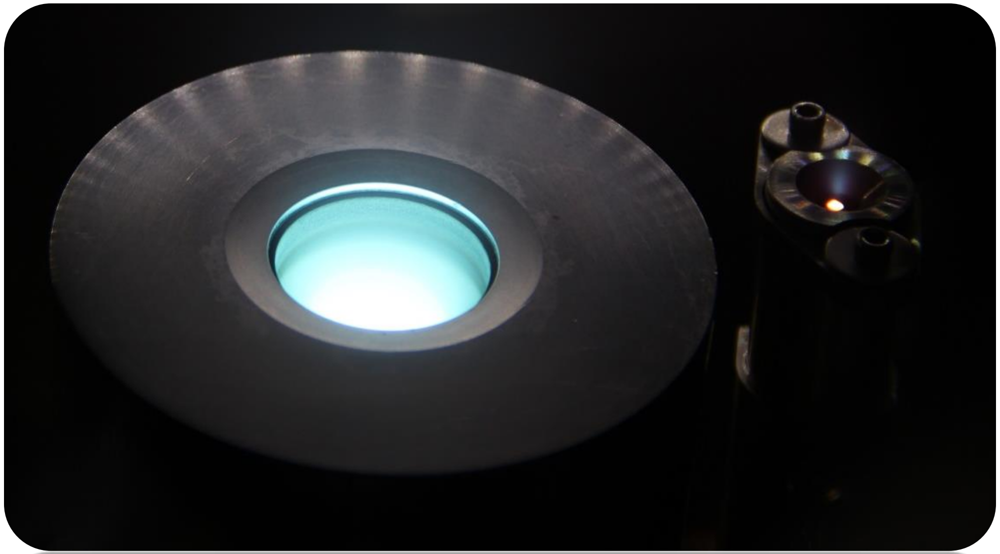
SSC16-WK-43

Canadian Electric Propulsion Development: A Cylindrical Hall Thruster



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...Big Performance, Smaller Satellites

Introduction

Why?

- Increased demand for small satellite missions incentivizes the development of advanced small satellite technology

What?

- Propulsion System: Enable orbit raising, Station keeping & de-orbiting for more advanced missions

How?

- Under the CSA's Space Technology Development Program (STDP) and SFL personal funding, SFL is developing the technology to suit Canada's future propulsion needs

The solution

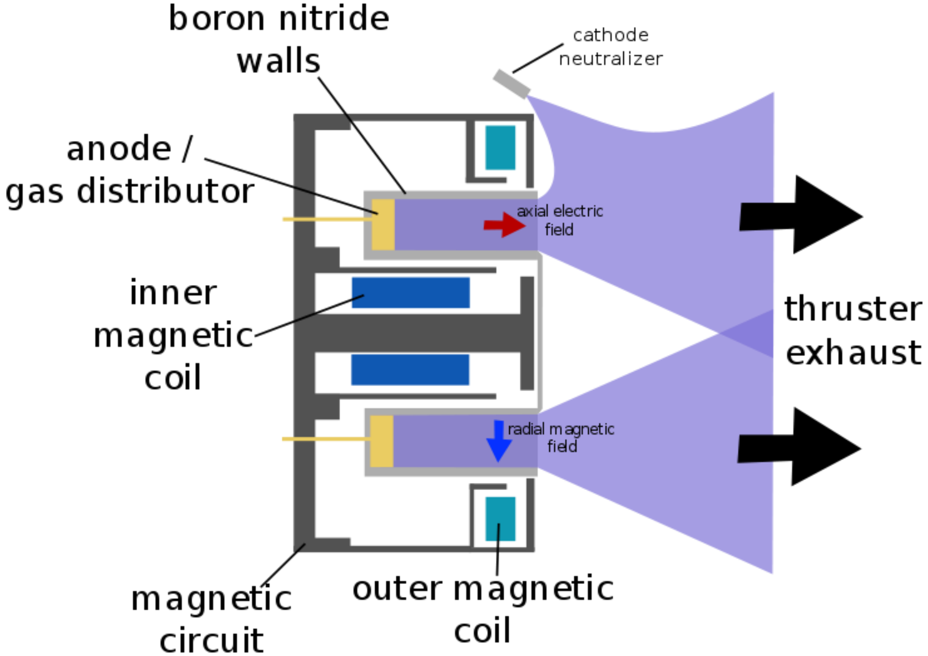
Electric Propulsion

- High specific impulse, low thrust
- Uses **electrical** energy to accelerate plasma, not limited by energy of **chemical** reaction
- Traditional technology consumes power far exceeding capability of small satellite missions

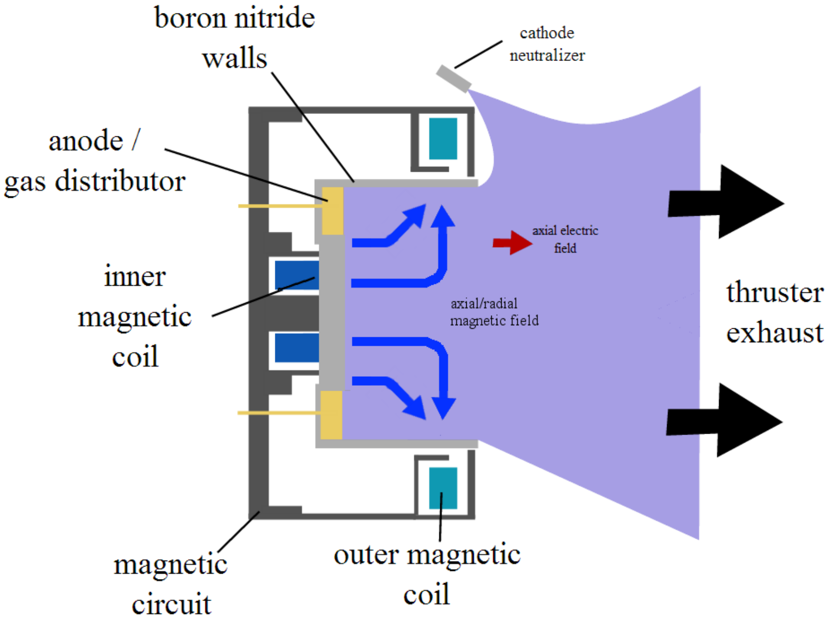
Rendering provided by the University of Michigan. PEPL

- The focus is on low power propulsion system (Sub 200 W)
- SFL chose to develop a hall thruster due to its relative high thrust to power ratio

Hall Thruster



Annular Hall Thruster

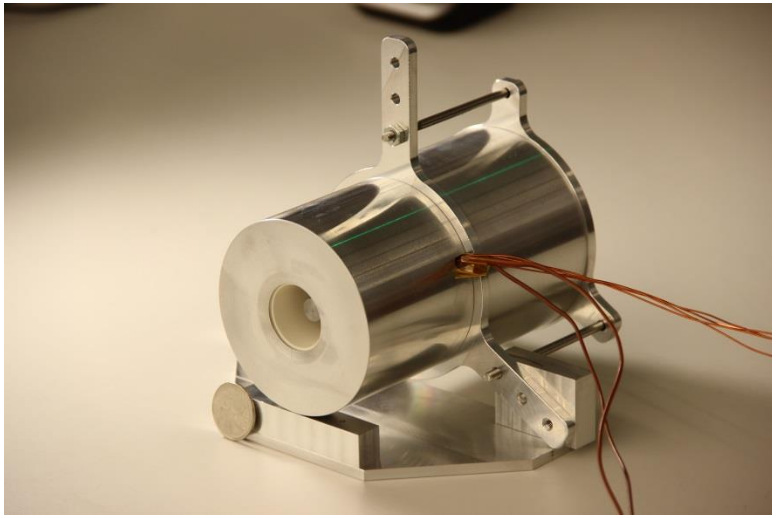


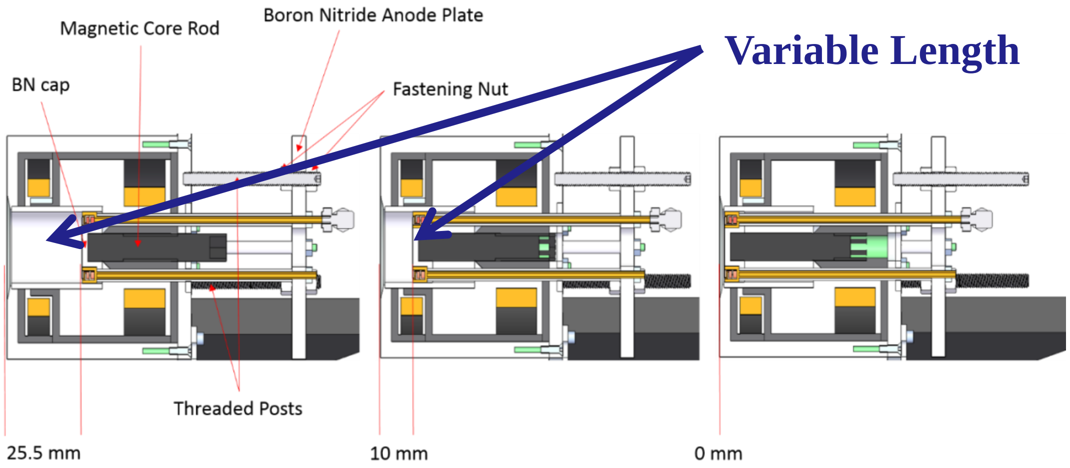
Cylindrical Hall Thruster

Mark 1 Model

- Developed for research purposes under CSA funding
- Designed to be re-configurable

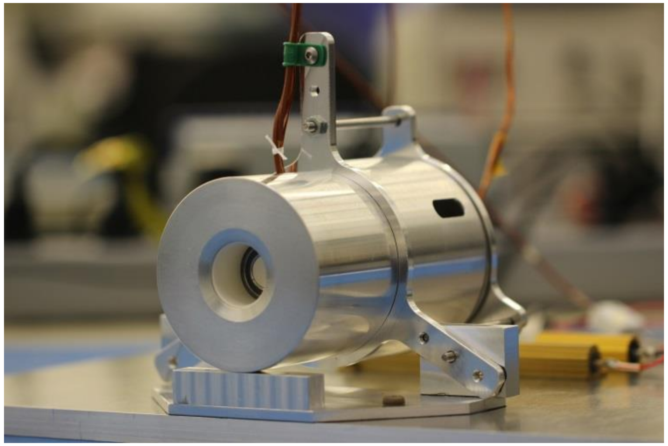
1. Electromagnets
2. Variable ionization chamber length
3. Adjustable propellant mass flow rate



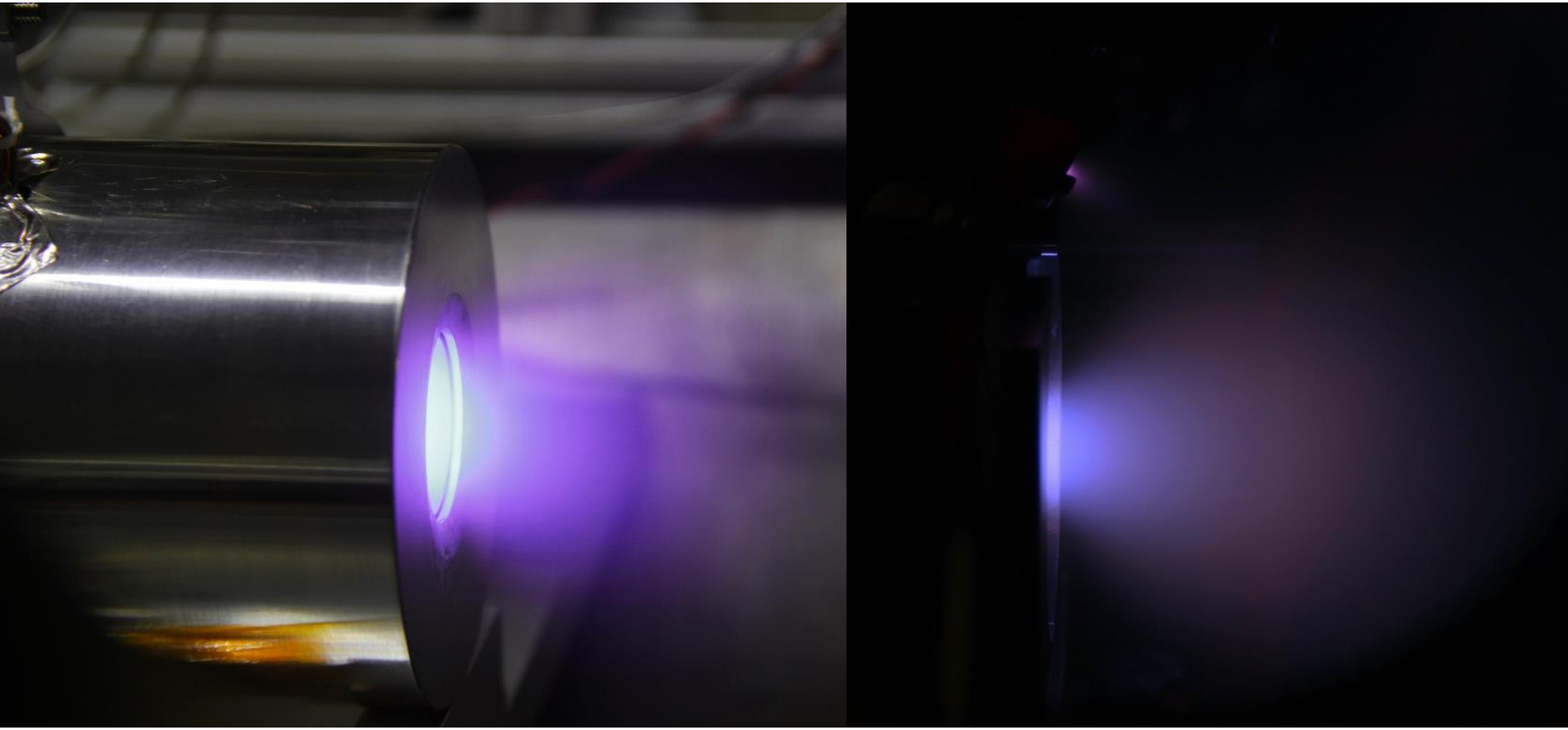


Test Campaign

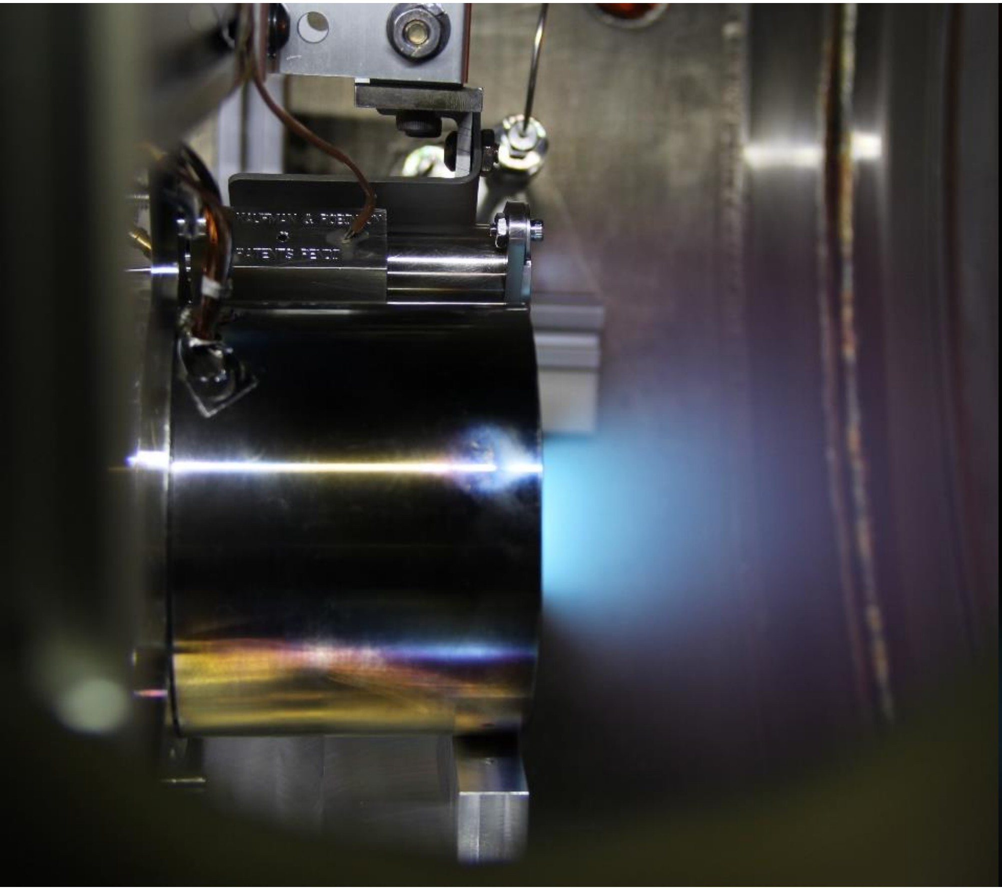
- Tested performance with Argon and Xenon
- Determined optimal configuration of parameters:
  - Magnetic Field
  - Ionization Chamber Depth
  - Cathode Position
- Measured thrust and Isp performance

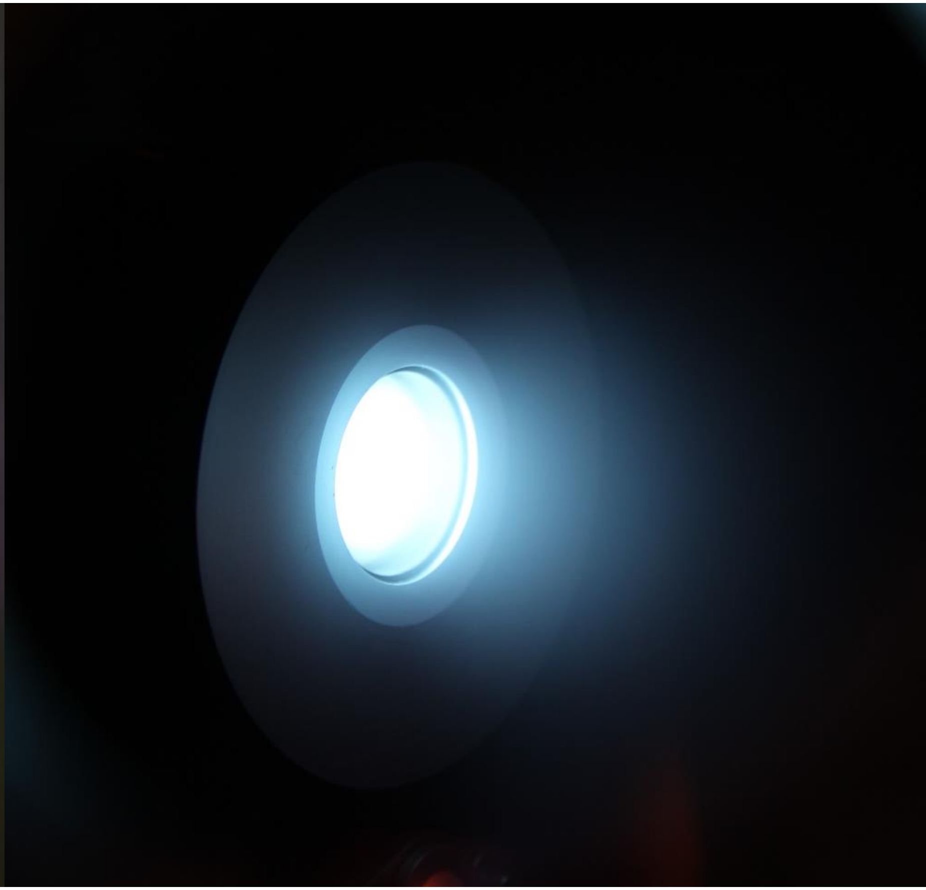


Argon Propellant

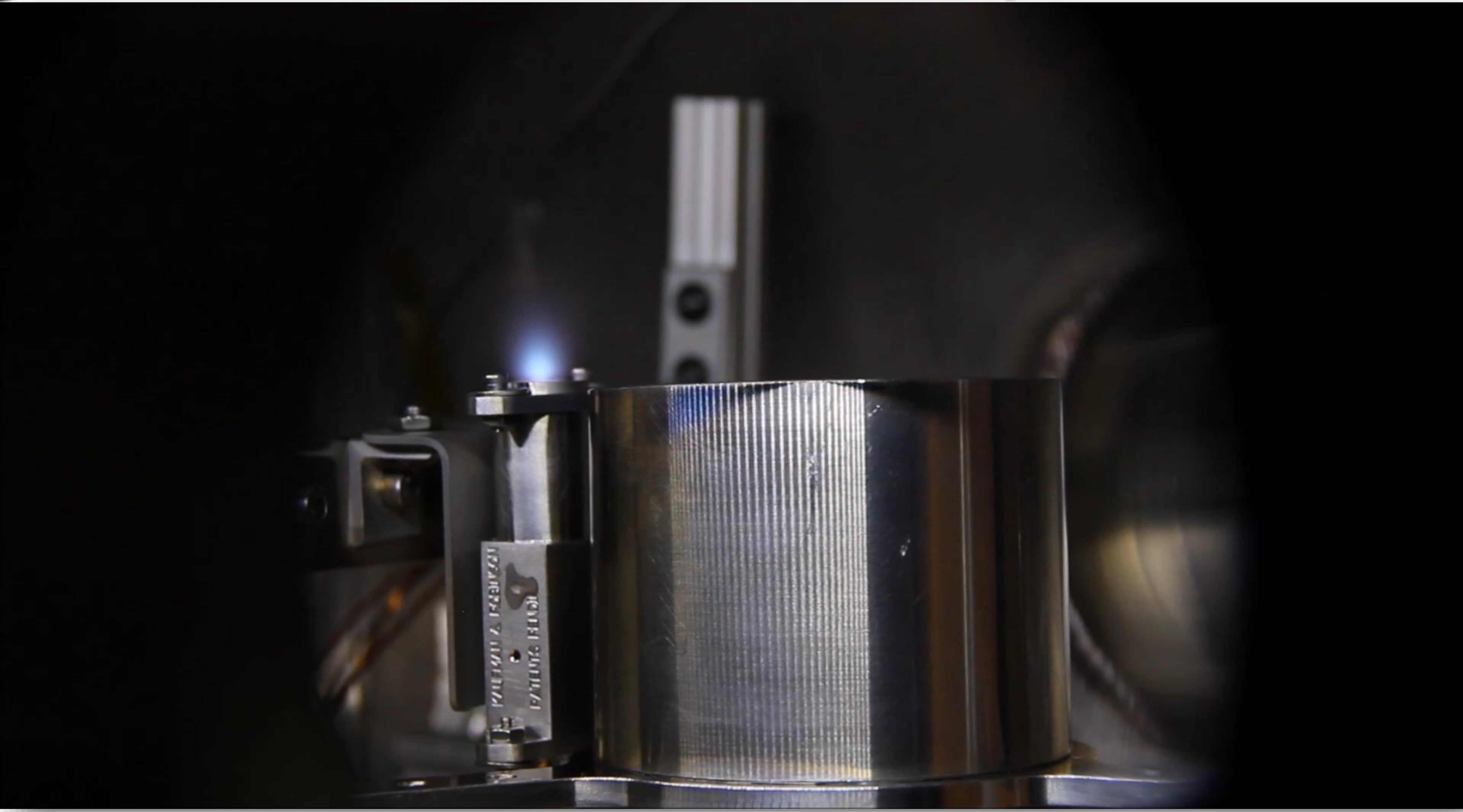


Xenon Propellant



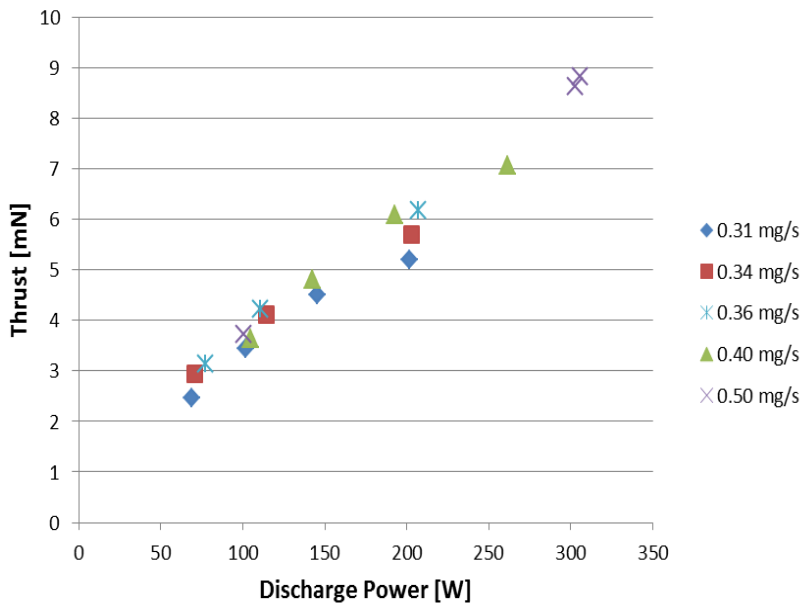


Startup

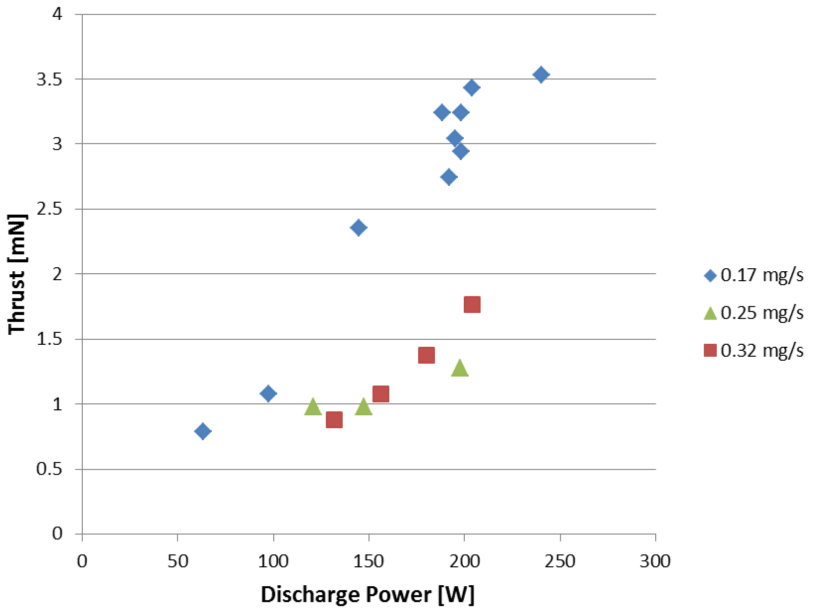


Thrust Comparison

- Performance requirements achieved as stated in contract (5-10 mN)
- 3% to 26% efficiency depending on propellant used and discharge power (typical for small CHT)



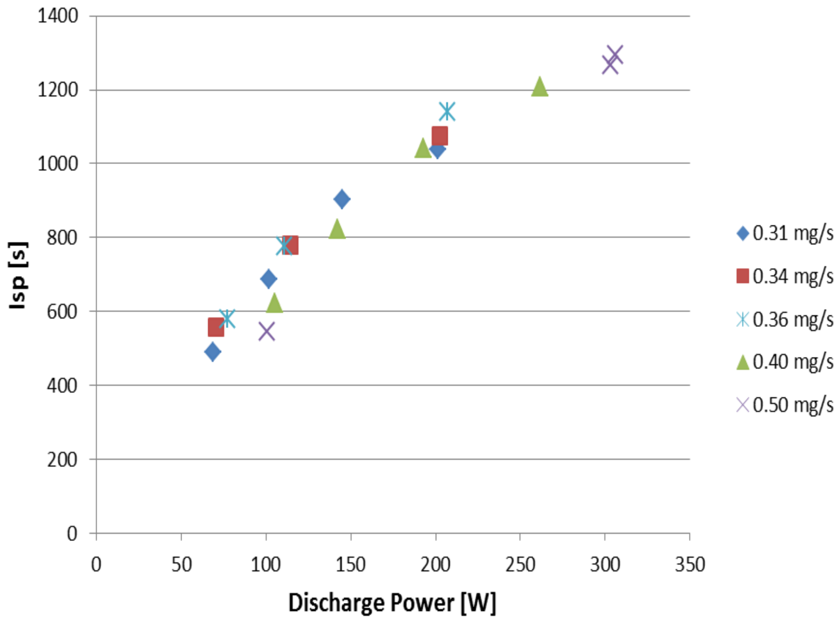
Thrust with Xenon Propellant



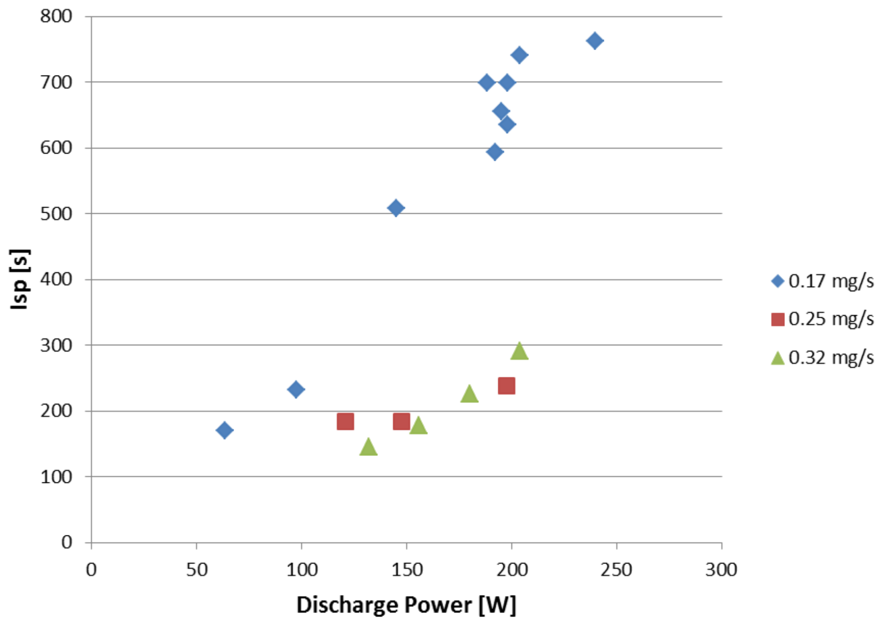
Thrust with Argon Propellant

Specific Impulse Comparison

- Higher specific impulse can be achieved with flight qualified Cathode
- Cathode flow rate = 0.3 mg/s Argon & 0.2 mg/s Xenon



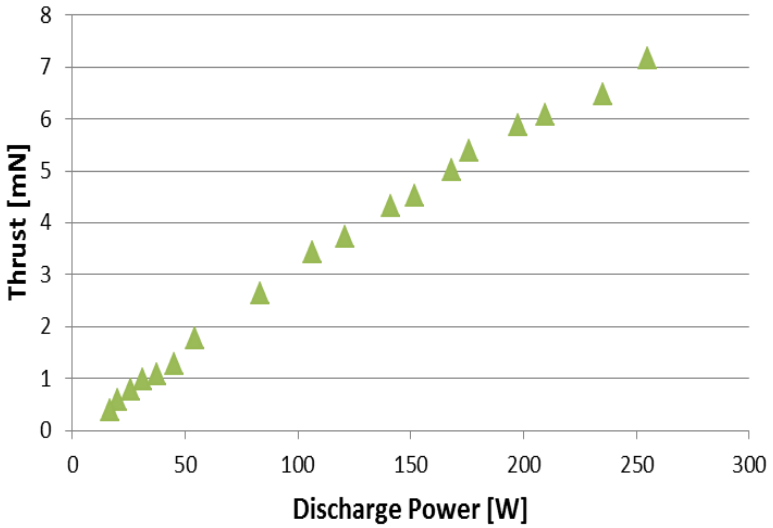
Specific Impulse: Xenon Propellant

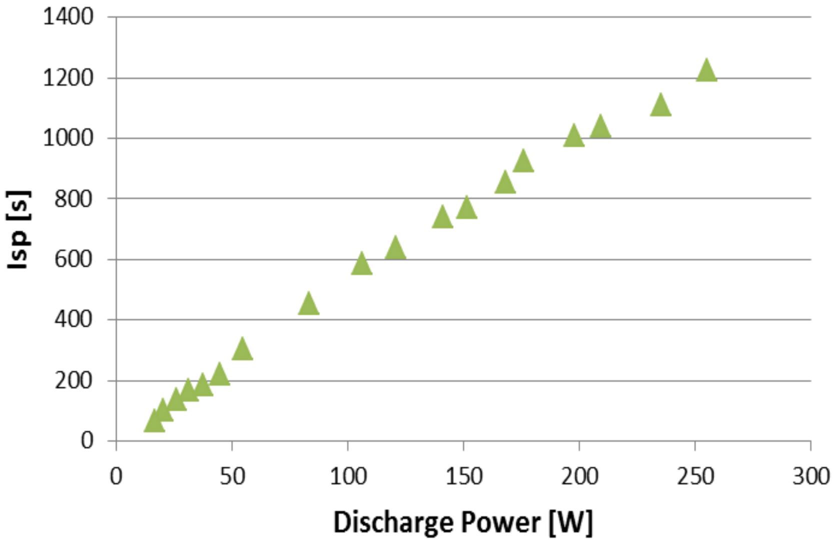


Specific Impulse: Argon Propellant

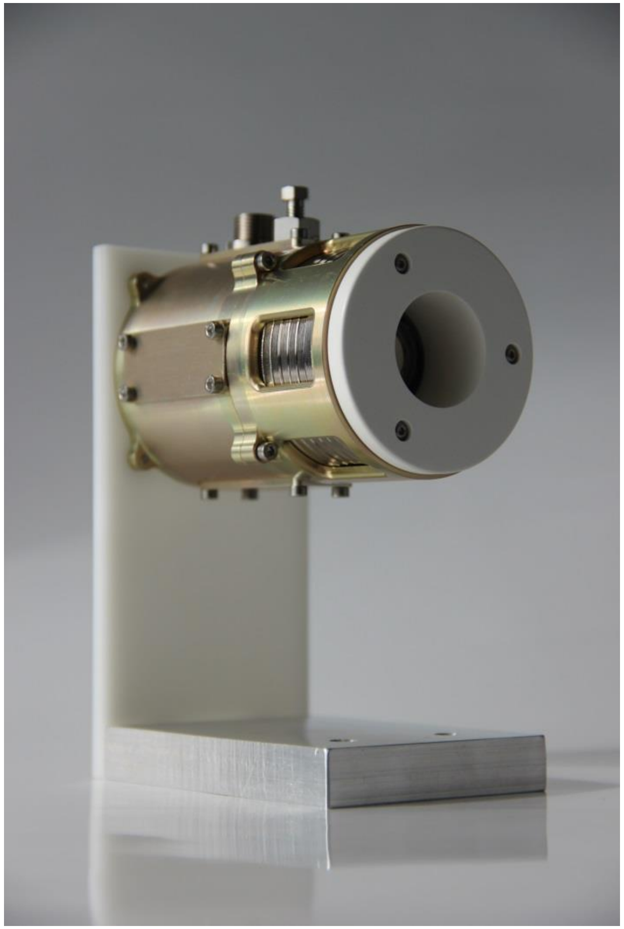
Variable Power Operation

- Xenon operation with fixed 0.4mg/s propellant flow rate
- Stable operation from 15W to 250W



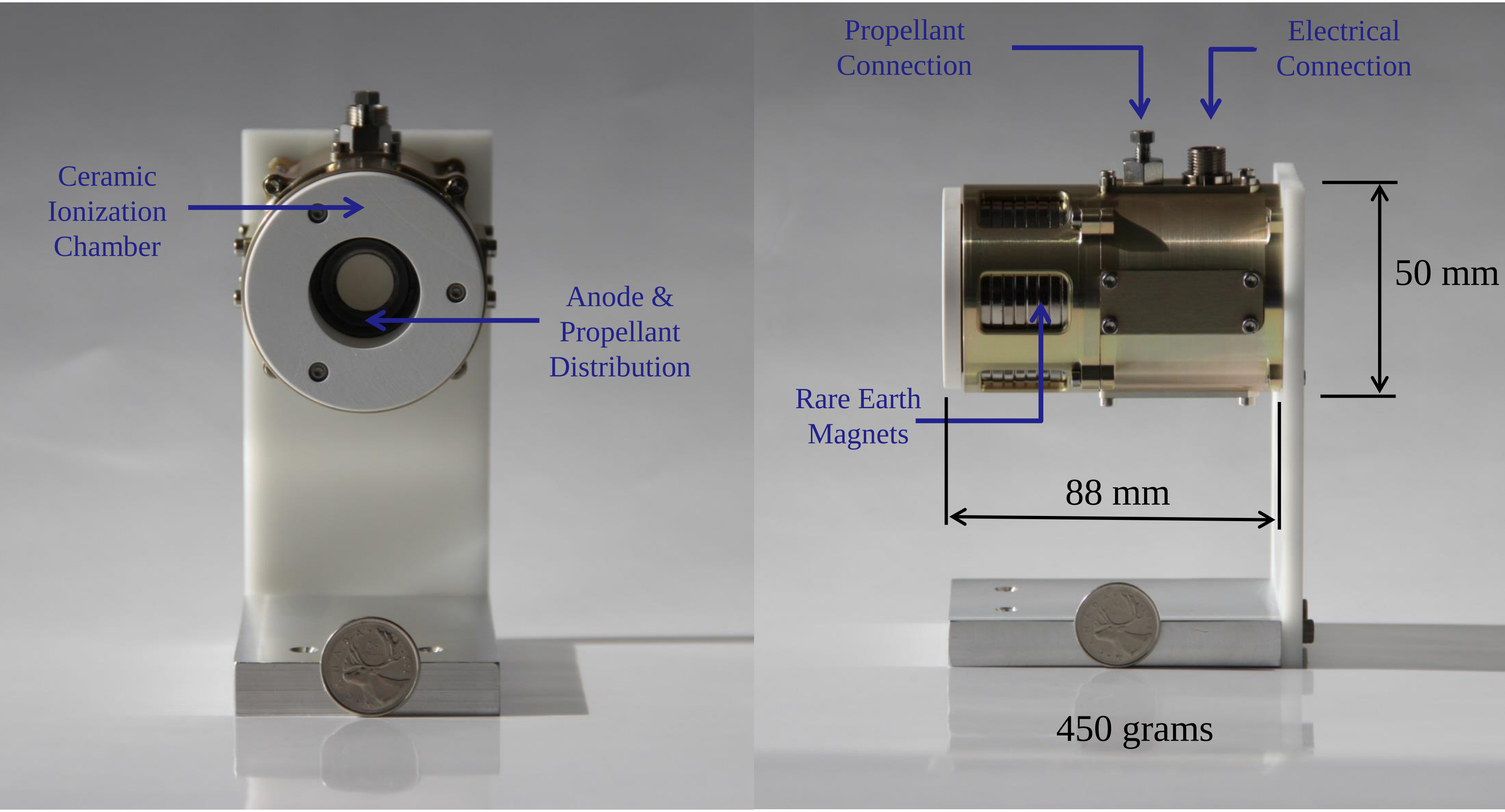


Mark 2 Model

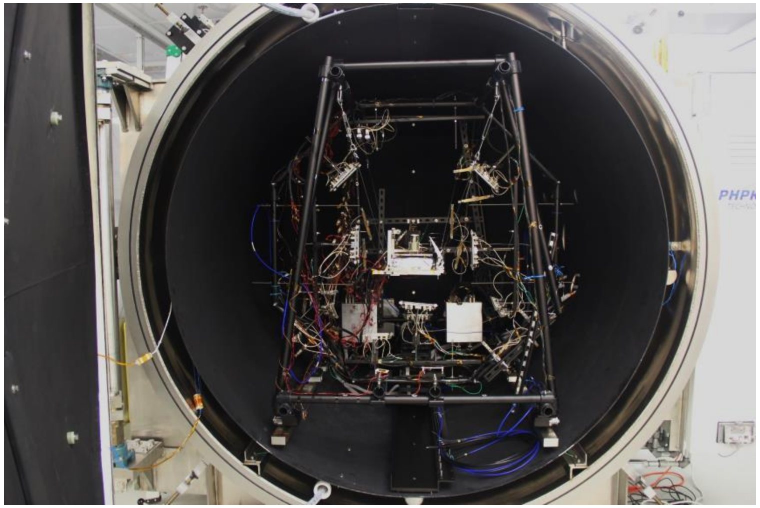


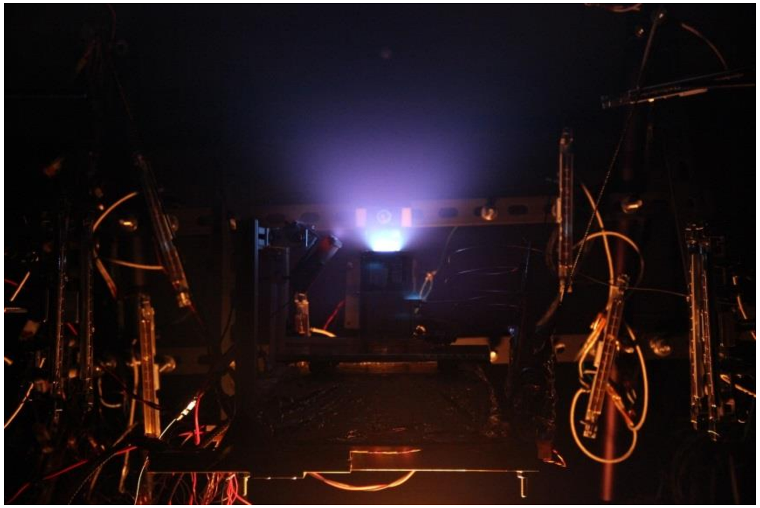
- Funded internally by SFL
- Electromagnets replaced with permanent magnets
- 70% Lighter than prototype
- Smaller (fits in standard 1U CubeSat volume)
- Designed for space environment
  - Passive thermal management
  - Launch loads
  - Gas & Electrical connections

Mark 2 Model


Ceramic Ionization Chamber
Anode & Propellant Distribution
Propellant Connection
Electrical Connection
50 mm
Rare Earth Magnets
88 mm
450 grams

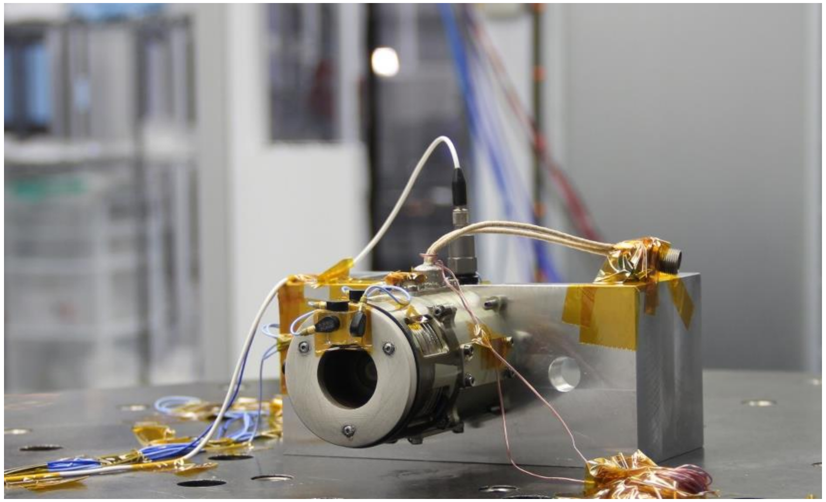
TVAC Acceptance

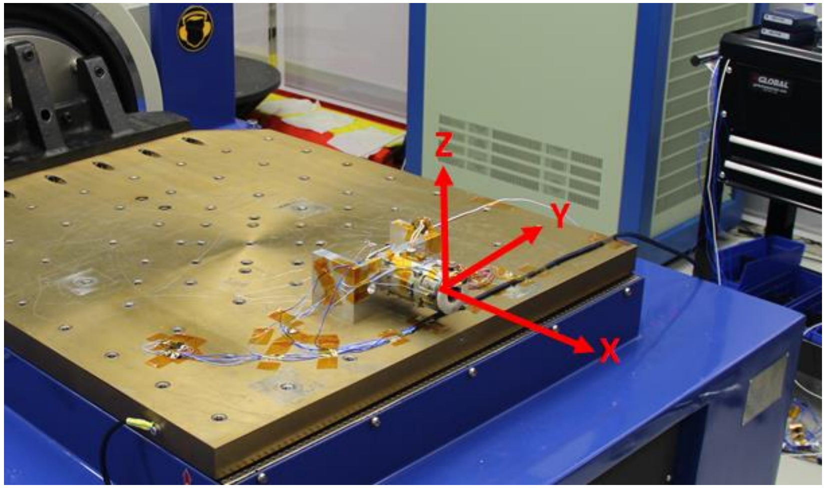




- Thruster was mounted on a radiator designed to dissipate 10 Watts when held at 60°C
- Test included:
  - Cold start at -20 °C
  - Steady state operation at 200 W
  - Cold soak (Thruster reached -70 °C)
- No cracks or degradation observed

Vibration Acceptance

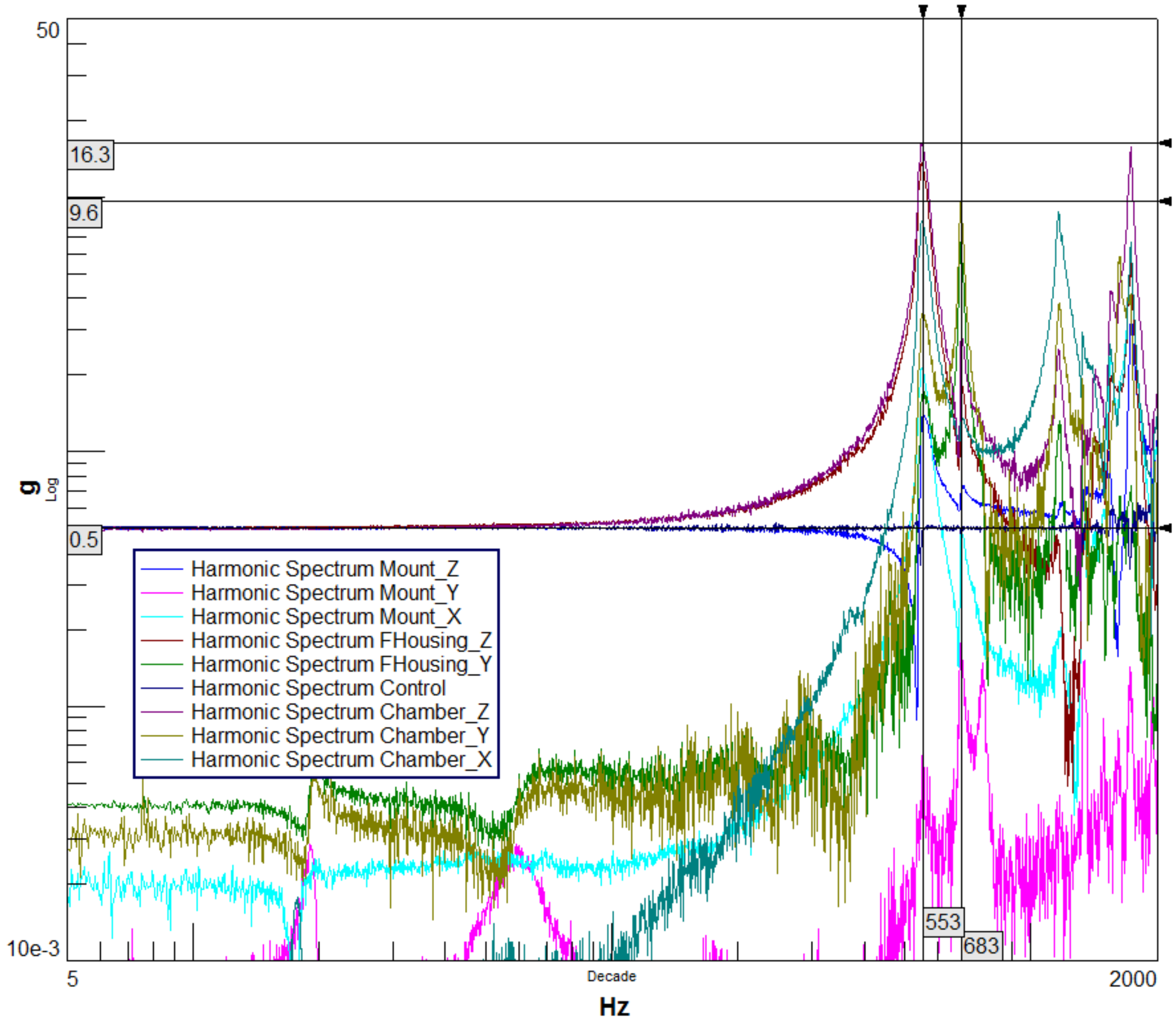




- **Goal:** Validate thruster design which was built to be indifferent of launch vehicle type
- Worse case scenario of all common launch vehicle systems tested
- Each axis tested as follows:
  - Sinusoidal burst
  - Sinusoidal
  - Random
  - 50 G Shock
- Functional test performed after each run (visual inspection & continuity checks)

Low level Sine Sweep

- Lowest natural frequency observed at 553 Hz



Conclusion

- SFL's Mark 2 Cylindrical Hall Thruster successfully passed vibe and TVAC testing
- Further performance characterization and optimization being performed on new model
- Aging studies on Mark 2 model will be performed to quantity improvement over Mark 1 model

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Sinusoidal Burst test

- Simulate quasi-static accelerations expected on the DNEPR launch vehicle
- 10.7 G's over frequency range of 9 Hz to 10 Hz at 0.5 Hz/sec

Sinusoidal test

Frequency (Hz)	Acceleration (g)	Displacement (mm, 0-peak)
5	1.74	17.4
8	4.5	17.4
100	4.5	0.099
Sweep Rate: 2 Oct/min		

Random vibration

Frequency (Hz)	Acceleration (g)
20	0.026
50	0.16
800	0.16
2000	0.026
g_{rms}	14.1
Duration	120 seconds

Shock test

- 40 g shocks have been experienced on PSLV. With added 25% margin, shock test was performed at 50 g, half-sine waveform for duration of 10ms