1.4 Target Summary

Measurements create the ability to judge a design with empirical data. It is essential to create rigorous targets in order to ensure that the test will run smoothly and will provide meaningful data to the sponsors. In addition, targets and metrics will be used in the concept selection phase of the design process to choose which possible designs have the most promise. Each relevant function from the functional decomposition is listed in the table below, alongside their metrics and foreseen targets.

1.4.1 Targets and Metrics Table

	Need	Metric	Target	Improvement Direction
1	Contains debris	Percent volume of debris lost	Contains 80-90% of debris	Increase
2	Achieve supersonic jet	Jet Speed	Supersonic Mach N. > 2	Increase
3	Holds sensors fixed	Position deviation while testing	Holds sensors to within 1 mm	Decrease
4	Holds jet fixed	Position deviation while testing	Holds jet within 1 mm	Decrease
5	Change nozzle	Variation in possible nozzle sizes	Changes to a nozzle with ten times output diameter	Increase
6	Change height	Variation in possible jet heights	Changes height 30 cm	Increase
7	Start jet	Time to start jet	Less than 10 sec	Decrease
8	Shut off jet	Time to stop jet	Less than 1 sec	Decrease
9	Measure crater width and depth	Accuracy of measurements	Within 0.5% of total measurement	Decrease
10	Time the experiment	Accuracy of timing	Within 1% of total experiment time	Decrease
11	Correlate data	Statistical significance	Create scaling laws that are accurate to 5%	Decrease
12	Display time readout	Accuracy of readout	Displays time to the millisecond	Decrease
13	Display sensor readout	Accuracy of readout	Displays sensor data every second	Decrease

14	Ensure minimal enclosure effects	Back Pressure	Minimize back pressure to 0 psi	Decrease
15	Experimental ease of use	Time to change nozzle/height	Less than 15 minutes	Decrease
16	Quality of the nozzle	Machined to certain tolerance	Machined to ±0.127mm of design spec	Decrease

1.4.2 Target Derivation

Targets and metrics were derived to satisfy customer needs and functional decomposition. Background research was conducted to inform and create valid targets and metrics. The team arrived at each target and metric by using what was learned during research then created justifiable results. Each function was given a metric which will be used to validate the function and each metric a target which is the specific value.

Target 1 was derived from what is an acceptable loss of volume considering reusing soil simulant and its cost. Additionally, maintaining a clean work area was also considered.

Target 2 was explicitly given by the needs of the sponsors of supersonic jet exhaust. Typical Plume landing systems contain supersonic jet exhaust with speed greater than Mach 2.0. Creating a nozzle that is able to compress air and exhaust it at this speed will result in a data with high-fidelity for PSI which may be used in future HLS.

Target 3 and 4 were derived from what is an acceptable displacement of the sensors for obtaining valid data.

Target 5 was derived from a suggestion by the project sponsors. They advised that a tenfold difference in nozzle sizes would be necessary in order to create useful correlation data. Current research has only studied differences in nozzle sizes within the same order of magnitude, which has not proven to be sufficient.

Target 6 was derived from the need to have a wide range of possible heights to study the impingement. 30 cm allows the experiment to run with an upper d/D value of between 30 and 300, which should allow enough adjustment to tune the experiment to the ideal height.

Target 7 and 8 were derived from the time it takes to for the flow inside the nozzle to become steady. At this time is when testing will initiate since it is when all the data on crater formation is taken.

Target 9 was derived from what acceptable error is considered based on research. The accuracy of the crater measurements are important so error must be small.

Target 10 was derived because the timing of the experiment must be measured with great accuracy to interpret results effectively.

Target 11 was derived from the statistical standard that less than 5% uncertainty can be taken as true correlation. The scaling laws generated should then fall within this window in order to be confidently presented as useful to the sponsors.

Target 12 was derived from the continuous small-intervals during the trials. This time measurement will account for more accuracy due to the small-time intervals where the high-speed jet is running. This measurement may additionally indicate the time necessary to achieve a steady flow to start testing.

Target 13 was derived from the team's need to see changing data over time with fast updates not to the point where interpretation is difficult.

Target 14 was derived from discussions with the project advisors and sponsors about the unwanted effects that overpressure could have on the experimental data. To eliminate this source of error, pressure in proximity to the system should not derive from standard pressure at all.

Target 15 was derived from the availability of team members and the desire to run experiments efficiently.

Target 16 is important to ensure that the flow of gas out of the nozzle is smooth and that turbulent flow is not created due to the scale of the experiment, any deviation of flow could create anomalies in the crater formation and geometry or may cause in energy losses when attempting to reach Mach 2.

There are critical targets and metrics which are required for project success. Other targets and metrics are key goals but not necessarily required for project success. These critical targets were determined from the importance of their associated functions. Critical targets and metrics include 2-13 and 16 from the table. That is because reaching those targets are necessary for the interpretation and validity of the data, even if the targets where there are maximum allowable percentages of error are at the extremes. Other targets are not included because they are key goals but not necessary for project success. For example, targets 1 and 15 would help the experiment run efficiently but are not necessary for project success.

1.4.3 Measurement and Validation

Targets for function 1 will be evaluated by introducing a limited and known weight of dust into the testing apparatus, running the experiment, and then measuring the weight of the remaining dust. The volume will be calculated from the density of the dust medium, as well as net weight change.

Target 2 will be measured with pressure differentials using pressure sensors. The possibility of using Pitot-Static tubes may be evaluated since it is the usual method for calculating speed using Bernoulli’s equation, however due to the small diameter of the nozzle, this may not be feasible. This value will later be used to calculate the jet speed at a target of supersonic speed, preferably over Mach 2 as suggested by the sponsors. This value relates to the usual plume jet exhausts used in space landers and achieving that speed will result in data with high-fidelity on crater formation.

Targets 3 and 4 will be validated using calipers to measure the initial and final positions of the sensors. Ideally, the sensors will not be subject to much vibration, and once calibrated, should not move much.

For target 5, validation will be achieved by testing the ability of the experiment to hold different nozzles. A variety of nozzles will be tested, and the function will be successful if the largest and smallest nozzles that fit have a four-times difference in exit diameter. The nozzle diameter will be verified from spec sheets using vernier calipers.

For target 6, the maximum and minimum height of the setup will be measured using a standard tape measure. The difference between the measurements will be compared to the target. Success is defined as having a larger measurement than the target.

For target 7, a timer will be used to determine the time to start the jet. The experiment will start ‘cold,’ or fully offline, and the time to start the jet will be measured. Each project member will perform their own test, and the maximum time will be compared to the target. For target 8, a similar process will be used for measurement, but the validation will come from the time taken between an active test and the jet shutting down. This will be compared to the target.

For target 9, several measurement runs of both crater depth and width will be taken on the same crater. The mean value will be calculated, and the error will be calculated from that. The maximal error will then be compared to the target for validation.

For target 10, several measurements will be taken for the timing of the experiment. A mean value and error will be calculated, and the maximal error compared for target validation.

For target 11, a statistical analysis of the data will be performed. A t-test will be run, comparing the size of the nozzle to the crater dimensions. From this, both a correlation coefficient and a measure of statistical significance can be found, which will be compared to the targets.

For target 12, there will be a time readout accurate to a millisecond. The timer will initiate when the jet initiates running, and a will display the time for the jet to create a crater.

For target 13, the sensor readout will display every second to ensure that the sensors read and display new values to account for accuracy and reducing aliasing in the readings.

For target 14, pressure measurement systems will be used outside of the plume to measure ambient pressure to ensure this stays constant, any deviation would be a result of back pressure which may potentially change the profile of the crater which would cause our data to be null and void.

For target 15, changing the nozzle should be quick and easy so that the experiment runs smoothly and is easy to replicate. The time it takes to change the nozzle will be timed to ensure ease of use.

For target 16, the nozzle needs to be machined to ± 0.127mm of design spec and will be verified with machinists at the manufacturing process. This measurement will ensure accurate dimensions in the nozzle to maximize the target of its performance when activated to account for potential energy losses due to the roughness of the material’s nozzle.