

Design of a Rocket Engine Thrust Augmentation Ejector Nozzle



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Background

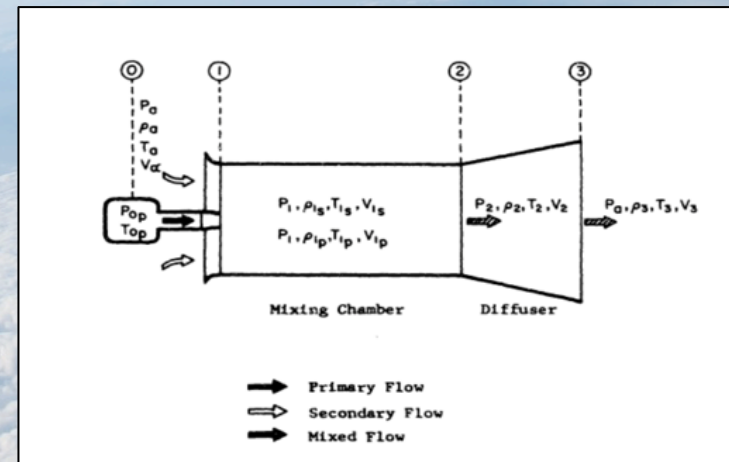
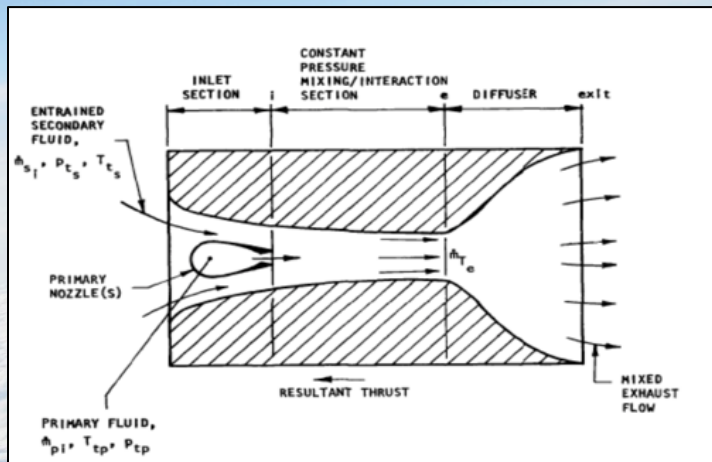
- The use of rocket propulsion to power various types of winged, high-speed vehicles during take-off and cruise
- Augment the thrust produced by the rocket engine
- By obtaining maximum production of mass flow while minimizing fuel consumption
- Following previous work, a numerical procedure was developed to design a high-performance ejector nozzle optimized to specific flight conditions

Objective

- To test this numerical method for its validity and real world boundary conditions
- Conduct cold flow testing to better understand the mass flow and the pressure distribution throughout the system
- The resultant boundary conditions will be used to modify and improve the nozzle design
- Once an ideal nozzle design is achieved, a hybrid rocket engine will be used to simulate flight environments

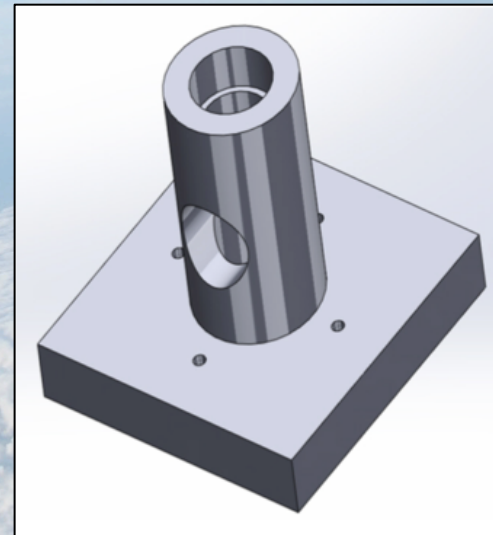
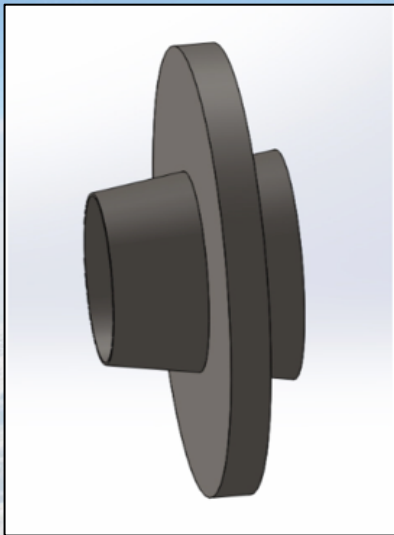
Initial Research

- Prior to analysis of the nozzle design obtained from the numerical optimizer, extensive research was conducted on the following topics:
 - Measurements of air flow characteristics using various probes
 - Nozzle testing using hybrid engines
 - Wing tunnel testing involving pressure measurements

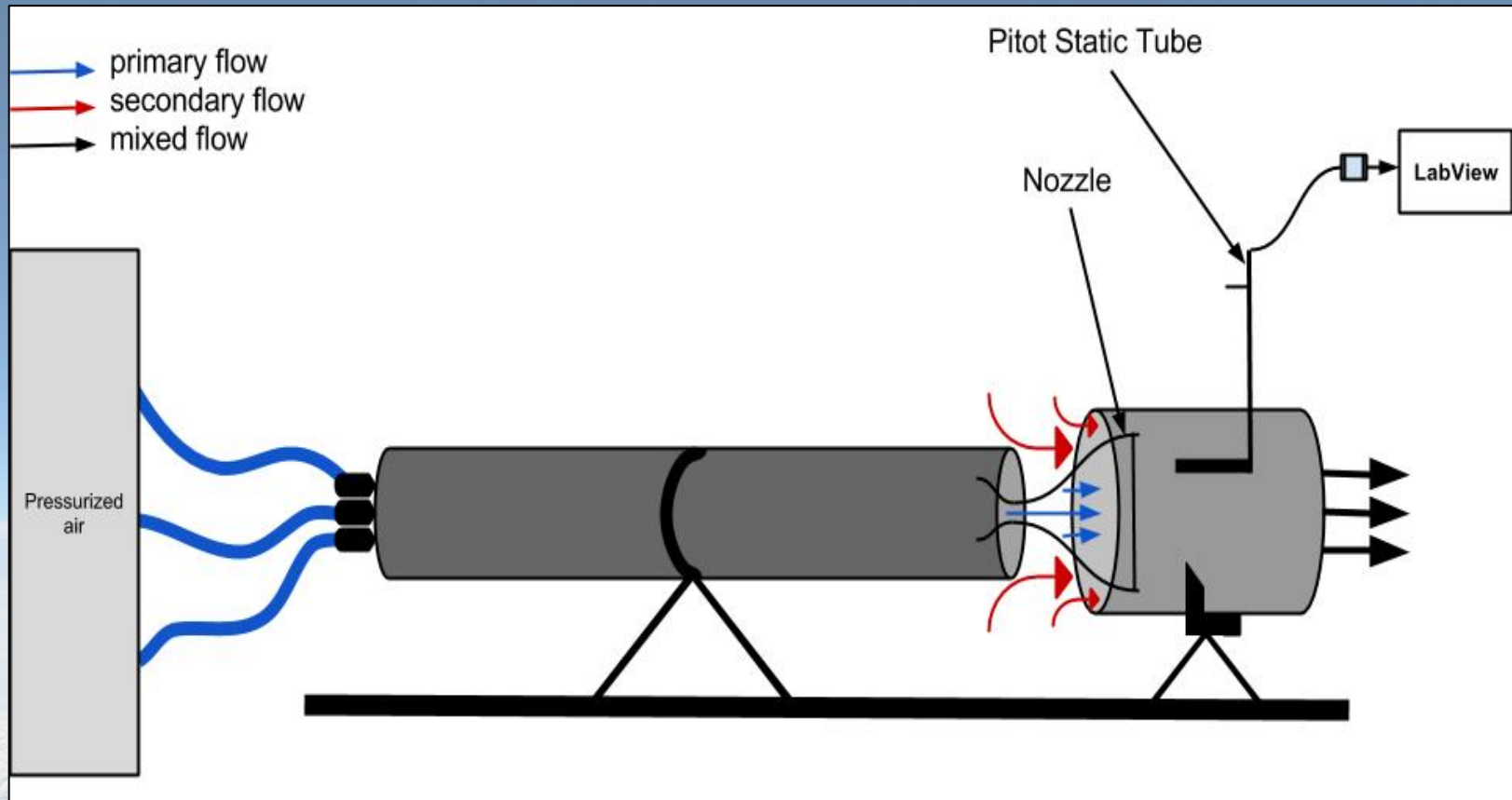


Preliminary Design

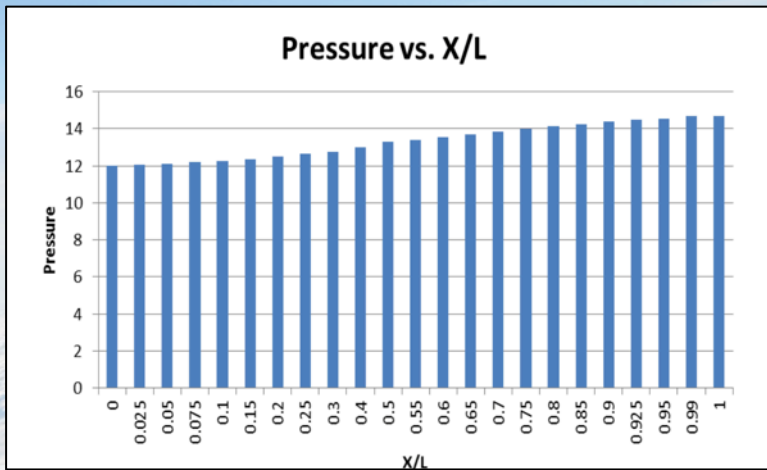
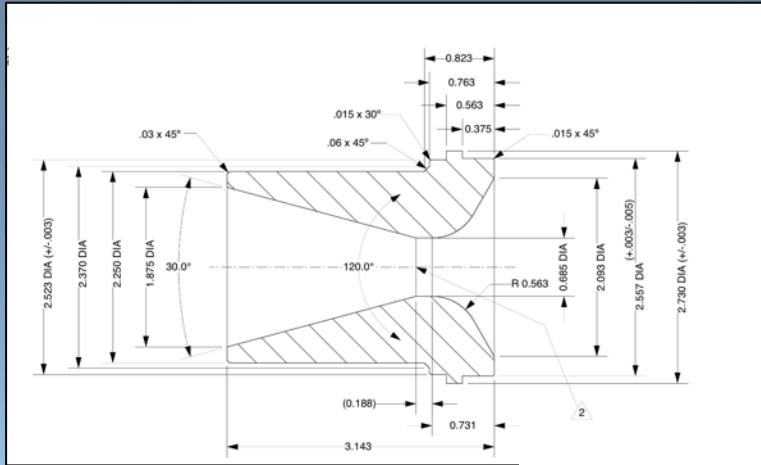
- CAD models of the ejector nozzle along with the mounting plate for testing on a small hybrid engine were designed
- Based on the geometry and dimensions obtained, it was determined that cold-flow testing was to be done to improve the nozzle design before machining the parts



Experimental Set up



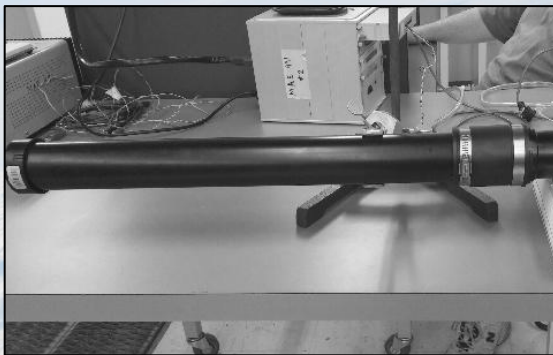
Experimental Design



- Single-throat nozzle was used to simulate high-speed flow using compressed air
- The objective was to compare the experimental pressure distribution and the mass flow gradient with the theoretical trends obtained using numerical procedures
- A constant-area duct was used to serve as the controlled parameter

Testing Procedures

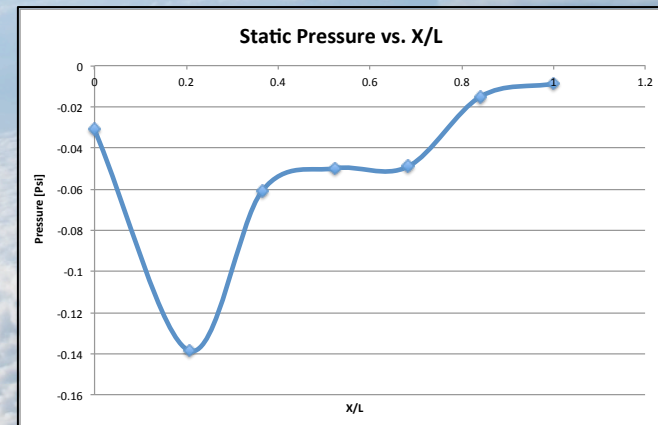
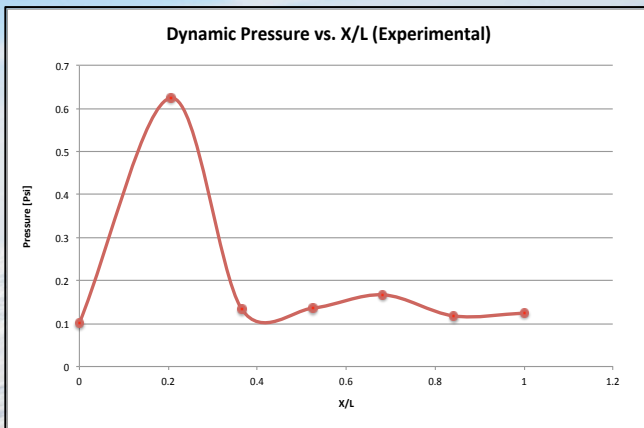
- Pressurized air entrained the nozzle where supersonic flow at $M > 1$ was reached
- Using a pitot static tube, total and static pressures were measured along the x-location of the nozzle to determine the air velocity
- Data collected was used to construct pressure distribution plots and perform mass flow analysis



$$T = \dot{m} V_e \quad \dot{m} = \rho A V$$

Results

- Assuming flow expansion occurred without separation, the results allowed for better understanding of static pressure and velocity at the inlet and exit of the ejector
- As predicted, the low static pressure at the inlet resulted in an adverse pressure gradient where the secondary flow was forced to entrain the ejector
- The results showed an increase in mass flow rate and thrust at the exit



Project Outline

- The experimental data provided the basis for understanding compressible air flow as it entrains the ejector and how it contributes to the increase in overall thrust of the rocket engine
- The boundary conditions obtained will be used to design a nozzle geometry which prevents flow separation and takes into account compressibility
- Ducts with varying cross-sectional geometry are to be tested for further analysis of mass flow behavior at the inlet and outlet
- After modifying and improving the design, a hybrid engine will be used to further test various geometry nozzles and establish the basis for future work and flight applications

Thank you!

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