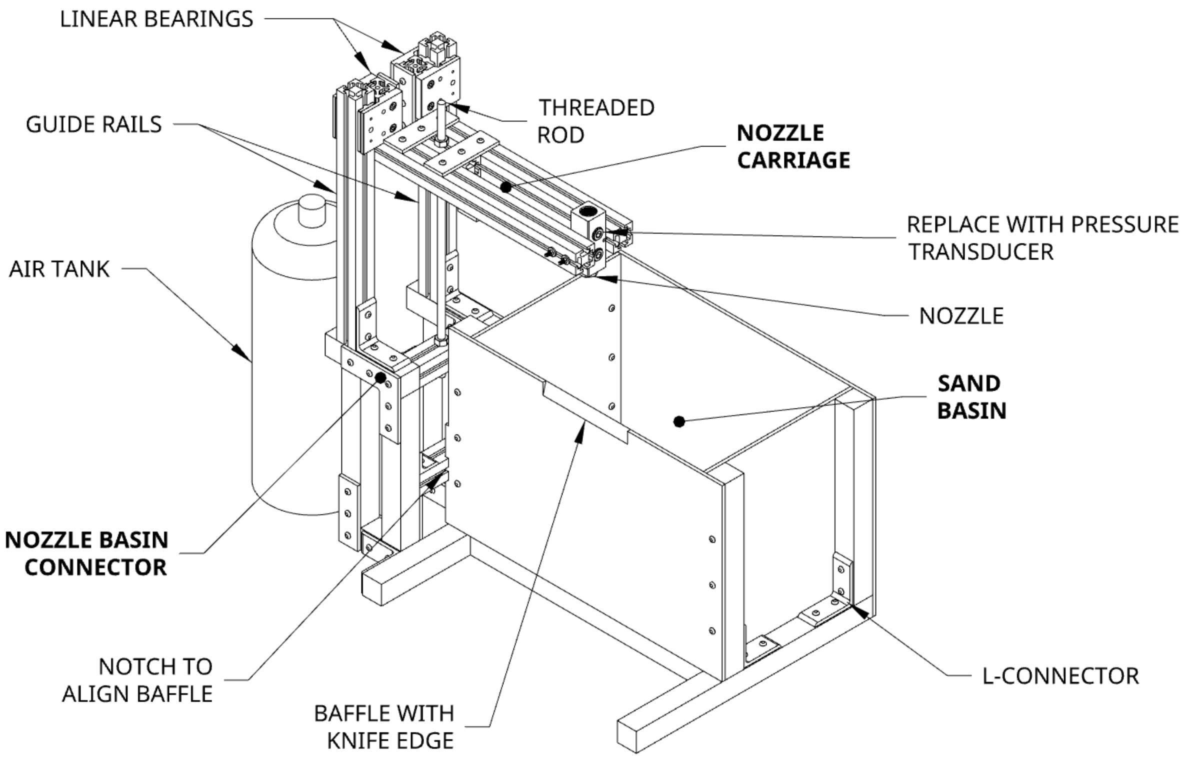
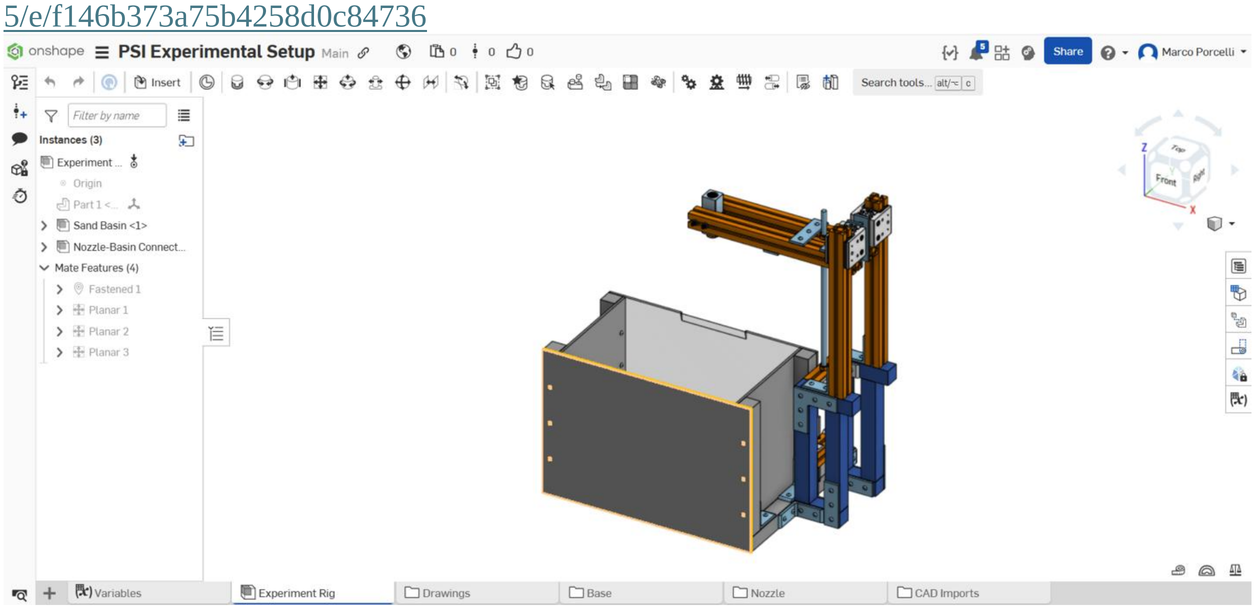
Component Description

CAD Files:



https://cad.onshape.com/documents/24a59ed4d6c91d154ee6d376/w/37967d9f271124e9a80a30f5/e/f146b373a75b4258d0c84736



MATLAB image processing:

The tools to process the individual videos of the crater gathered will be through three individual MATLAB scripts that process the video in the following steps:

1. Select the sand pit area where the crater will be formed and rewind the video to break down the video into the frames of the cropped sandpit and saves these frames.
2. Asks user to create a scale factor by measuring one point of the ruler to the other. MATLAB then divides this pixel distance of the ruler by the known distance.
3. Tracks the lighting differences of each frame from the video and measures the pixel distances of these differences to track crater depth and width. Then divides this distance over the generated scale factor. It later plots these differences over time and outputs final length and width.
4. Process the last frame of the video and traces the edges of the crater to plot the crater geometry.

Step 2 and 3 belong to the same script.

Integration

On the bottom of the page, there will be a few different tabs corresponding to the relevant parts of the CAD model:

- “Variables” contains many parameters that can potentially be changed, including width and length and the nozzle throat sizes.
- “Experimental Rig” is the final CAD model of Team 518’s assembly.
- “Drawings” contains all the drawings that were sent to and machined by the machine shop.
- “Base” contains all the 8020 parts and subassemblies of the model.
- “Nozzle” contains the nozzle CAD file and the manifold-nozzle assembly.

While these CAD files cannot be directly changed by another user, they can either be exported to another file format, or opened as a new Onshape project. Onshape is very similar to other CAD programs, and the controls can be changed (in preferences) to mirror either CREO or SolidWorks. It is web based, which means the files file can accessed on any device, but creating local copies is more difficult.

To build the rig, use the CAD subassemblies as a template, building each one up until they are ready to be fit together. To measure lengths of various parts, select the desired edge and look in the bottom right corner to find the length of that edge. Start with creating the “Sand Basin,” located under the “Base” folder on the home page. At the same time, the “Nozzle-Basin Connector” and “Nozzle Carriage” (also within the “Base” folder) can be created. It is best to leave complete the linear bearings and their sliding mates last because the loose tolerancing of the linear bearings creates the need for adjustment of the overall positioning to ensure that the nozzle sits directly over the knife edge of the "Baffle.”

Once all three subassemblies are created, connect the “Nozzle-Basin Connector” to the “Sand Basin.” This is the most difficult part to assemble because the alignment lip of the “Baffle” makes it so sliding the “Nozzle-Basin Connector” on the L-connector along the side of the “Sand Basin” will not work. To remedy this, loosen the connections on the L-connector to allow for the “Nozzle-Basin Connector” to be slid on perpendicularly to the “Sand Basin.”

With these two parts connected, attach the “Nozzle Carriage” onto the “Nozzle-Basin Connector” using the linear bearings and the threaded rod fastened as shown in the "Tower Assembly.” It is best to ensure that the nozzle sits directly over the knife edge such that the flow leaving would be split evenly. To do this, lower the “Nozzle Carriage” so it is sitting directly over the knife edge and look down at the top of the manifold to verify that it is centered. Measure the distance from the knife edge to outside of the nozzle manifold using calipers; if that twice that distance is the length of the manifold, then the nozzle is centered. If adjustments are needed, loosen the L-connector on the linear bearing 80/20 guide rails and pivot them slightly around the threaded rod to adjust the positioning of the nozzle.

With all the CAD model components assembled, some finishing touches are required. Remove one of the brass plugs on the manifold and replace it with To ensure sand does not escape the basin, place tape (or caulk) along the edges of the enclosure. To ensure that there are no air leaks, first wrap pipe tape (in the same direction as the NPT threads) along each NPT male part. Next, with some pressurized air now being supplied, apply some soapy water to the connections – if bubbles appear, then the connection is not airtight, and additional losses will be added to the system. Shims can also be added to the linear bearings to make them hold tighter against the guide rails.

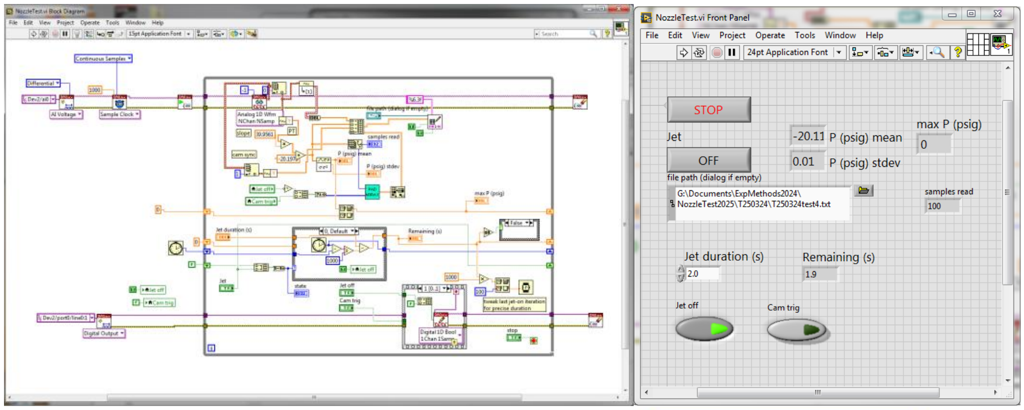
Operation

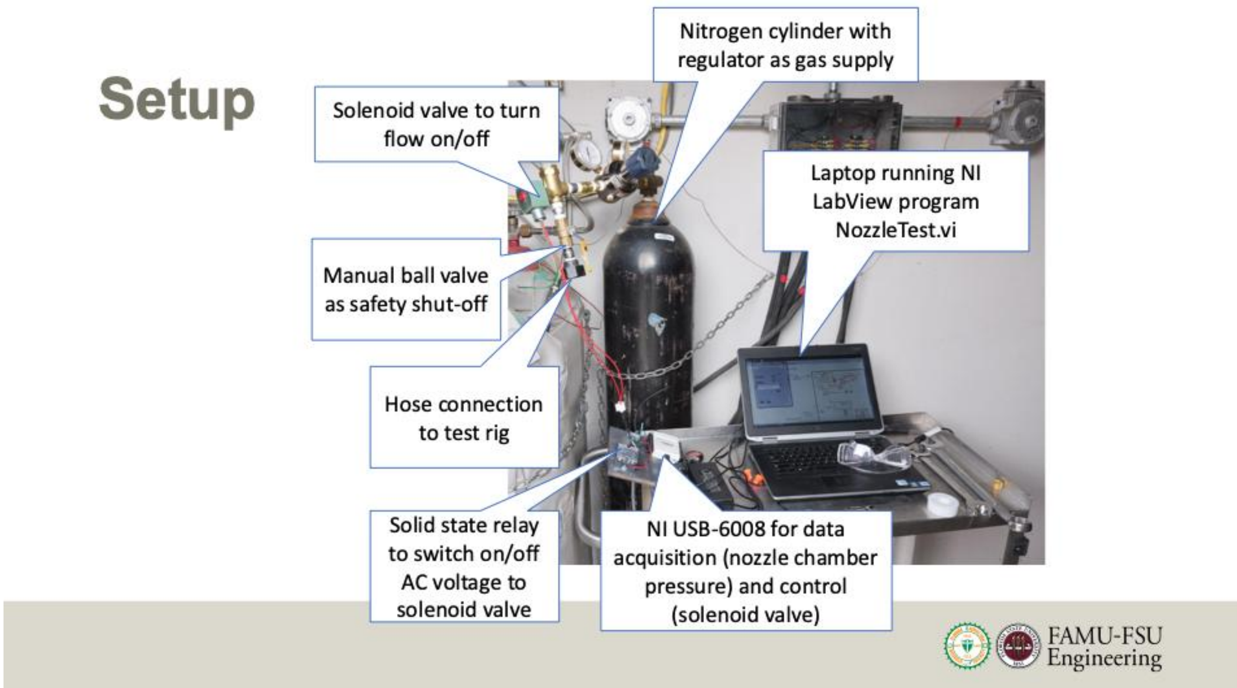
With the rig completed and air-tight, testing can now begin. Since there will be loose sand ejected from the rig, it is advisable to conduct testing outside with either a portable air tank or an air supply on the outside of a building. Move the rig into place and place a high-speed camera (phone or other) to be facing the baffle. Ensure that the camera is parallel to the knife edge to ensure that minimal perspective effects will be introduced. Place a ruler or calibration grid in view of the camera to allow for video processing to extract distances. Fill the basin with sand, ensuring that the sand is below the opaque knife edge. The sand should be dry and preferably fine – the moisture content has a large effect on the properties of the sand, reducing this experiment's accuracy for predicting PSI cratering in regolith. While regolith is finer than commercially available sand, the size of the sand can be characterized and accounted for in the experimental results.

Connect a pressure supply tube to the nozzle. The larger the diameter, the better – smaller diameters will have more pressure losses through the pipe, making it difficult to reach the higher Mach numbers the nozzle is capable of. Again, ensure that all connections have pipe tape applied and that there are no leaks. A calibration run will be required (covering the sand bed) to ensure that the pressure at the nozzle (measured through the pressure transducer in the manifold) is sufficient to achieve the mass flow rate and Mach number desired. Measure the distance between the nozzle and the sand bed, to be used to calculate the relative elevation (H/D_{exit}). Be sure to wear ear plugs, safety glasses, and a mask – the larger supersonic nozzles will generate a lot of noise near the rigging, and the sand particles will be moving through the air.

To begin the test run, first setup the high-speed camera in the desired position. The images below show the software that was used to run the test. While keeping the manual valve set to the off position, set the regulator to the determined value for the desired pressure at the nozzle. Once that pressure is reached, turn on the camera and release the manual valve, this will allow the solenoid valve to be what controls the gas flow. Now click the OFF button to open the solenoid valve, the DAQ will record various measurements such as time and pressure at the beginning of the hose and inside the nozzle manifold. Run the test for a short period of time (2+ seconds), ensuring that the crater does not come within 10 cm of the walls or ground of the sand bed. Testing can be done to determine a more accurate time, but the limiting factor is the size of the sand bed introducing surface effects on the crater growth. Once the test is run for the desired time, click the OFF button to close the solenoid valve and close the manual valve. Stop the high-speed camera and export all the data to be analyzed in another software. To run subsequent tests, either fill the sand bed or measure the new relative elevation, adjust the elevation or replace the nozzle, and restart the experiment. Once all trials have been completed, collect the sand that has been ejected and clean up the area around the experiment. Here is the process summarized:

1. Set up the high-speed camera in the desired position.
2. Open the software used to run the test (refer to images for guidance).
3. Ensure the manual valve is set to the **CLOSED** position.
4. Set the regulator to the desired value to achieve the correct pressure at the nozzle.
5. Once the desired pressure is reached, turn on the high-speed camera.
6. Release the manual valve—this allows the solenoid valve to control the gas flow.
7. Click the **OFF** button in the software to **open** the solenoid valve.
8. The DAQ system will begin recording measurements such as time and pressure (at the hose and nozzle manifold).
9. Run the test for at least 2 seconds, making sure the resulting crater does **not** come within 10 cm of the sand bed's walls or bottom.
10. Adjust the test duration as needed, keeping in mind the sand bed size limits crater growth.
11. After the desired time, click the **OFF** button again to **close** the solenoid valve.
12. Close the manual valve.
13. Stop the high-speed camera recording.
14. Export all data for analysis in other software.
15. For additional trials:
    - Refill the sand bed **or** measure the new surface elevation,
    - Adjust elevation **or** change the nozzle if needed,
    - Restart the experiment.
16. After completing all trials, collect any ejected sand and clean the area around the experiment.





The next step after experimenting is data processing. In this step, the user is required to upload the video into the first script and select the sand pit to capture the individual frames of the video while crater is forming. The next step is to locate that file path into the next code to create the scale factor. Here the code will upload an image of the initial frame for the user to select two points in the ruler of known distance. The script then asks the user for that distance and then creates the scale factor of cm/pixel. The next section of this script then tracks the image differences of these frames and outputs the crater depth and width over time as well as these final measurements of the crater. In the final script, the user is required to locate the final frame of the video and upload it. This will output the 2D crater profile geometry on and off the frame.

Troubleshooting

Problem	**Remedy**
Significant pressure losses along the tubing.	Significant pressure losses along the tubing are normal and likely due to friction. To eliminate the problem as much as possible use pipe tape to improve your connections. Pipe tape should be applied with the threads of the connection and should not bunch up. To check you may also put soapy water over your connections and check for bubbles.
Non-symmetric crater formation.	The crater should create a symmetric profile. If it does not, ensure that the sand underneath the nozzle is level and that the baffle is aligned and properly splitting the flow.
Bending of the acrylic baffle.	Due to the packing of the sand in the sand bed the acrylic baffle may bend. To remedy this, provide additional support for the wall without impacting the data acquisition. An example of this would be to use a second acrylic baffle adjacent to the one with the knife edge.
Uneven leveling of the manifold.	If the manifold is uneven when leveled it may be because the support system itself isn't properly leveled. To fix this the entire system should be leveled at all points as it is being assembled. Additionally, using shims on the linear bearings will provide a tighter, improved fit.