (%)
		Ideal resoluble range	0.01 - 0.5	
		Marginal resoluble range	0.05 - 0.4	
Testing	Calculates wear volume	Calculates value	0.05 - 50	Millimeters cubed (mm^3)
		Height loss resolution	5 - 50	Micrometers (μm)
Testing	Calculates wear rate	Calculates value	10^{-4}-10^{-7}	Millimeters cubed per Newton meter (mm^3/Nm)
		Error of calculation	±5	Percent (%)
Testing	Trigger emergency stop	Time to kill	0.3	Seconds (s)

Targets and Metrics Derivation

The function of holding the samples is a critical target because the customer explicitly stated that the goal of this project was to test 4-6 samples simultaneously using a tribometer within vacuum. Therefore, our most important target is the 4-6 samples that the system must be able to test simultaneously. This function also has two other metrics and targets it needs to reach. There are many different types of samples a tribometer can test. After discussions with Adam Delong, the target for our system is to be able to test 2 different kinds of samples. This will add to the versatility and future uses of the system. The last metric for this function is the time it takes to load the samples. The overarching goal for the system is to increase efficiency and work throughput of using a tribometer within a vacuum. The 30-minute target was set benchmarking from prior tests using a tribometer within a vacuum. The target number represents the same efficiency as prior experiments, beating the target represents a higher efficiency than prior experiments.

The testing function of the tribometer is crucial. The tribometer will need to sense the temperature change. This includes the ability to go to a maximum temperature of 200 degrees Celsius, a minimum of -100 degrees Celsius, resolution of temperature, the ideal error for readjustment, marginal error for readjustment, and including readjustment while in transient. This is all incredibly important to providing the best results for sensing the temperature change. Next, the system must calculate the coefficient in friction, which involves calculating the value, then the error of calculation, the ideal resoluble range, and the marginal resoluble range. Testing must also measure wear rate and wear volume, which both involve an error of calculation. Finally, safety is an essential subfunction of the testing function. The device must have the ability to trigger an emergency stop. During the emergency stop, the DC power will need to be diverted. When that happens, the device will stop to protect the device and its user.

Since this project outputs the desired parameters in a graphical user interface designed in MATLAB, most of the outputs are going to be displayed in a plot. The system uses stored inputs and a series of equations written in a MATLAB script to calculate the desired critical targets such as wear volume rate, coefficient of friction and number of cycles done by the testing. The graphical user interface of this project is not going to be made from scratch. An already existing graphical user interface will be connected to our system to test its functionality. However, the MATLAB script that returns our critical targets should be written by our software engineer if time permits to avoid returning values outside the project's scope.

Method of Validation

Validation of the targets is vital to ensure each component of the system is working properly in getting its task done. The critical targets of the system fall into the input and testing functional categories. Breaking this down further and looking at one function of the system at a time, the team will formulate a systematic method of validation for each of the targets deemed critical. These methods will occur after the concept generation and selection when a functional prototype is being fabricated, during validation the team can see which functions are working and which are not to make corrections and improvements for the final design.

Holding samples is the only input considered a critical target, it means that the system can test 4-6 samples and the tests can be run on two different kinds of samples. To clarify, a different kind of sample would be considered the different shapes of a sample such as round or square not the material a sample is made of. To validate that the system meets these specifications the team would have to have the functional prototype run the tests and see that 4-6 samples being tested are working simultaneously and to make sure that it works with two different kinds of samples. To validate that the time it takes to load a sample meets the goal of 30 minutes the team can set up the tests 10 times and use a timer to find how long it takes each time. These can be averaged together to get an estimate for validation without having to run the prototype.

The temperature regulation is our key parameter to simulate a close space-like environment. For temperature regulation we have two ranges that need to be controlled: high temperature, which has a maximum of 200 degrees Celsius, and sub-zero temperatures, which have a maximum negative range of -100 degrees Celsius. We need a heater able to withstand temperatures greater than the max temperature so we can avoid any overheating problems in the system, and something constructed entirely of low-outgassing materials. This is an important constraint when working in vacuum chambers. Because of the space constraint, we need lightweight heaters that will allow us to apply heat where it is needed, reducing overall operating cost, and the low mass construction should save space. We will be using liquid nitrogen supplied through a plumbing system to create low temperatures. We will need a material with high thermal conductivity so it can decrease thermal resistance and reach the desired temperature by conduction as fast as possible. To validate both high and low temperatures, we will need a sensor to continuously check the temperature in the material. If the temperature remains within ±5 degrees Celsius of the desired temperature, we can affirm our temperature regulation is working properly.

The coefficient of friction is the parameter that governs the force required to move a test sample at a constant speed. This coefficient (μ) is obtained by dividing the frictional force by the applied normal force. There are two primary coefficients of friction: the static coefficient of friction, which quantifies the force required to initiate motion, and the kinetic coefficient of friction, which characterizes the force needed to sustain motion. Our primary focus in this system is on the kinetic coefficient. To validate this calculation, we will utilize the predefined applied load (N) and the measured frictional force (F) to compute the coefficient of friction. The applied load will be manually input and continuously controlled to remain within a ±3% margin of the set load. The frictional force will be a variable that is found utilizing testing equipment. The applied load and frictional force value will be verified using a load cell, which detects and quantifies the applied force. The mechanical stress on the load cell will be transduced into electrical signals by strain gauges. The error in the force calculations will be assessed using the root mean square method, accounting for standard tolerance levels associated with off-the-shelf load cells and strain gauges. To calculate the coefficient of friction, the frictional force (F) will be divided by the normal force (N). The load cell's manufacturer's data sheet will specify the resoluble range and marginal resoluble range, and the signal resolution will be determined in accordance with the load cell manufacturer's data sheet.

The wear volume is the volume loss of the sample during testing worn away by friction. The wear volume (ΔV): $\Delta V = Vi - Vf$ where Vi is the initial volume of the sample and Vf is the final volume of the sample. However, the system will need to calculate real time data for volume loss. This can be achieved by measuring the dimensions of the sample prior to testing and comparing the value to the real time data acquired. The sample volume can be measured during testing using a sensor to track its height loss. The error of calculation is associated with the tools that will be used to measure the wear volume loss.

The wear rate is a direct function of the change in volume of the sample, force on the sample and the distance traveled. The formula for wear rate (K): $K = \Delta VFnD$K= ΔVFnD where ΔV is the change in volume of the sample, Fn is the normal force and D is the displacement. Therefore, to calculate wear rate, these other values must be measured throughout testing. The measurement of the change in wear volume is mentioned above. The normal force can be measured using a load cell. Load cells measure normal forces by detecting changes in electrical resistances from the strain gauges attached to it. The displacement can be measured in many ways, two of the most common are a predefined stroke length of the tribometer and having sensors giving real time feedback of the displacement of the sample. The error of calculation can be measured using uncertainty propagation.

During testing, an emergency stop must be implemented. The tribometer must have the ability to be halted/stopped manually or automatically. The target for the emergency stop is to divert the input of DC power, which is 120 Volts (V). This will add an extra safety measure to protect the tribometer, its samples, and most importantly the users. The samples are highly essential, so, during testing the samples must be protected during events of failure, making the emergency stop even more valuable. To validate this function, switches will be used that will give the ability to stop a single sample without impeding the other samples and this can be tested outside of the vacuum and inside of the vacuum without loaded samples to verify the success of the emergency stop. This will help protect the data collected by other samples in case of failure.