Plume Surface Interaction: Scale-Up Study

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Objective

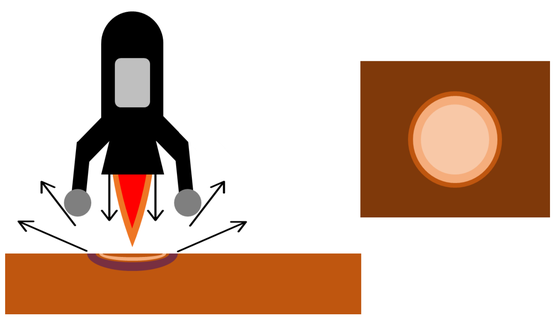
The objective of this project is to design and implement a testing apparatus to study the effects of scaling on crater formation due to Plume Surface Interaction.

Goals

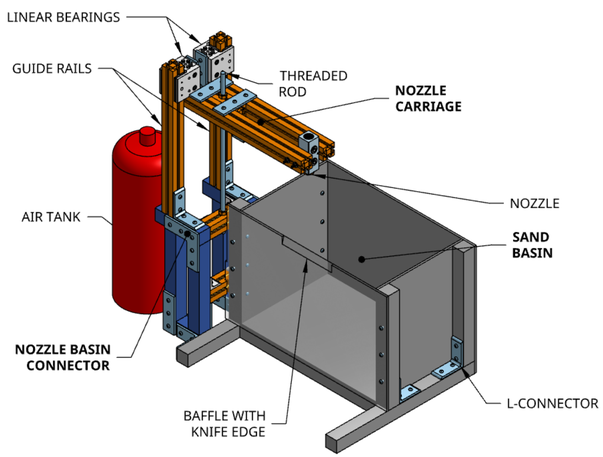
- Design Testing Apparatus
- Measure the effect of the nozzle diameter on the crater geometry
- Analyze the data to find a correlation between scaling and crater geometry

Background

Plume Surface Interaction (PSI) is a field of study focused on the effects of rocket plumes on extraterrestrial surfaces. NASA and members of the Human Lander System (HLS) have already done research on many subtopics within PSI, but crater formation under supersonic conditions has yet to be fully characterized. Team 518's project focuses on studying the effects of supersonic plume flow on crater formation to aid in lander design.



Experimental Rig



The team conceptualized an apparatus featuring a clear baffle with a knife edge to separate the jet flow. The rig structure works as an extended beam from the tank for the flow to impact on the surface, as well as a threaded rod for height adjustment. Images of the half-crater formed will be captured to measure its depth and width. The experiment will be performed by maintaining the nozzle's relative elevation, or height divided by diameter, constant throughout the experiment.

Key Targets

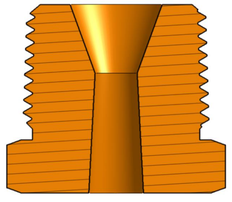
- **Exit Jet** Reaches Supersonic Speeds
- Minimize **Enclosure Effects**
- **Measure** Crater Profile

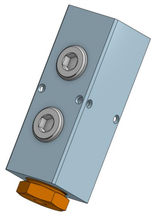
Components and Materials

1. Air supply
   - Carbon Steel 40 3AA2015
   - Holding at around 2200 psi
   - Regulator Attached set to 120 psi
2. Tubing
3. Pressure Guage
4. Structure
   - 8020 Aluminum
5. Walls
   - Plywood
   - Plexiglass

Nozzles

A Converging-Diverging nozzle must be used to achieve supersonic speed. The team designed several nozzles of different sizes. Those sizes are 0.5, 0.78, and 1 centimeters in exit diameter. The first trials of the experiment will be run at subsonic velocities at these diameters, and the next trials will gather data at supersonic velocities. To achieve the desired exit speed the throat to exit cross-sectional area is A/A* = 1.6875.





Pressure Source

A Carbon Steel 40 3AA2015 air tank capable of up to 2000 psi will be provided by the school and used for the experiment, along with a regulator (up to 250 psi) to limit the flow for subsonic testing.

Camera

The device used for the experiment is an iPhone 12 Pro that has a frame rate of 240 frames per second and will be mounted securely to minimize vibrations.
A calibration board will be used to ensure accurate extraction of position data.

Data Processing

During the experiment, the camera will capture a slow-motion video to obtain the images of the crater. These images will be used for processing. After testing and observing a valid crater profile, these images will be processed through the image edge detector functions on MATLAB to determine a crater profile for each x/D parameter as well as a measurement of the profile's depth and diameter. The team will establish a for the measured parameters and their respective crater profile along with an analysis of their results.

Results

The experiment's result will be placed here. The team is expecting a valid 2D crater profile for the different x/D testing scenarios. A very simplified preview of the expected results is shown below.