Optimization of an Adamantane Thruster for CubeSat Deorbiting

Unconventional Electric Propulsion Propellants

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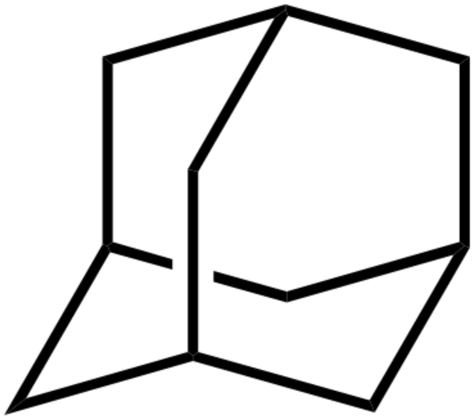
Introduction

Advanced Spacecraft Propulsion & Energy Lab

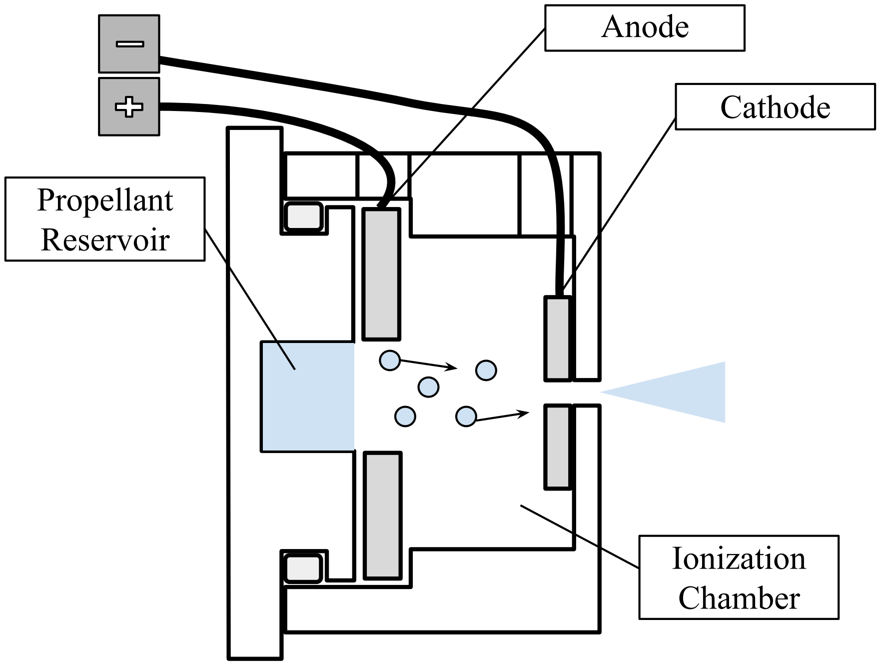
Thruster Design

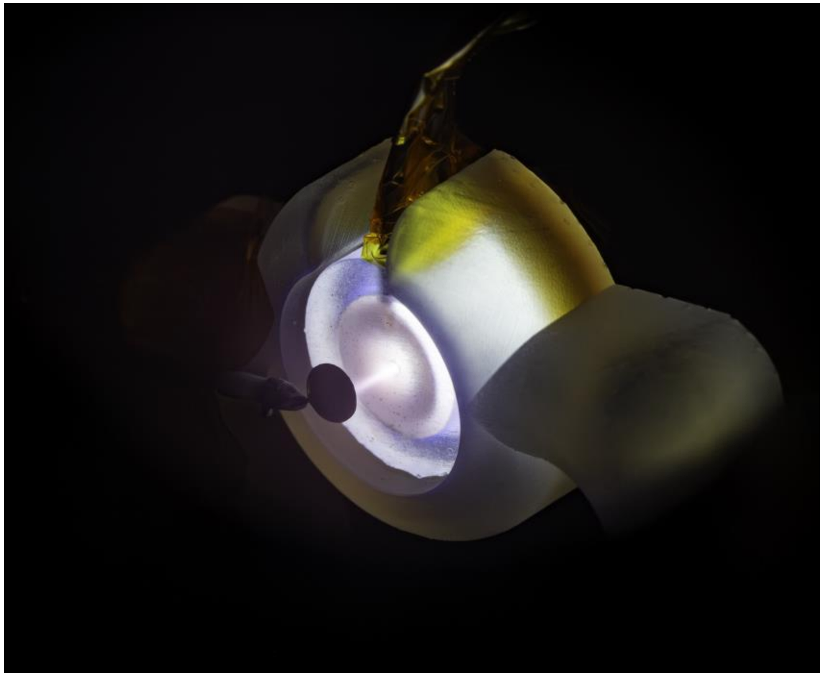
- Goal: to construct and test an ion thruster using solid adamantane propellant
- Adamantane: $C_{10}H_{16}$
  - Solid at room temperature
  - Sublimation pressure of 93 mTorr at room temperature
  - Ionization energy of 9.75 eV
  - Easy to contain
  - Density of 1.08 g/cm^3



Thruster Design

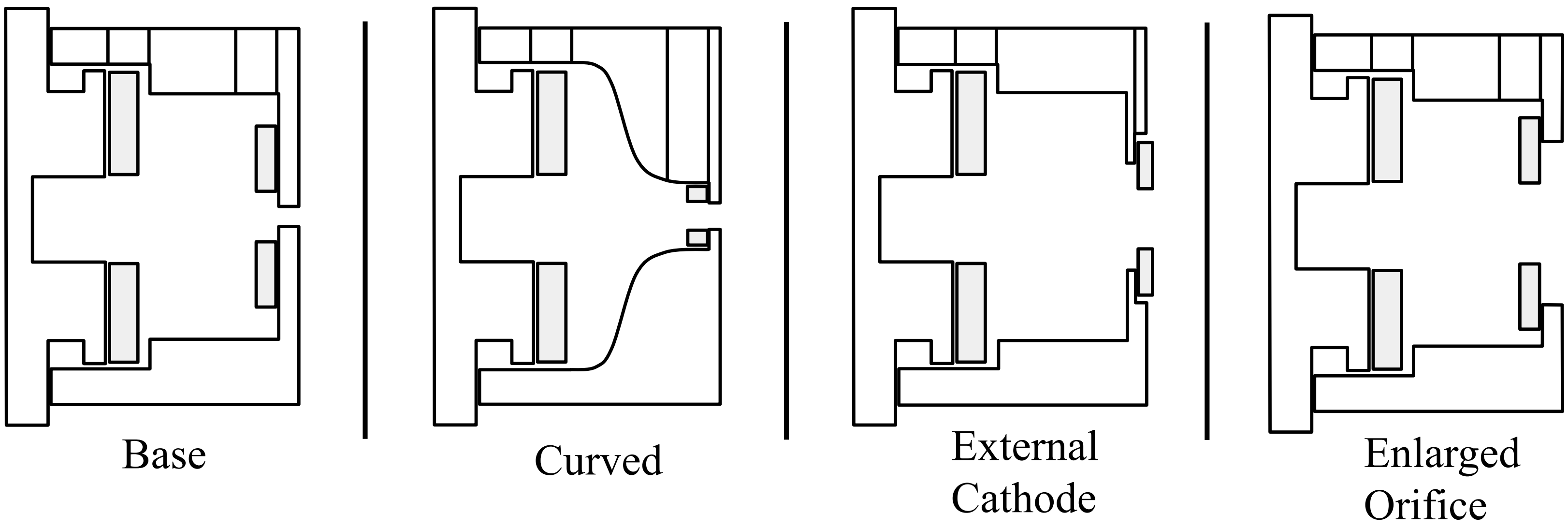
Adamantane is stored as a solid powder in the propellant tank and sublimates into a vapor where it is ionized and accelerated in the ionization chamber





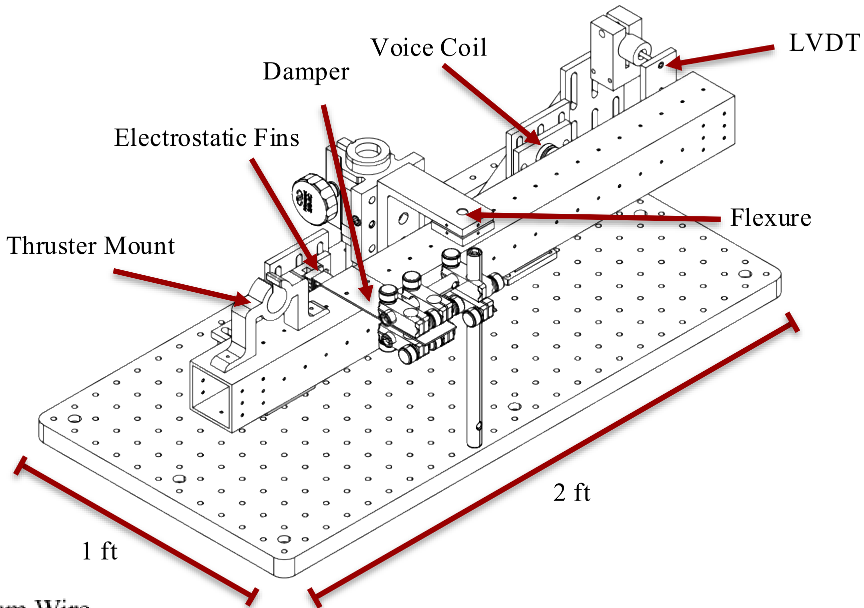
Thruster Design

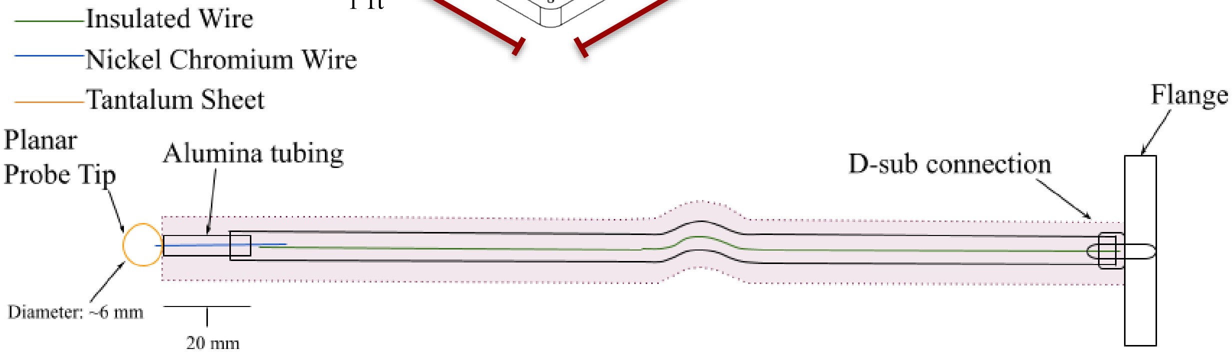
A curved ionization chamber, enlarged orifice, and external cathode design were explored to analyze the behavior of adamantane plasma



Diagnostic Capabilities

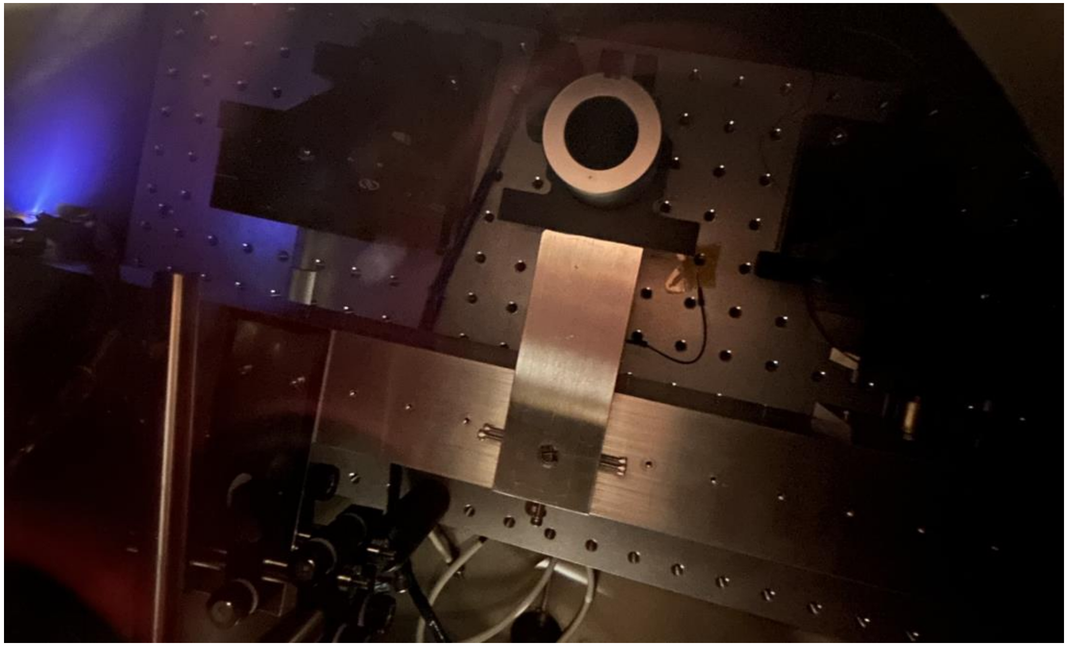
- Torsional null balance pendulum thrust stand
- Langmuir probe





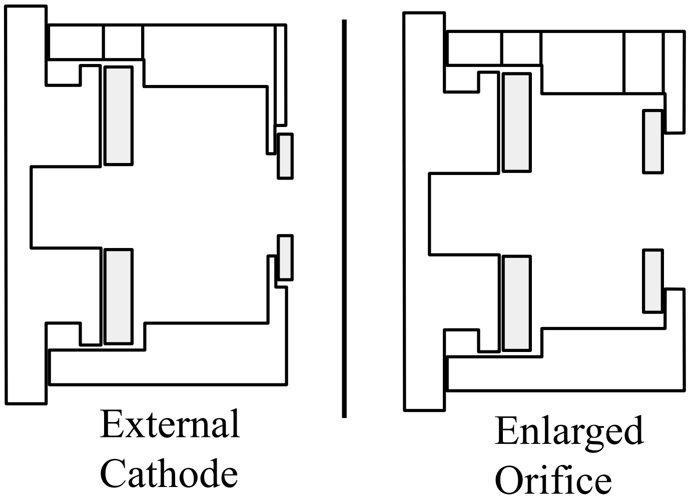
Thruster Testing – Procedure

- Chamber pressure: 1E-4 Torr
- Power supply current limited to 2 mA
- Thrusters fired until no plasma was observed



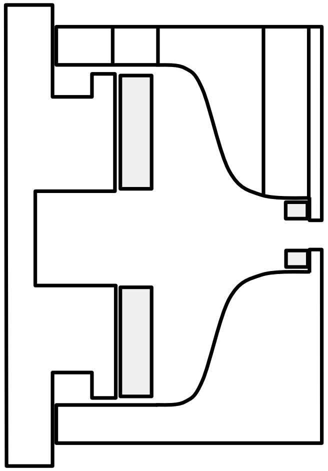
Thruster Testing – Enlarged Orifice, External Cathode

- Failure to ignite
- Larger orifice leads to low chamber pressures



Thruster Testing - Curved

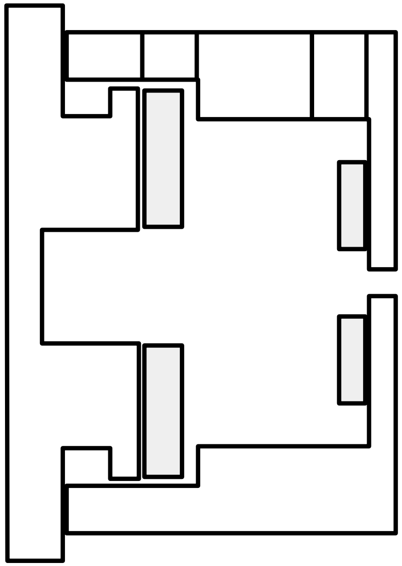
- Unstable ignition
- Excessive arcing
- Introduced problems with data collection



Curved

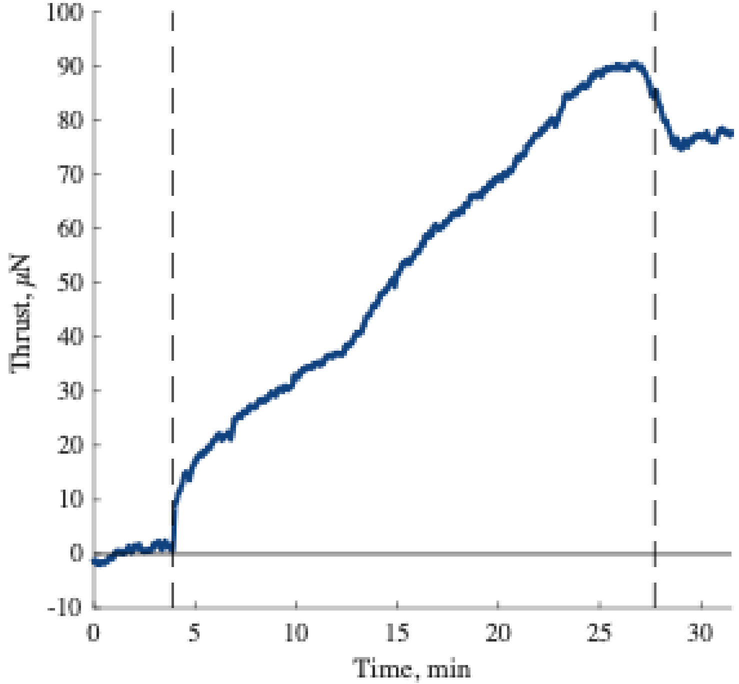
Thruster Testing - Base

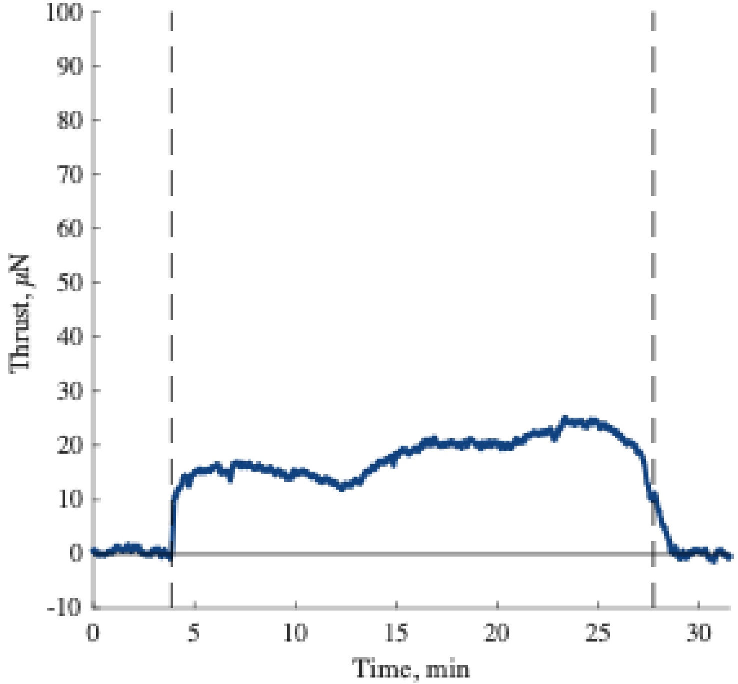
- Reliable ignition
- Stable operation behavior



Base

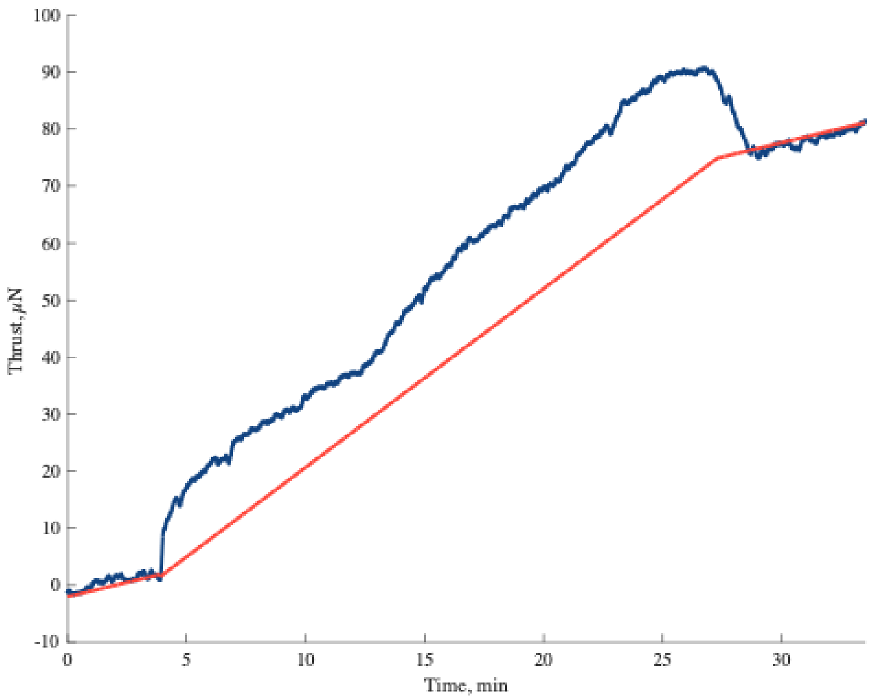
Thruster Testing – Thrust Stand

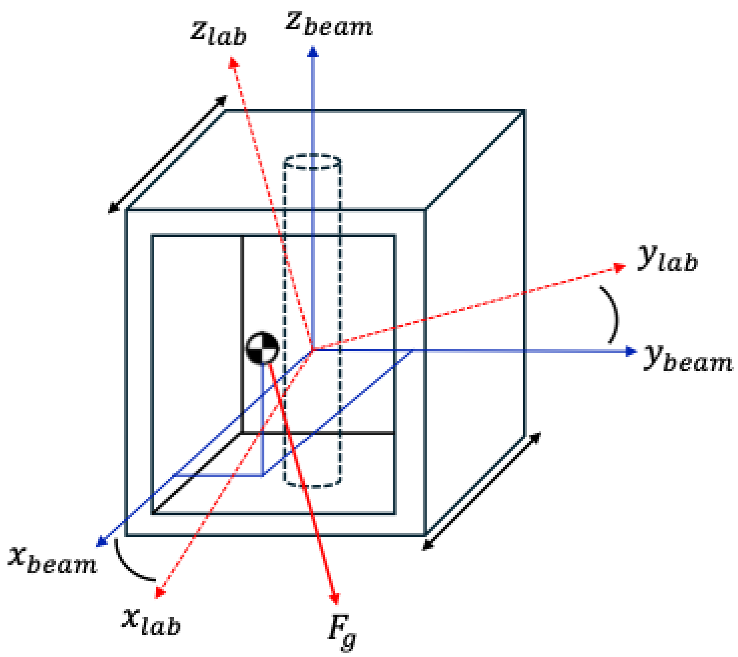




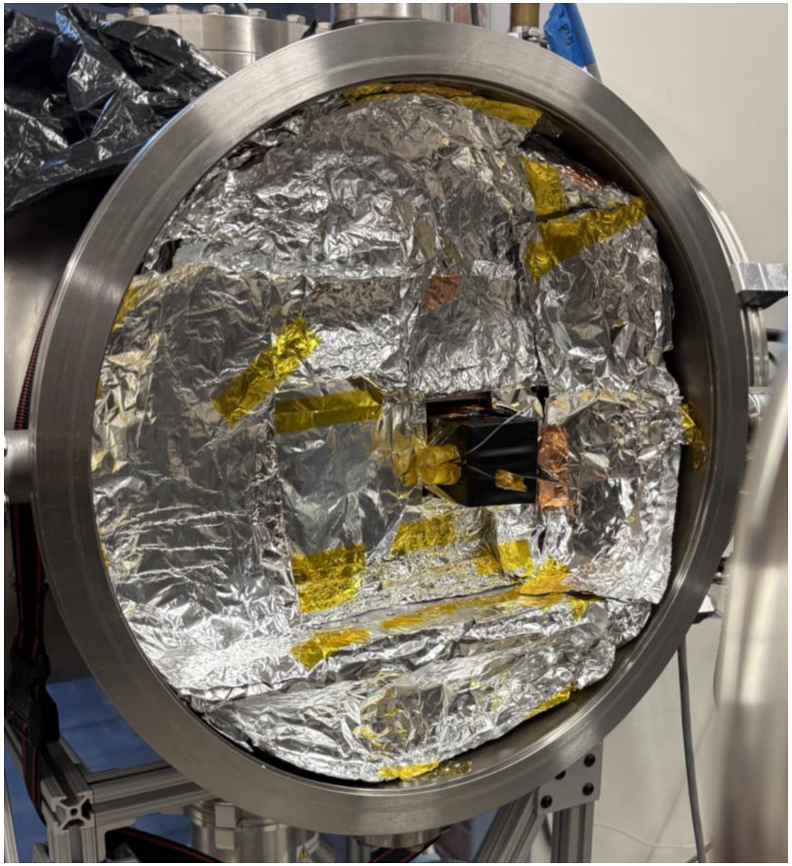
Geometry	Thrust, μN	Power, W
Base	20 ± 6	1.9 ± 0.3

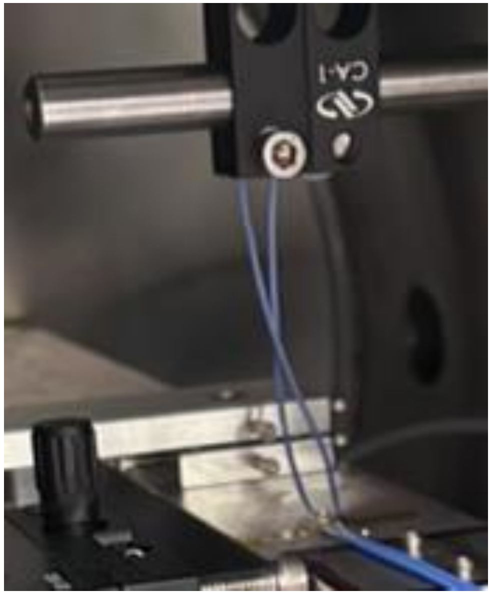
Thruster Testing – Thrust Stand



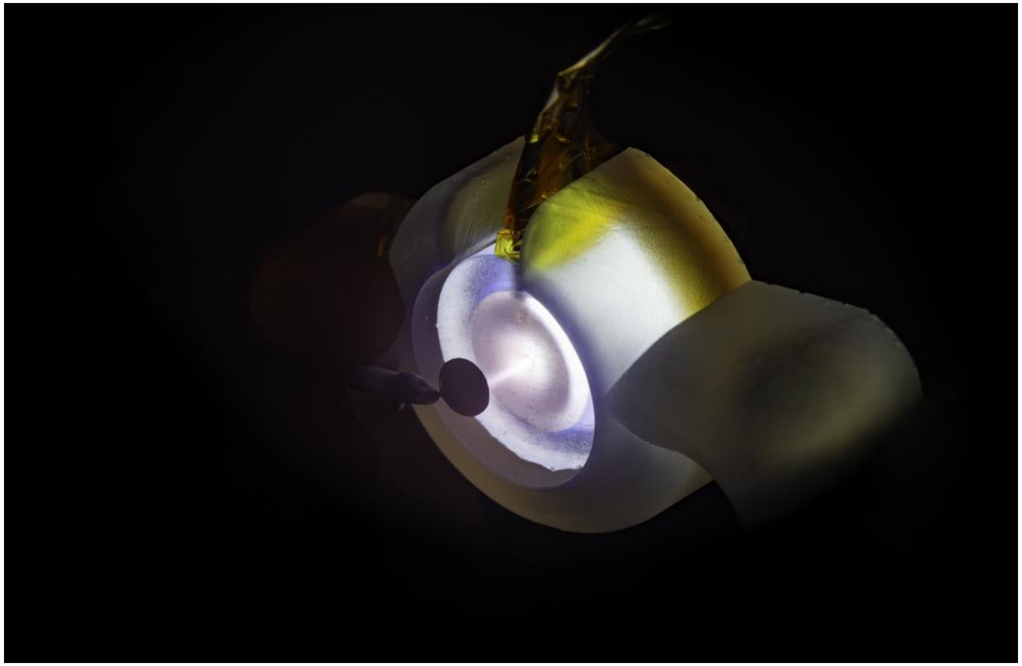


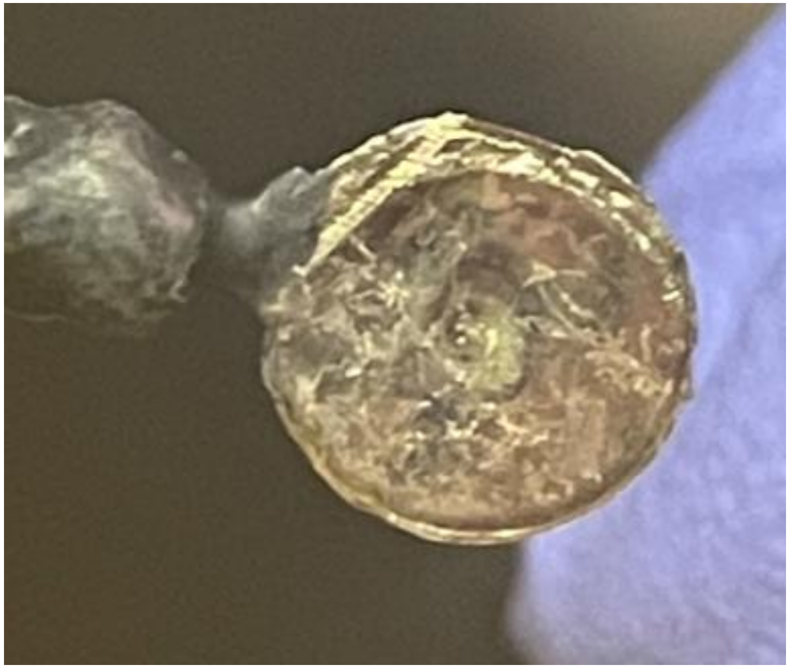
Thruster Testing – Thrust Stand





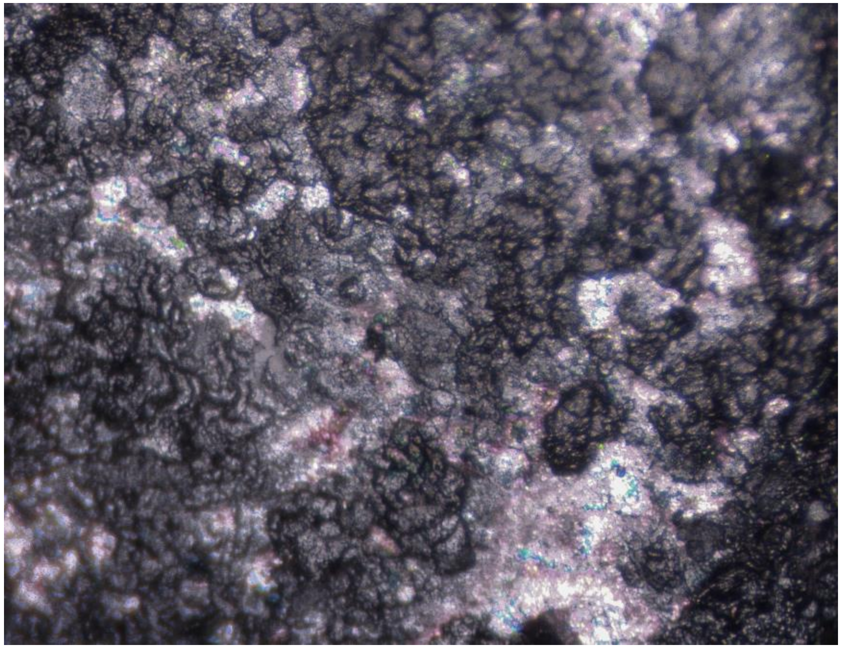
Thruster Testing – Langmuir Probe





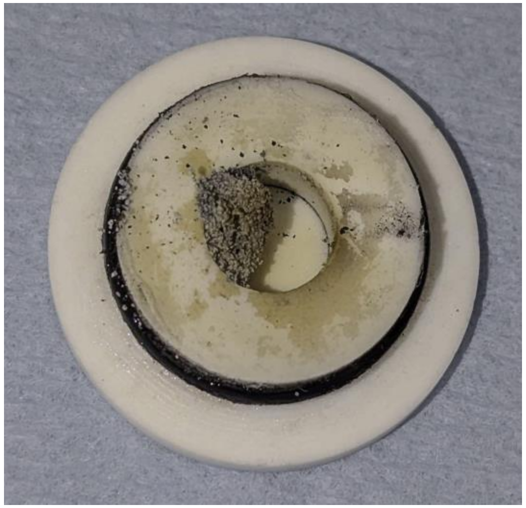
Thruster Testing – Contamination Study

- As a hydrocarbon, one major issues with adamantane is the carbon byproducts
- Thruster operation created amorphous carbon deposits on the interior of the thruster



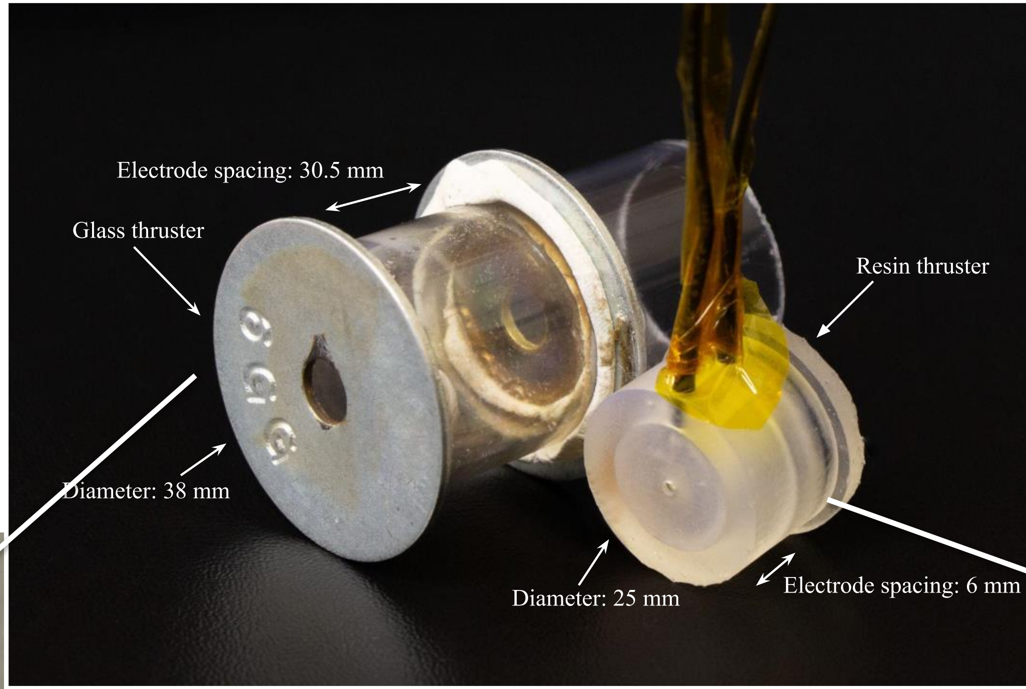
Thruster Testing – Contamination Study

- In addition to the amorphous carbon found on the electrodes, a glass-like carbon was found in the propellant tank
- Ultem, Macor, and glass thrusters were tested to mitigate deposition
  - Ultem and Macor generated both types of carbon
  - Glass only generated amorphous carbon

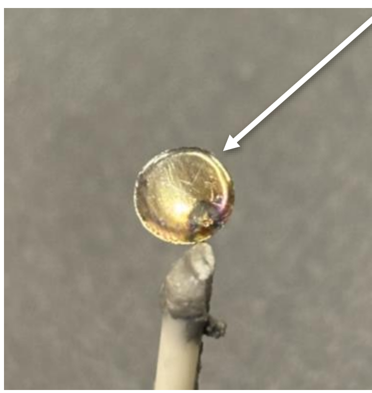


Thruster Testing – Contamination Study

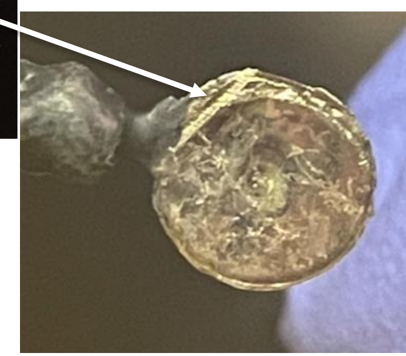
Initial resistance: 0.4 Ω



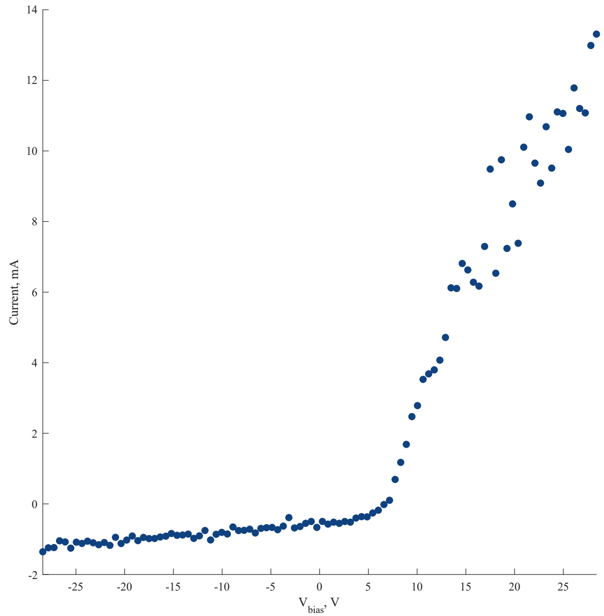
Resistance: 0.7 Ω

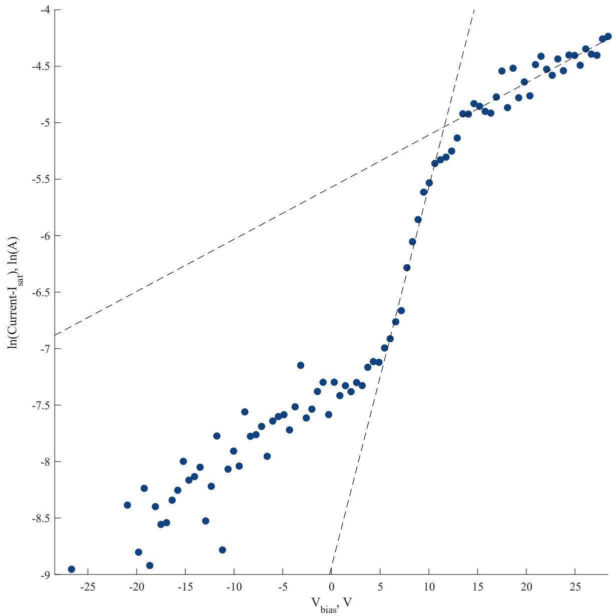


Resistance: 5.7 kΩ



Data Analysis



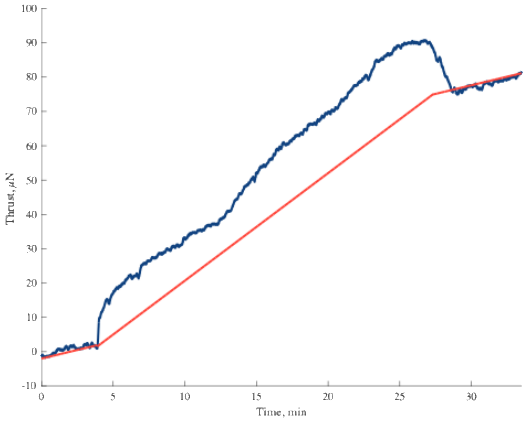


Property	Propellant Flow
Electron density (n_e), m^{-3}	$1.4 \cdot 10^{17} \pm 1.1 \cdot 10^{16}$
Electron temperature (T_e), eV	3.0 ± 0.4
Plasma potential (Φ_p), V	12 ± 0.2
Floating potential (Φ_f), V	6.9 ± 1.4

Data Analysis

$$I_i = F_t \sqrt{\frac{q_i}{2 m_i V_0}} \longrightarrow I_i = 0.4 \pm 0.1\, mA$$

$$\eta_b = \frac{I_i}{I_d} \longrightarrow \eta_b = 20\% \longrightarrow$$ Geometry impacting efficiency



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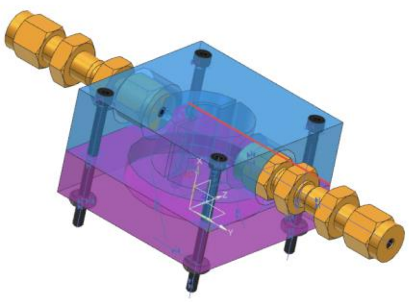
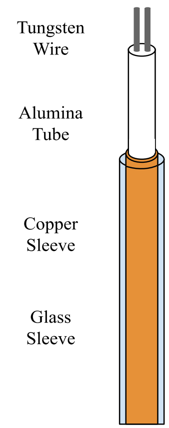
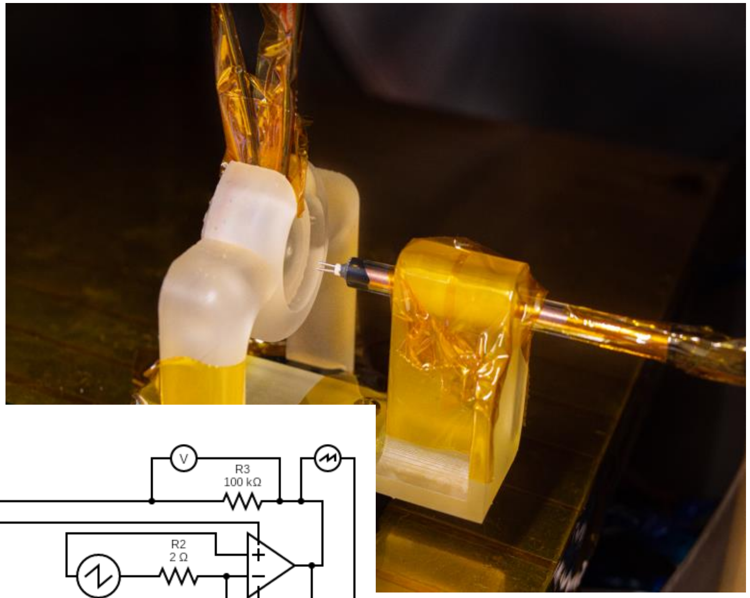
- Passive propellant loss
- Warm gas thrust from comparison with simulations

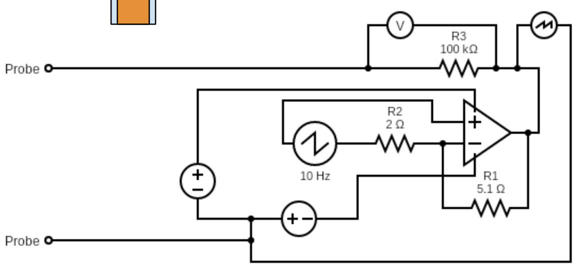
Future Work

- Propellant canister and feed system
- Thruster redesign with material selection in mind
- Expand diagnostic suite
  - Double Langmuir Probe
  - Faraday Cup









Conclusion

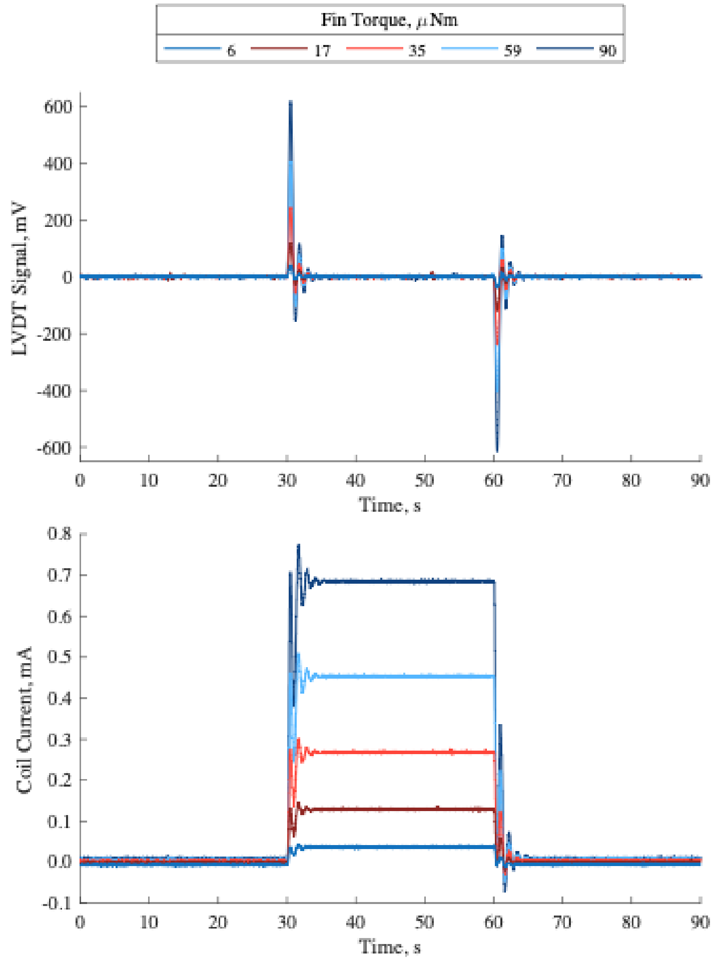
- We have constructed a thrust stand and Langmuir probe, establishing a strong foundation for continued electric propulsion research.
- Thrust and power data have been obtained for the lab's base geometry thruster. Low efficiencies in both current and mass utilization require further thruster iteration.
- Adamantane's behavior has been analyzed, and work is being done to incorporate compatible materials for reducing contamination.
- Adamantane's plasma parameters have been measured suggesting adamantane is easily ionized.

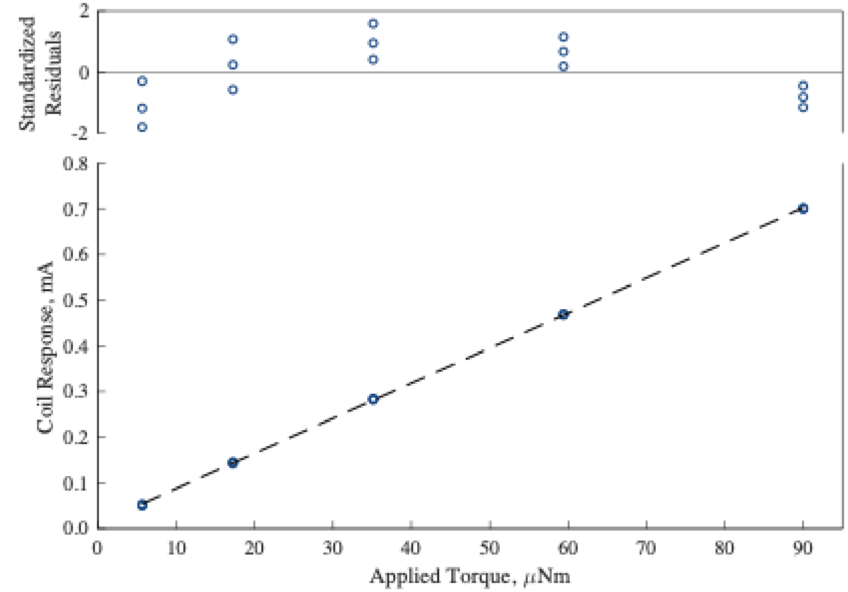
ASPEN will work towards developing a CubeSat deorbit thruster by further expanding the lab's diagnostic suite and iterating the thruster design.

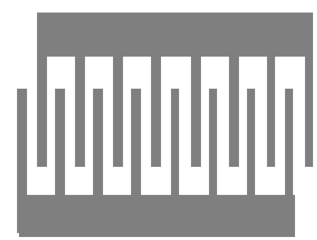
THANK YOU
Q & A

ASPEN

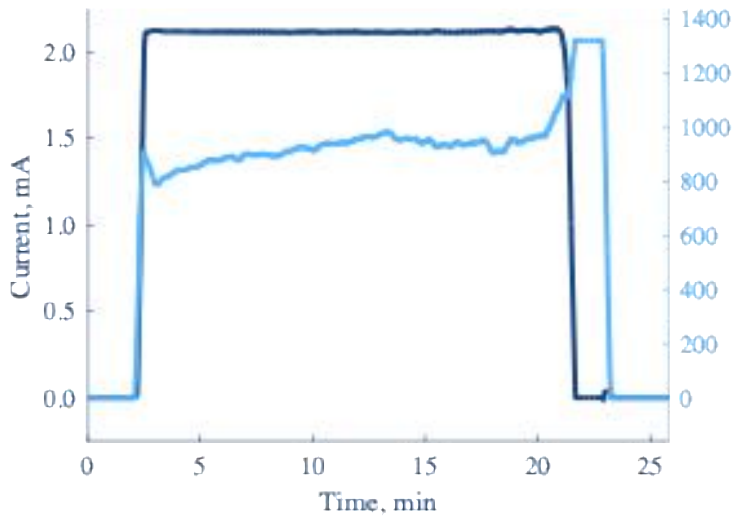
Backup – Thrust Stand Calibration

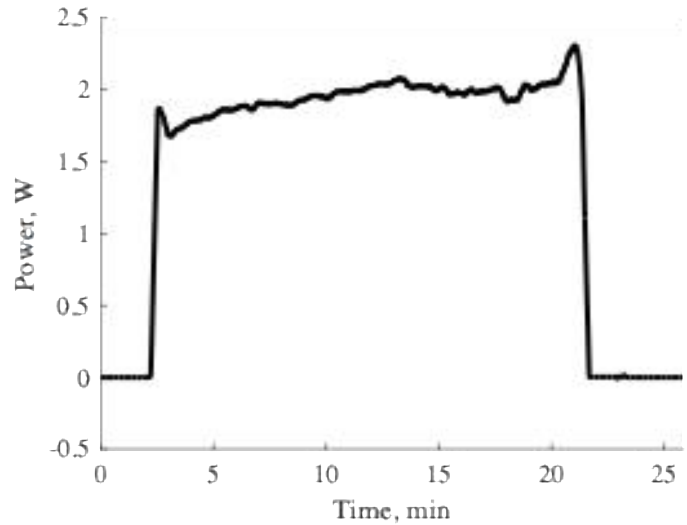






Backup – Power Data





Geometry	Current, mA	Voltage, V	Power, W
Base	2.10 ± 0.09	900 ± 100	1.9 ± 0.3

Backup – Ion Current Derivation

$$F_t = \dot{m} v_e$$

$$\dot{m} = \frac{I_i m_i}{q_i} \qquad v_e = \sqrt{\frac{2 q_i V_0}{m_i}}$$

↓

$$I_i = F_t \sqrt{\frac{q_i}{2 m_i V_0}} \longrightarrow I_i = 0.4 \pm 0.1\ mA$$

$$\eta_b = \frac{I_i}{I_d} \longrightarrow \eta_b = 20\%$$