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FACULTY OF ENGINEERING
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Team 23 – RSS Thrust Measurement System

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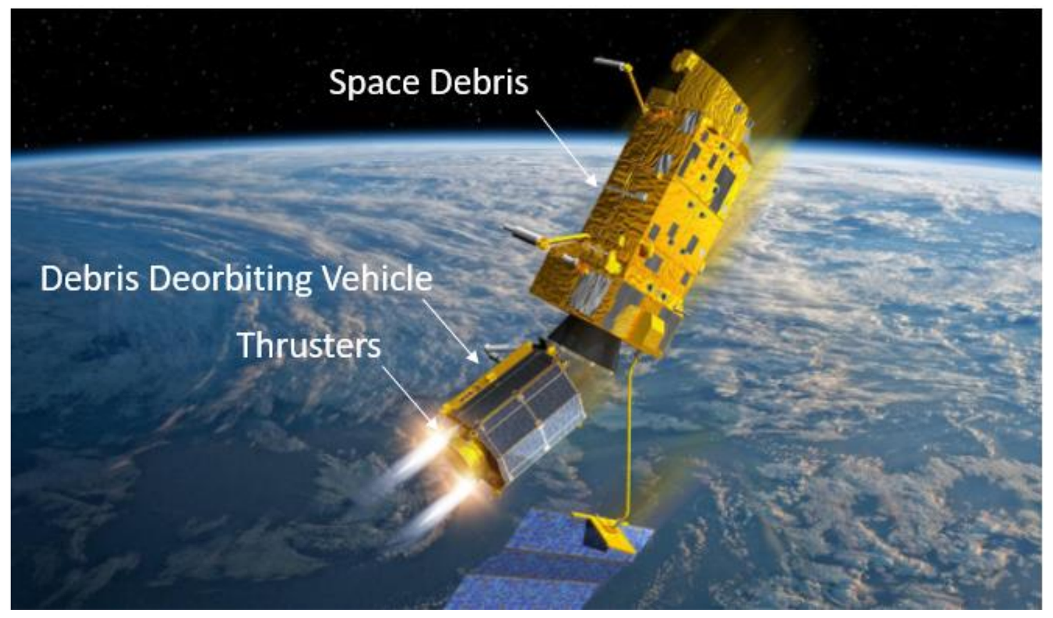
Introduction

Robotic Spacecraft Simulator

- The Robotic Spacecraft Simulator (RSS) is a robot used to simulate the deorbiting of space debris in 2D
- The robot floats on air bearings and maneuvers using converging, cold gas (air) thrusters
- The air thrusters allow the RSS to match position and rotation of space debris



Artistic rendering of a space debris deorbiting vehicle

Project Scope

- The objective of this project is to design and construct an apparatus to quantify the thrust force of the RSS thruster nozzles
- Thrust characterization will assist with development of the propulsion control system

Requirements

The final design must:

- Support testing of up to 4 thruster nozzles
- Be configurable to test nozzle outlet diameters ranging from 0.2 mm to 1.0 mm
- Measure and vary thruster supply pressure up to 100 psi
- Measure thrust forces up to 2 Newtons

The experimental results shall be validated via CFD model.

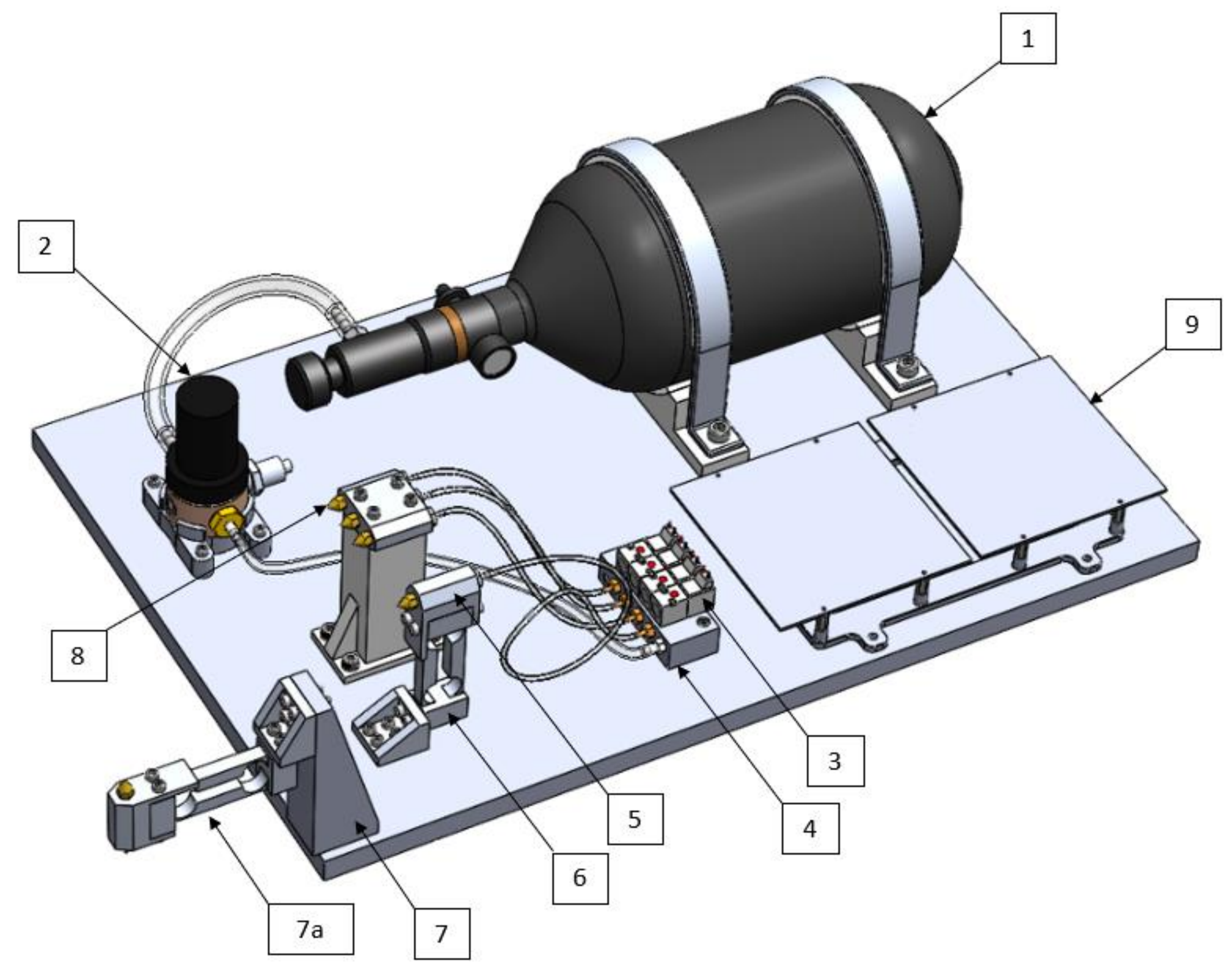
Design Process

- Explored methods to measure thrust including measuring deformation, displacement, acceleration, and volumetric flow rates
- Research into similar experiments to see what solution worked for low thrust applications
- The bending load cell force measurement system was selected due to ease of implementation, cost, and example use in literature
- Two prototypes were developed including a CAD model using SolidWorks and a CFD model using ANSYS

Details of Design

How it works:

1. The load cell is calibrated using the calibration stand and known masses
2. Air is supplied by the air tank at 300 psi
3. Air is regulated to desired supply pressure via second stage regulator
4. Actuating the solenoid valves provides air flow to the nozzles
5. The thrust output from the nozzle mounted on the load cell causes a deformation
6. Strain gages internal to the load cell measure the deformation and convert it to an electrical output signal
7. The output signal is read by an Arduino and converted to grams of thrust force

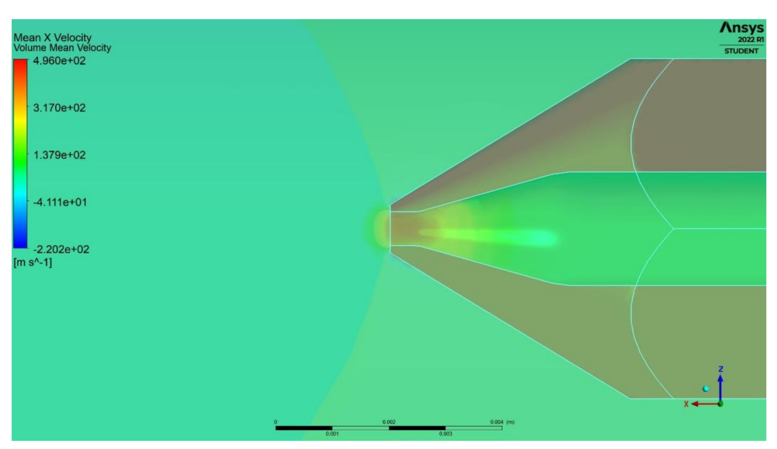


	Components
1	Air Supply Tank
2	Second Stage Regulator
3	Solenoid Valves
4	Manifold
5	Thruster Nozzle Holder
6	Load Cell (testing orientation)
7	Load Cell Calibration Stand
7a	Load Cell (calibration orientation)
8	Three Thruster Nozzle Holder
9	Circuit Board

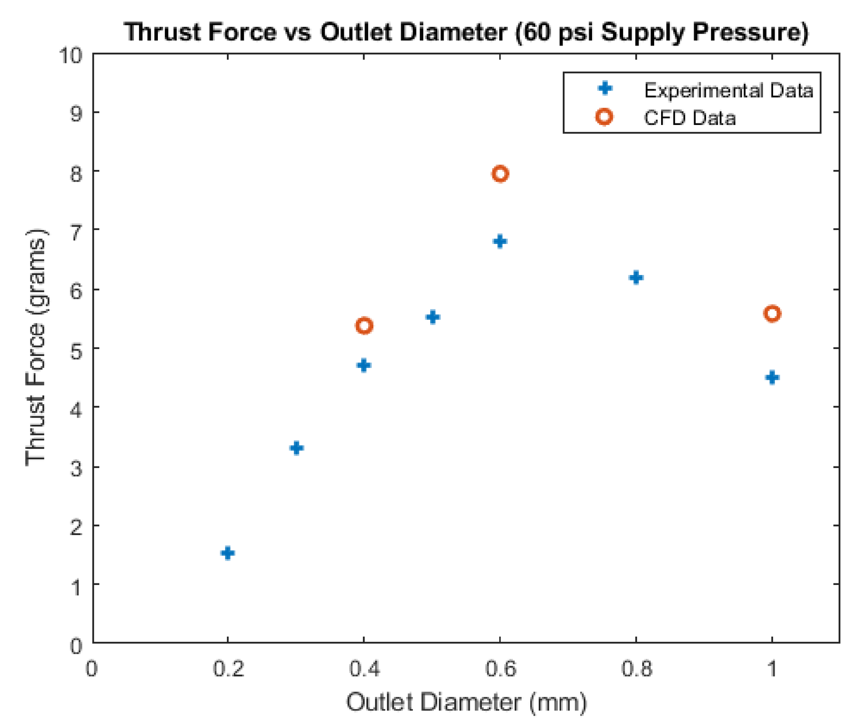
Results

CFD Results

- ANSYS Fluent was used to perform CFD analysis on the nozzle
- Nozzle diameter sizes of 0.4, 0.6, and 1.0 mm were analyzed
- Results were compared with the experimental results and are in good agreement
- The error between CFD and the experimental data is hypothesized to be due to frictional effects from wall roughness and boundary layer effects

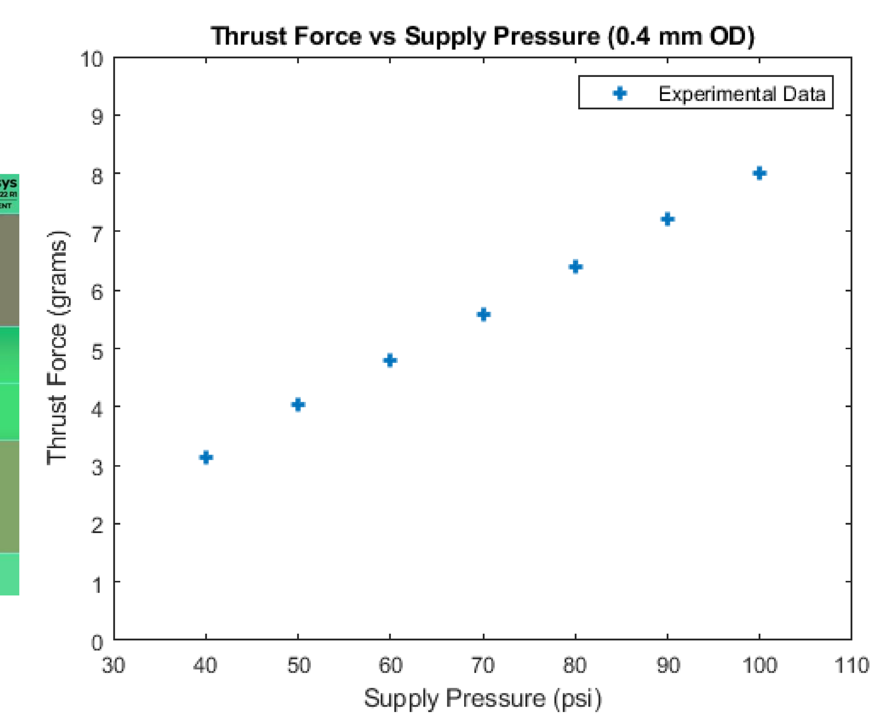


CFD model velocity profile



Thrust Force vs Outlet Diameter

- The effects of the outlet diameter of the converging nozzle on thrust force was examined to determine the optimal outlet diameter for the RSS
- The supply pressure was regulated to 60 psi to mimic the conditions on the RSS
- The thrust force reaches a maximum using the 0.6mm outlet diameter nozzle



Thrust vs Inlet Pressure

- The effects of the inlet supply pressure on thrust force was examined to determine the optimum supply pressure for the RSS
- The 0.4 mm nozzle was used to mimic conditions on the RSS
- Thrust output linearly increases as inlet supply pressure increases

Recommendations

The following is recommended for implementation on the RSS:

- Use 0.6mm nozzle to maximize thrust output
- Use 0.2mm nozzle to maximize runtime
- Use maximum allowable supply pressure to maximize thrust output

The following is recommended to improve the experiment apparatus:

- Minimize tube length and nozzle chamber
- Purchase an ADC with a faster sampling rate
- Purchase a second stage regulator with greater precision

The experiment should be repeated using converging-diverging nozzles and compared to converging nozzle results

References

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Vautour, E. (2021) "RSS Propulsion Capstone - Graduate Student User Requirements".