Supersonic retropropulsion is a promising way for space-shuttles to decelerate when reentering the Earth or during Mars landing. The goal of our project is to simulate the physics of supersonic retropropulsion by visualizing and recording the flow effect (shock wave) and measuring the parameters such as pressure, velocity and thrust.

Due to the high cost of conducting full scale experiments, this field is seldom touched by university researchers. The miniature rocket project provides a new perspective to study this complex phenomenon: reproduce the results using a small scale experimental setup.

This project was ongoing from last year and 3 major problems need to be solved: short running time, humidity, and manual operation. This year, the improved version of setup needs to be designed and constructed to have longer running time and contain minimum moisture condensation. The improved version of setup needs to be designed and constructed to have longer running time and contain minimum moisture condensation. The new setup will also be highly automated, requiring minimal human effort.

### Design

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Design Value</th>
<th>Achieved value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental run time</td>
<td>10s</td>
<td>14s</td>
</tr>
<tr>
<td>Moisture condensation (Binary)</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Wind tunnel flow velocity</td>
<td>Mach 1.5</td>
<td>Average Mach 1.61 Max Mach 1.78</td>
</tr>
<tr>
<td>Thrust of nozzle</td>
<td>60N</td>
<td>38N</td>
</tr>
<tr>
<td>Cost of raw materials</td>
<td>&lt;$500</td>
<td>$451</td>
</tr>
</tbody>
</table>

- **Larger tank capacity**
  - Six 60-gallon storage tanks + one 80-gallon expansion tank

- **Removal moisture in the air**
  - A filter and desiccant air dryer were installed

- **New nozzle manufacturing method**
  - Inner geometry printed with SLA printer, highly accurate and smooth finish
  - Outer shell printed with PLA, high strength

- **Integrated data collection / experiment control system**
  - Temperature, pressure, humidity, thrust are measured
  - A LCD screen displays the current time during recording
  - A master switch controls the start/stop of the experiment

- **CFD Simulation**
  - CFD simulations were done on the converging-diverging nozzle to evaluate its interaction with the wind tunnel. On the left shows the Mach number plot of a simulation where the internal pressure of the nozzle was set to 0. On the right shows the same plot for a simulation where the internal pressure of the nozzle was set to 145 psi, the applied pressure in the experiment.

- **Control System**
  - An Arduino-based integrated data acquisition and control system was built. A master switch controls the start/stop of the experiment and electric/pneumatic actuators ensure the fast response of the system. Data from all sensors are sent to the Arduino, where they are post processed. The Arduino then prints the data to the screen.

- **Shock Wave**
  - One important metric of this project is the visualization of the shockwave. In this project, a projector is used to cast a shadow of the shockwave on the screen.

One master switch controls the start/stop of the experiment. Data from all sensors are sent to the Arduino, where they are post processed. The Arduino then prints the data to the screen.

Testing revealed that all valves open/close within 0.8s of the action of the master switch. The Arduino collects sensor data at 5Hz and loads cell reading at 1Hz. This meets the need of our customers.