Reaction Control System for High Altitude Balloons

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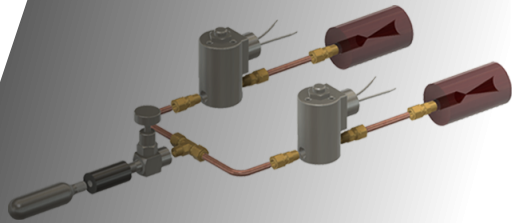


Introduction

- What is a high altitude balloon (HAB)?
- What is a reaction control system? (RCS)?
- Why collect data with HAB payloads? (HABPs)?

Motivation

- There are problems with HABPs!
  - Sporadic winds control and limit data acquisition
- Solution: integrate a reaction control system (RCS)

Options for RCSs

1. Reaction/Momentum wheels
2. Control moment gyroscope
3. Combustion thruster
4. Cold gas thruster

Gyroscopic Reaction Control Systems

Figure: Reaction wheels

Cold Gas Thruster Reaction Control Systems

Figure: ”Four of VACCO’s extremely robust, man-rated triad assemblies were used in each Space Shuttle MMU”

Narrowed Objective

- Develop a robust, efficient cold gas thruster for high altitude balloon payloads (HABP.)

Methods

1. Determine viability
2. Develop experiment
3. Collect data
4. Ground testing
5. Take flight

Determining Viability

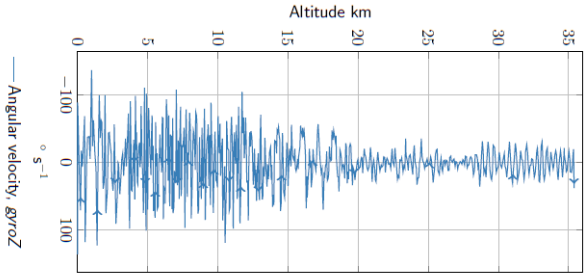


Figure: Flight data from the Titan 1 HAB flight.

Develop an Experiment

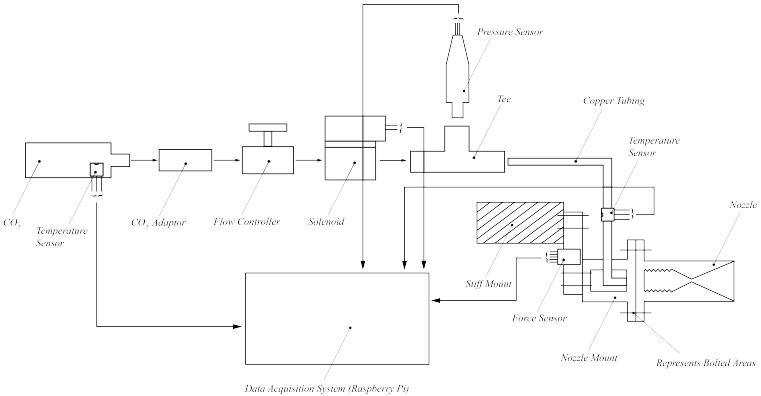


Figure: Minimal test rig schematic.

Existing Nozzle Theory

$$\frac{A_t}{A_e} = \left(\frac{k+1}{2}\right)^{\frac{1}{k-1}} \left(\frac{P_c}{P_a}\right)^{\frac{1}{k}} \sqrt{\left(\frac{k+1}{k-1}\right)\left[1 - \left(\frac{P_c}{P_a}\right)^{\frac{k-1}{k}}\right]} \tag{1}$$

Optimum expansion ratio for nozzle

Manufacturing

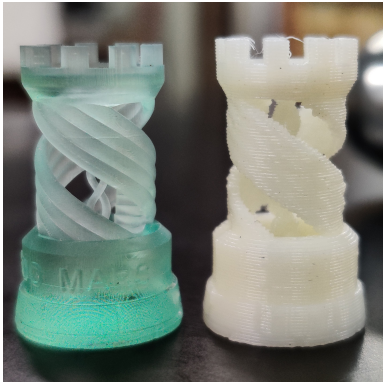
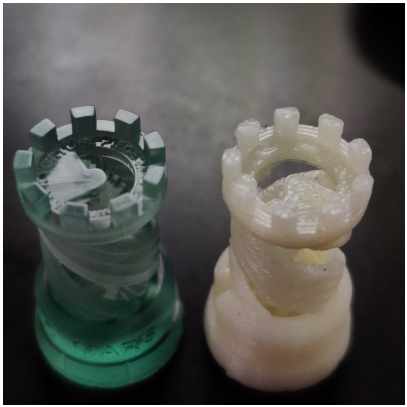


Figure: Left: ELEGOO MARS, Right: uPrint SE Plus

Manufacturing



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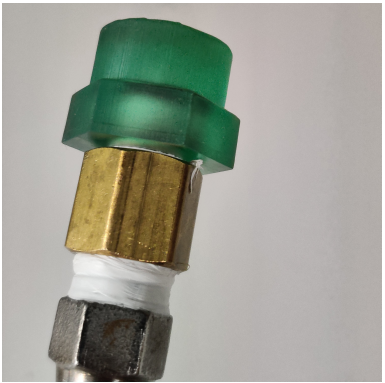
Manufacturing



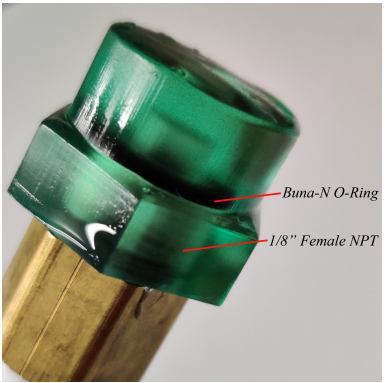


Figure: Left: end cap for pressure testing, Right: same end cap, but wetted to show internal details.

Manufacturing

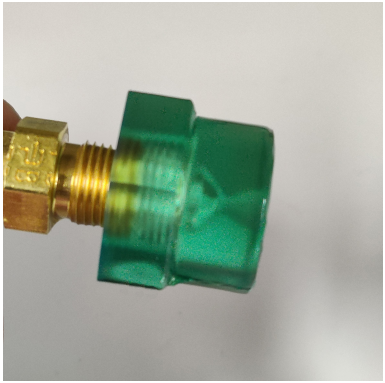


Figure: Nozzle printed with the ELEGOO MARS.

Data Collection and Corrections

$$I_{sp} = \left[\frac{2\gamma G T_c}{(\gamma - 1) W} \left(1 - \left(\frac{P_a}{P_c} \right)^{\frac{\gamma - 1}{\gamma}} \right) \right]^{1/2} \tag{2}$$

Condition for maximum specific impulse.

$$I_{sp} = \frac{\int F dt}{m} \tag{3}$$

Integration into a Payload

- After optimizing nozzle design, the design would be integrated into a HABP.
- More testing
  - Simulating windy conditions
  - Fuel storage ability, etc

Payload Integration

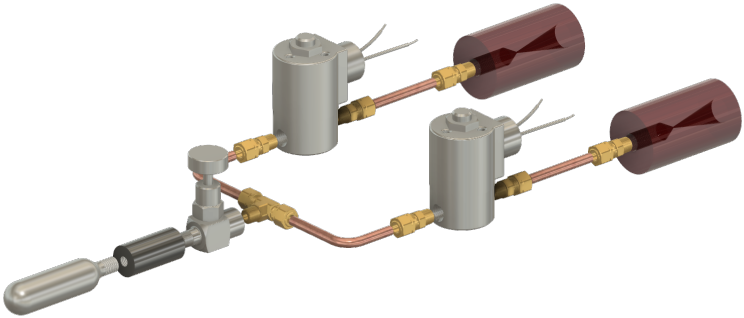


Figure: CAD Render of the plumbing system for my RCS.

The Ultimate Objective

- The best test of the RCS would be a flight
  - Stabilizing through regions of the atmosphere
  - Point at the sun, a ground target, etc

Results and Analysis

- Data collection has not yet begun

Conclusion

1. Determine viability
2. Experimentation
3. Data collection
4. Ground testing
5. Flight!

Bibliography

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