Imperial College London

Miniaturised Cold Gas Thrusters
A 3D-printed Propulsion System for CubeSats

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Background

The aim of the project was to design, manufacture, and test a micro-thruster propulsion system for a 3U CubeSat. The system was tasked with producing thrust for desaturation of the reaction wheels and for attitude-control of the satellite. System design constraints are:

- ≤ 1kg and within 1U (10 cm x 10 cm x 10 cm)
- Budget of £1000
- Must comply with CubeSat design specifications and space debris mitigation requirements

Analysis

Cold gas propulsion was favored due to its safety, low-cost, and simplicity. One-dimensional isentropic flow analysis was performed to characterize various propellants (Figure 1).

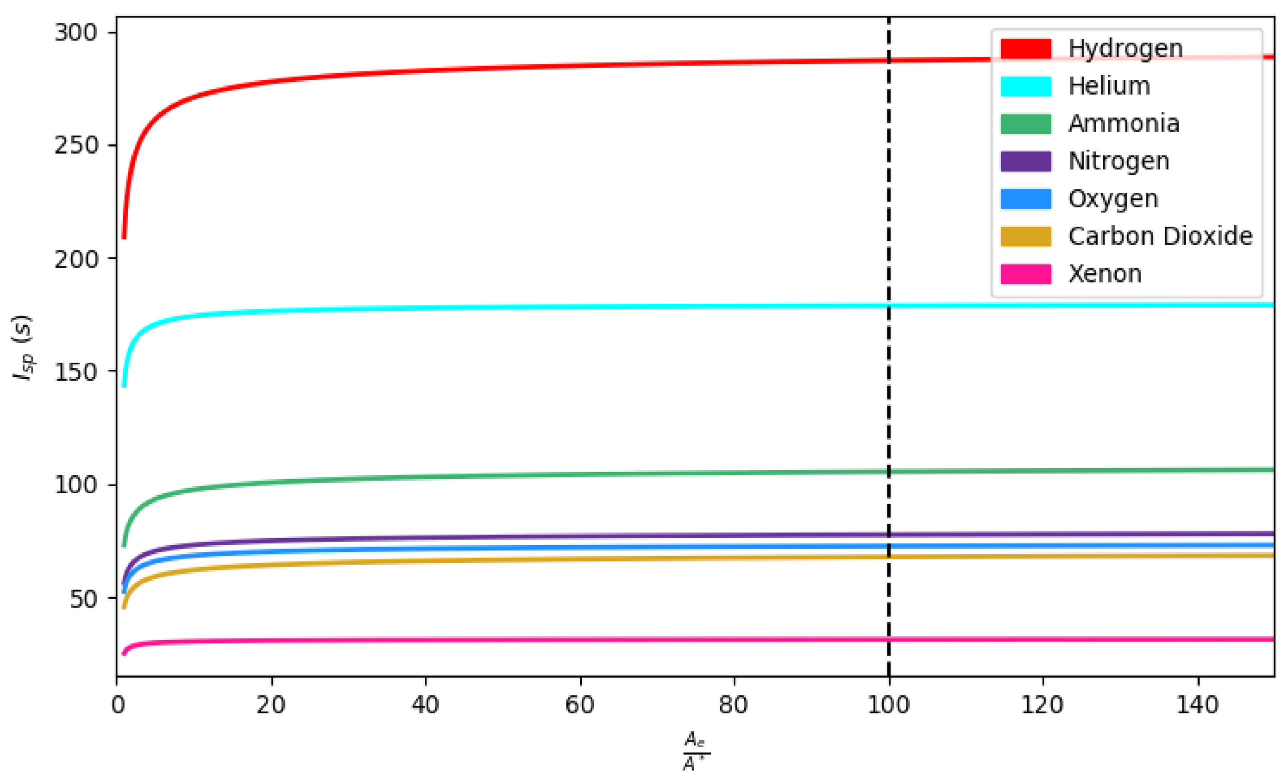

Figure 1: Variation of I_{sp} with expansion ratio for seven possible propellants

Helium was chosen over xenon due to its higher specific impulse and hence a higher thrust potential. However, it was later found that density would be the main constraint, hence xenon, though significantly more expensive, would offer the best potential for dense propellant storage.

Manufacturing

Direct metal laser sintering (DMLS) was employed due to its ability to produce complex features and components, though with limited precision. Additive manufacture allowed for a propellant tank design that could utilize the limited volume more efficiently and a base-plate with integrated angle-optimized nozzles.

Overview of Product Design

Propellant Tank

The propellant tank is comprised of five cylindrical pressure vessels. Functional elements, such as piping between tanks, are integrated directly into the component. Minimum safety factor of 5.7 at 60 bar.

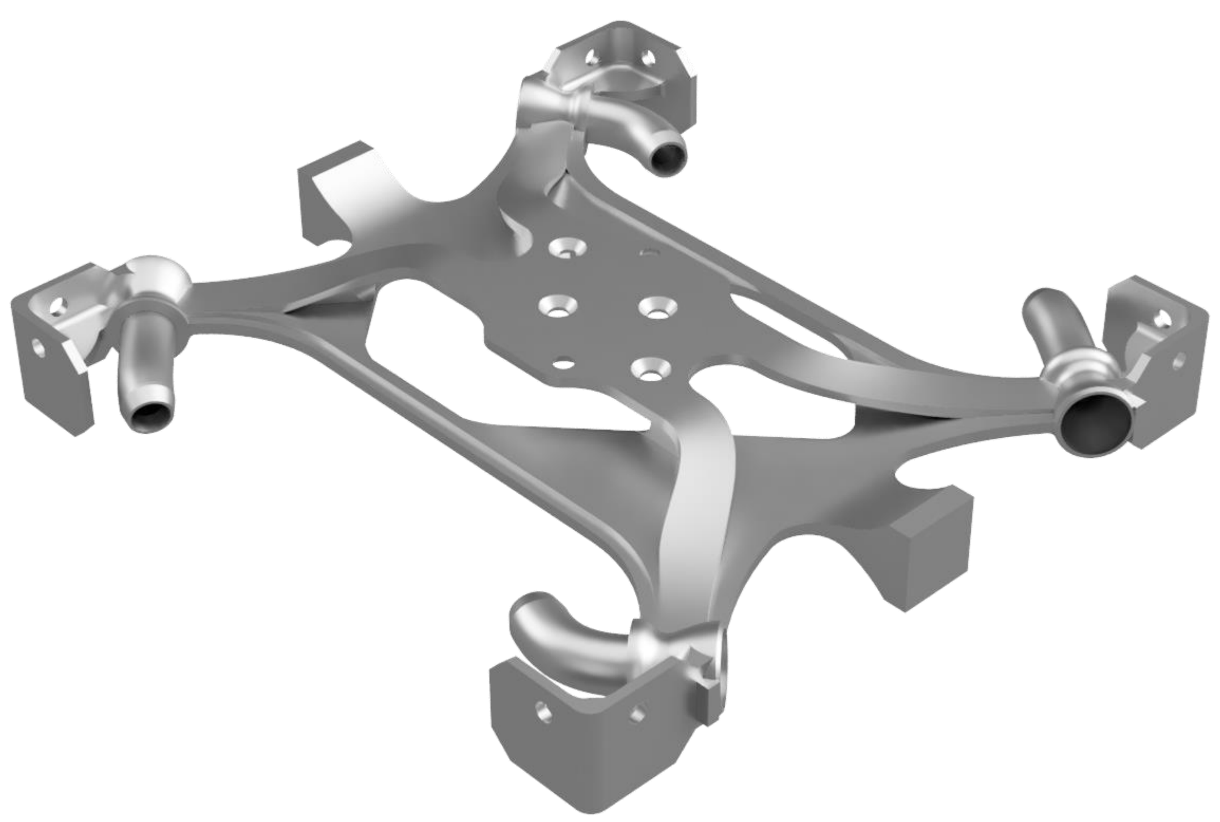

Figure 2: DMLS base-plate

Base-plate

Key features include mounting points for the rails, the nozzles, the hose connections, the burnwire mechanism mounting, and the tank support. Integrated nozzles are accurately positioned to maximize the effective moment arm of each nozzle, increasing propellant efficiency (Figure 2).

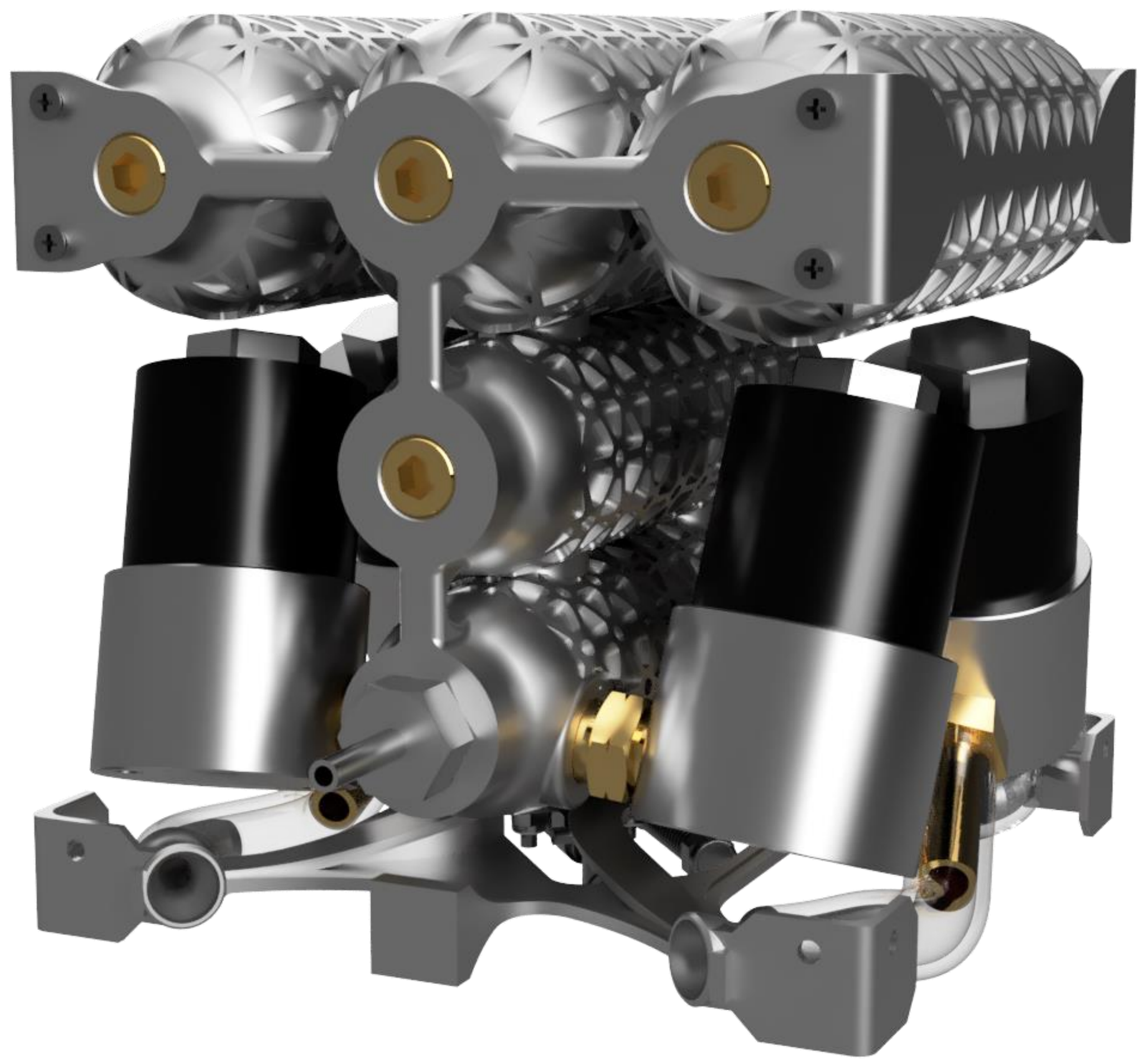

Figure 3: Micro-thruster assembly

Rig Automation

A computer connected via USB ran a Python script to send control signals to an Arduino. A MOSFET transistor circuit was controlled by the digital-out pins on the board to open the valves in the thruster module. A graphical user interface (GUI) was designed to improve usability of the test rig.

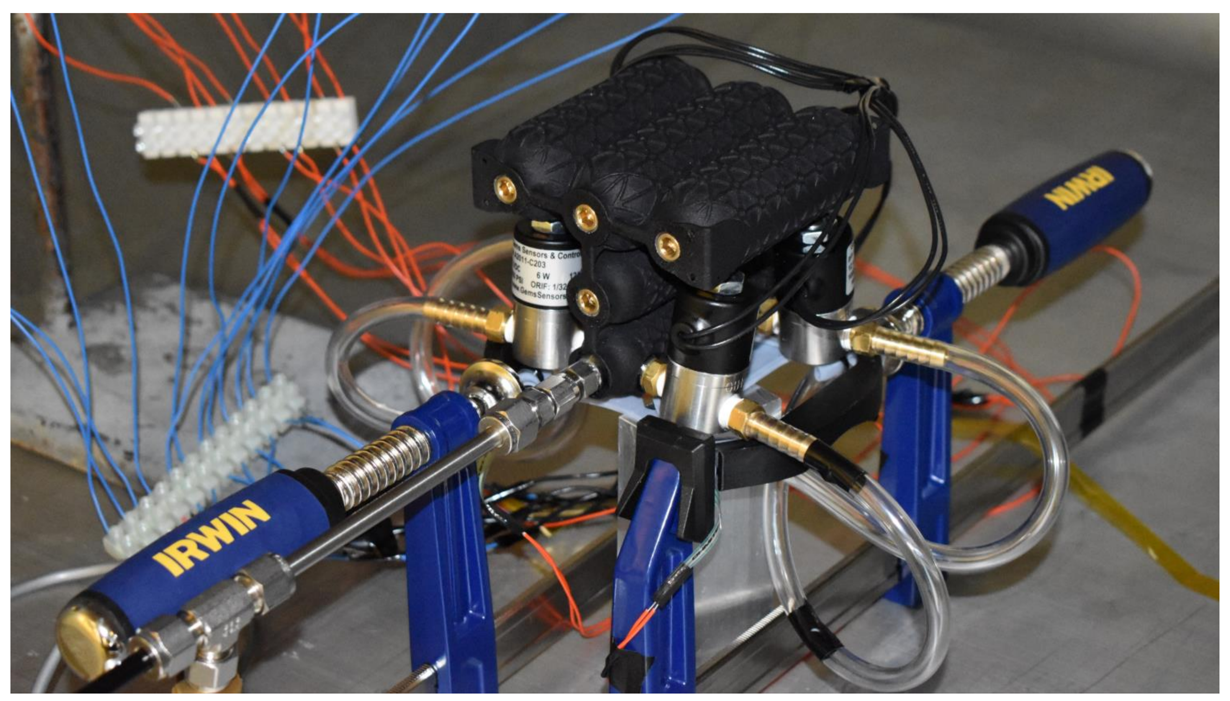

Figure 4:Testing rig for micro-thruster performance characterisation

Key Features

- DMLS propellant tank and base-plate
- Four off-the-shelf solenoid valves: Gem Sensors & Control A-Series A2011
- Prototype printed in nylon weighs 831 grams
- Cost of manufacture is £762.02

Testing

Leakage test

Zero leakage detected in SLS nylon prototype propellant tank at internal pressure of 5.2 bar (Figure 5).

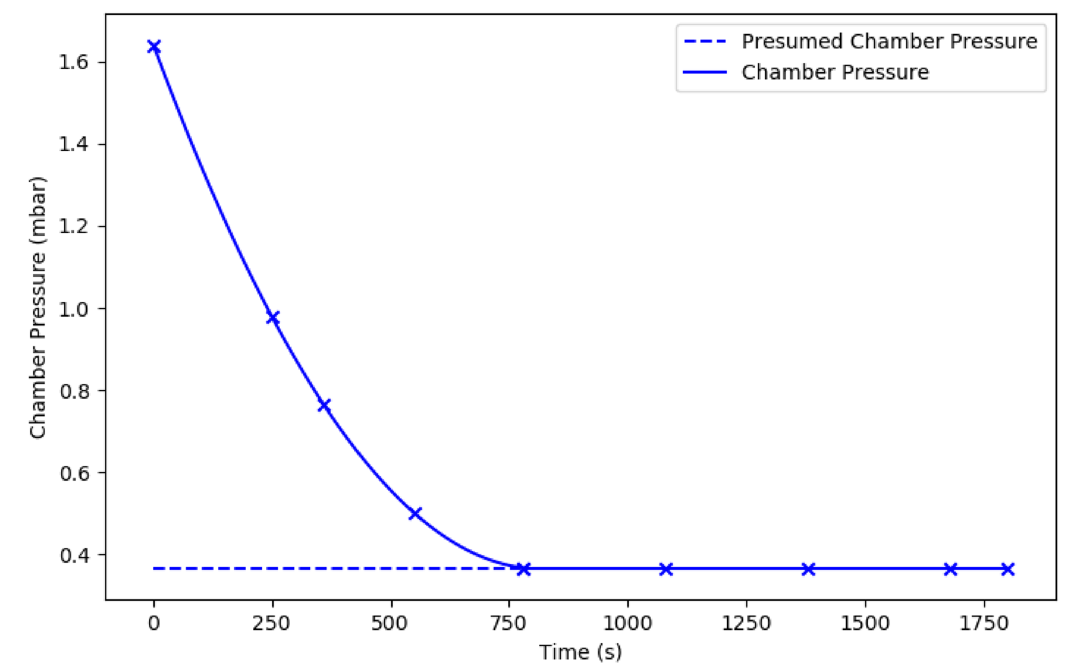

Figure 5: Measured and interpolated leakage rate

Transient test

Shockwave effects caused flow to cease being choked, causing an oscillation between super and subsonic flow (Figure 6).

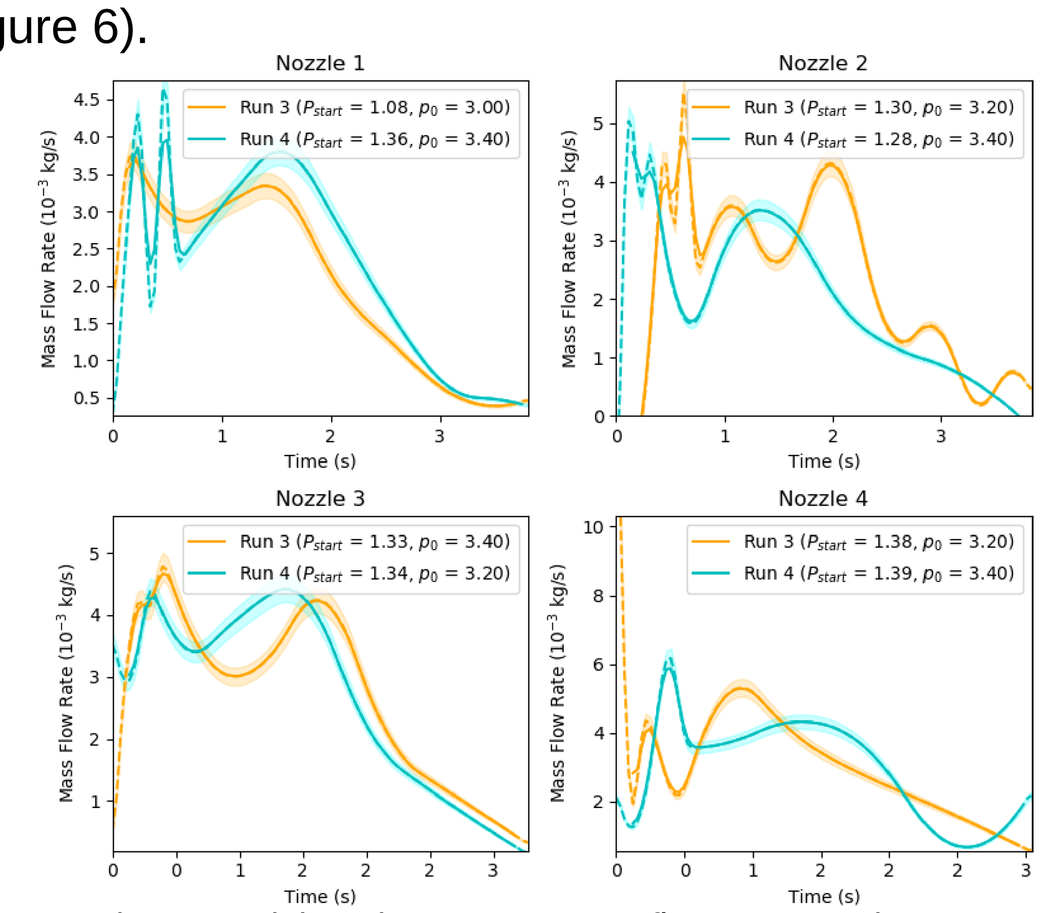

Figure 6: High tank pressure mass flow rate transients