# Testing of a Solid Fuel Adamantane Ion Thruster

## The Asteria Project

*Kayden Elmer-Schurr†; Olivia Kukar†; Sebastian Matiauda*; Dev Pokhriyal*; Kayden Cutchins†; Jonathan Fisher†*

Advisors:

*Lubos Brieda‡; Matthew Gilpin§*

*† Student in AME/ASTE/CHE, University of Southern California*

** Alumni, University of Southern California*

*‡ Part-time Lecturer of Astronautical Engineering, University of Southern California*

*§ Associate Professor of Aerospace and Mechanical Engineering Practice, University of Southern California*

# Who We Are

ASPEN


Advanced Spacecraft Propulsion & Energy Lab

- Undergraduate student-led organization, founded in 2018
- Focused on educating students in industry-applicable skills, introducing them to state-of-the-art propulsion technology, and performing cutting-edge research

BLUE ORIGIN

BOEING

# Motivation

- Provide undergraduate students experience in working with plasma physics, vacuum facilities, and spacecraft electric propulsion

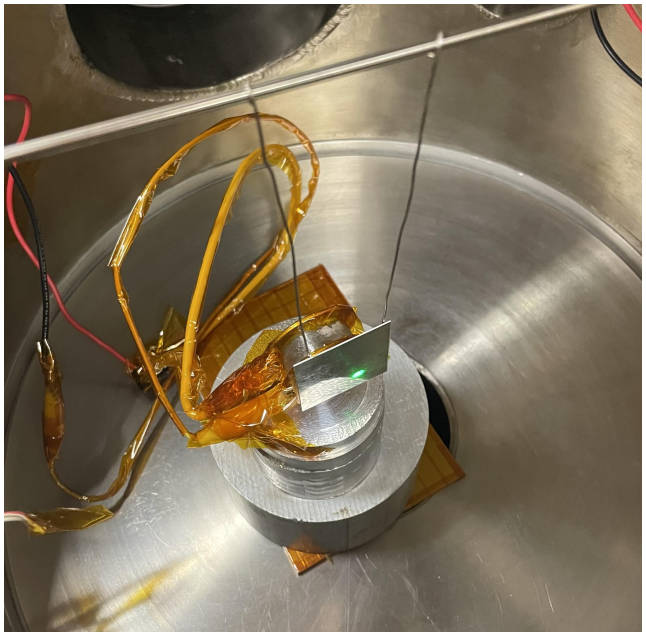
Asteria  Project Objectives:

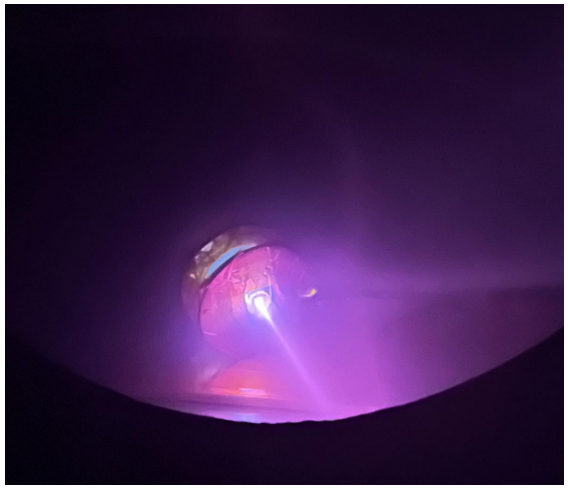
- Developing an “electric solid rocket” ion-gun type thruster for use on Cubesats
- Combines the high  Isp of electric propulsion thrusters with the tankless design of chemical rockets
- Offers test bed for conducting research into molecular propellants and the potential use of solid fuel propellants
- Longer term, demonstrate bench-top and possibly flight integration with ISE/SERC satellites

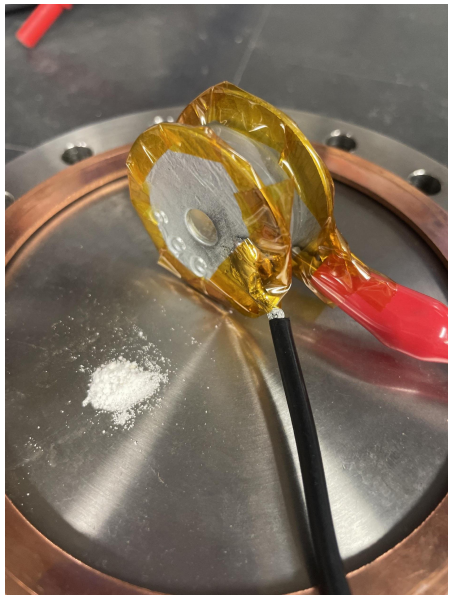
# Project Description

## The Asteria Project

- Evaluate effectiveness of solid Adamantane ($C_{10}H_{16}$) as a propellant for EP
- Utilizing a low power (10W), high-voltage power supply

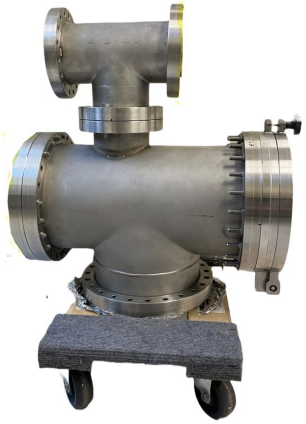






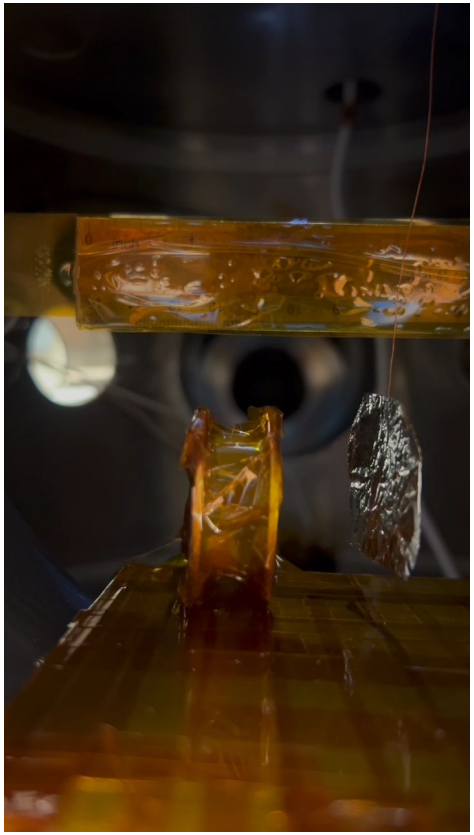
# Lab Build-Up

- Sourced & learn to operate vacuum chambers
- Started with  Bell Jar to produce initial plasma
- Built specialized chamber for testing solely operating on roughing pump
- Moved to a large shared chamber to access turbo pump
- Department and sponsor funded

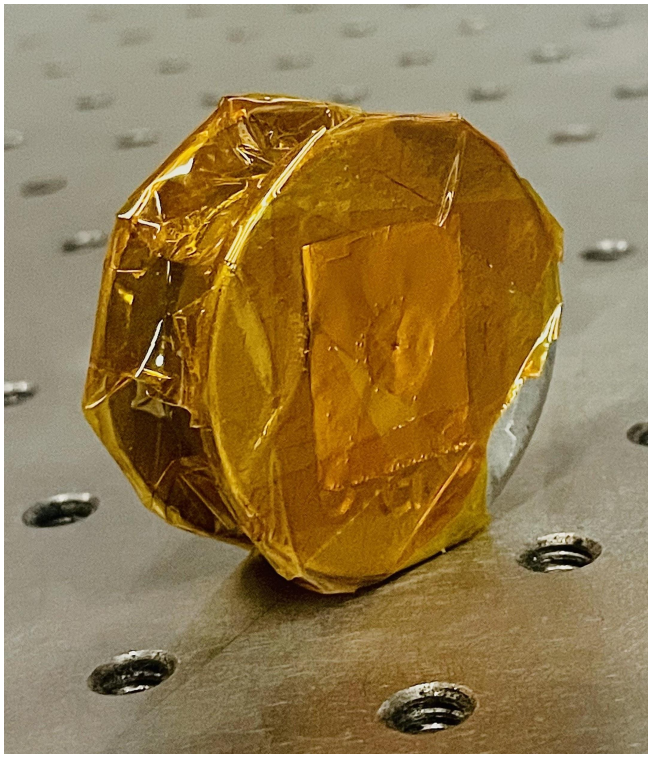



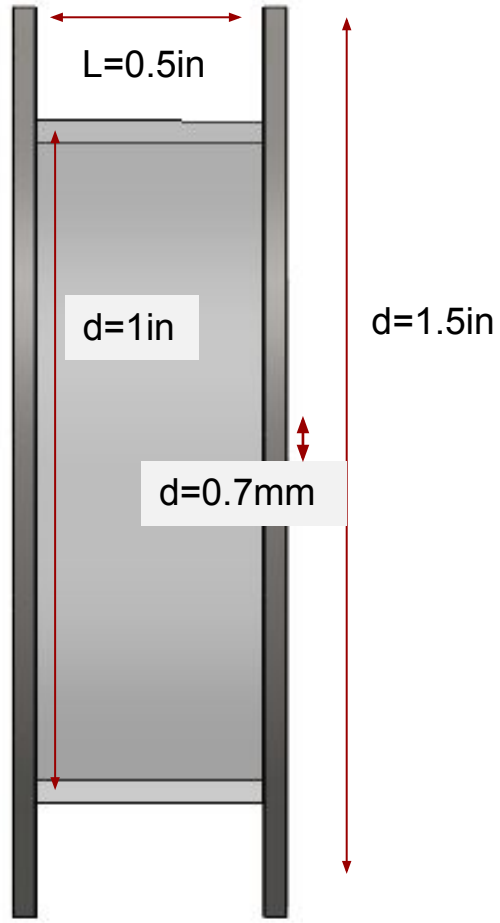
# Initial Test Setup

- Manage sublimation rate of adamantane with pump down time
- Building a proof-of-concept thruster using off the shelf parts
- Learn how to control outgassing & electrostatic effects



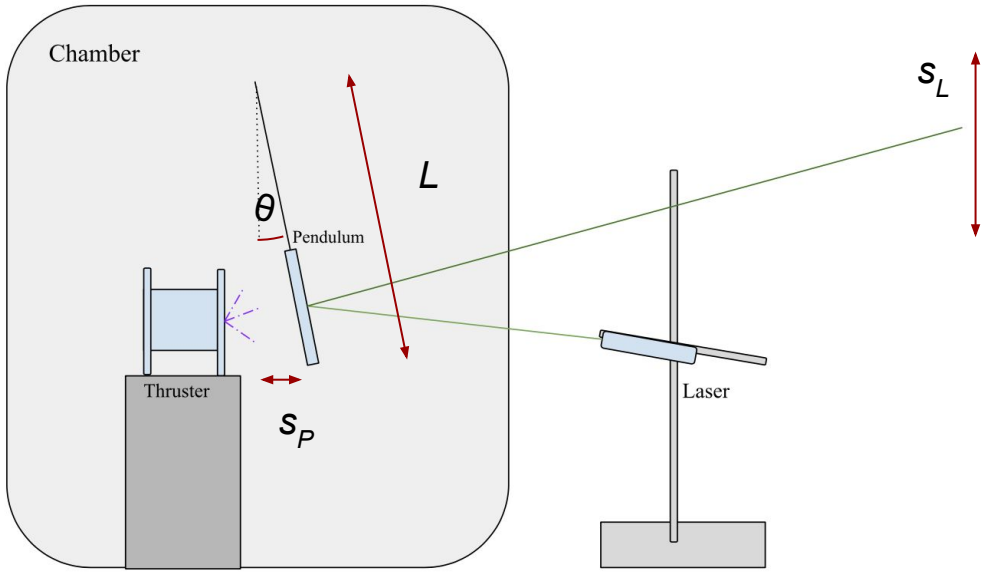
# Thruster Design





# Thrust Measurement

- Indirect thrust measurement with simple pendulum
- Horizontal displacement of the pendulum converted to vertical displacement of a laser
- Operating at 0.3kV and 50mTorr
- Roughing pump only
- Grounded pendulum and chamber



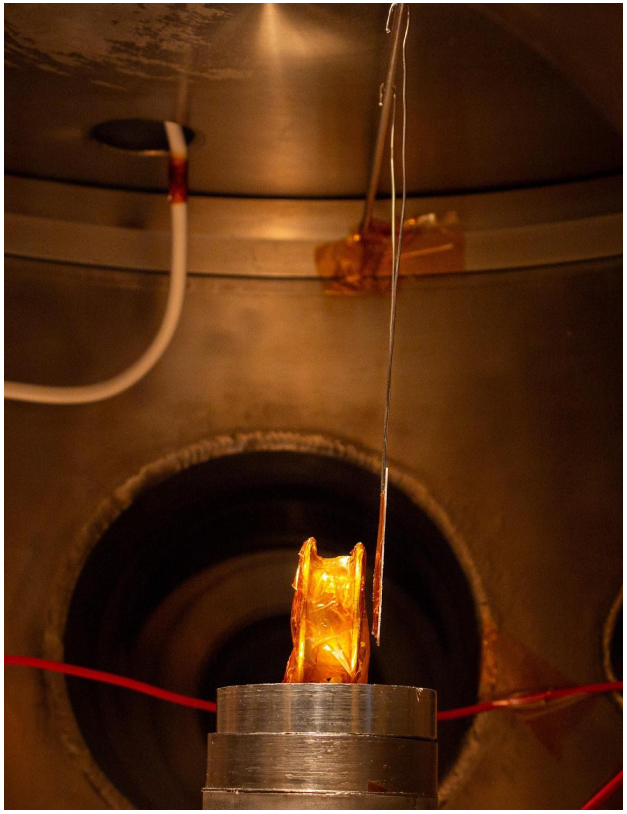

$$F_T = mg \sin\theta$$

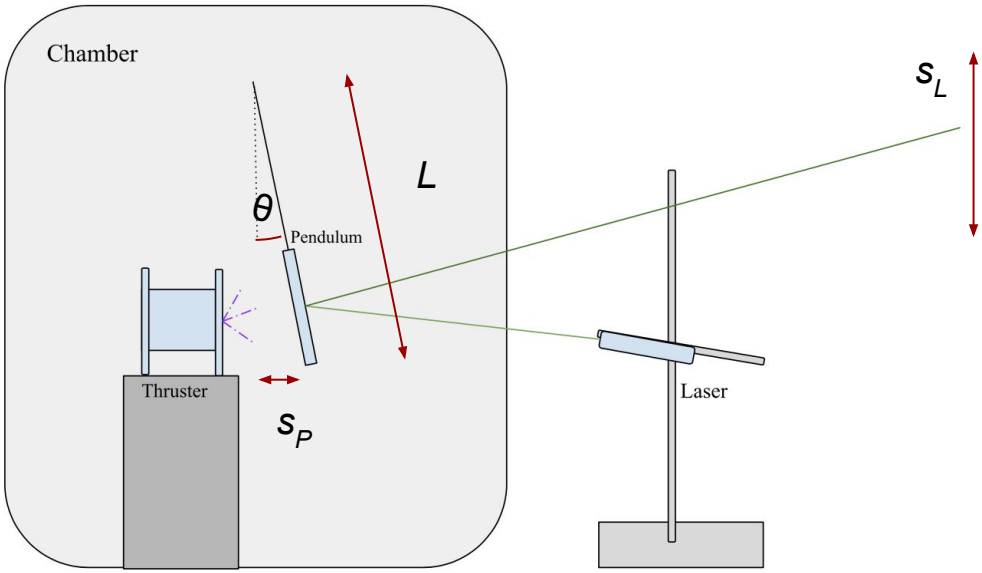
$$F_T = \frac{mgs_P}{L}$$

$$s_P = Cs_L$$

$$\boxed{F_T = \frac{mgCs_L}{L}}$$

# Thrust Measurement



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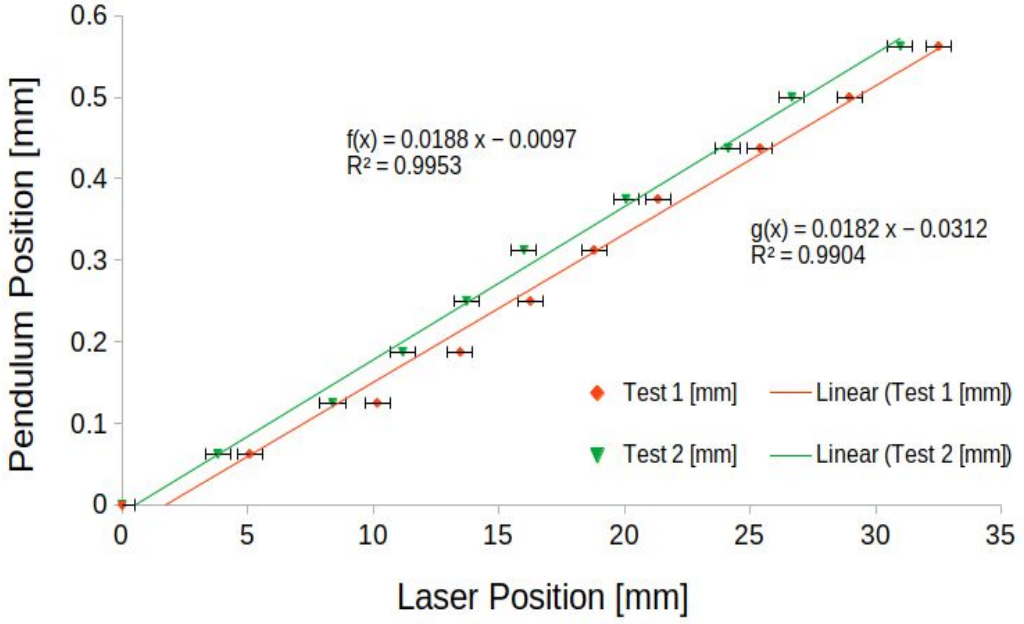
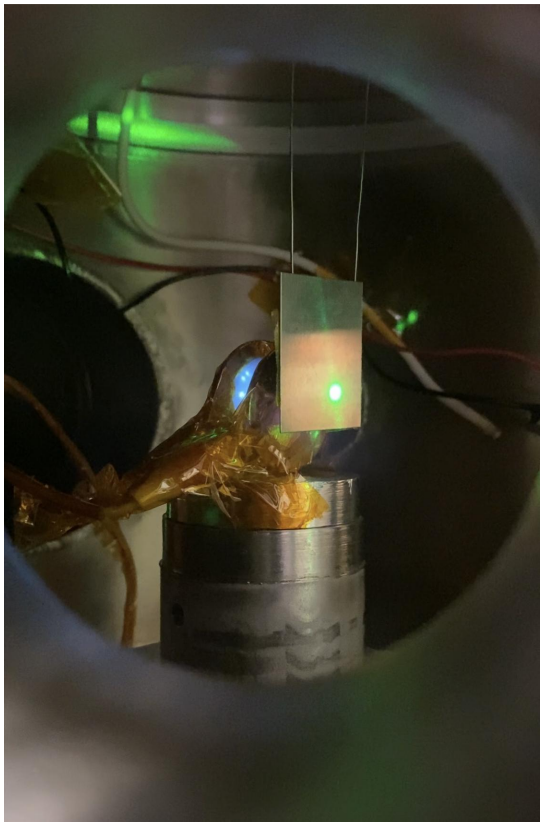
# Calibration

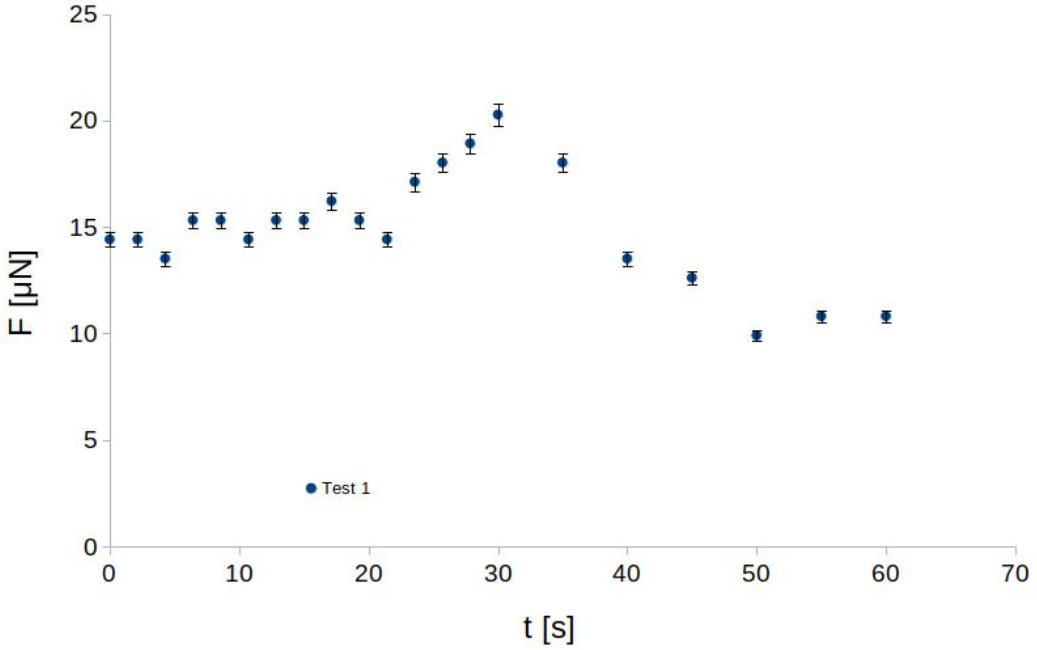
- Laser position is calibrated using a micrometer to displace the pendulum
- 1/16 mm horizontal displacement of the pendulum




Calibration Constant, $C = 0.0185 \pm 0.0006$
~50x Signal Amplification

# Results



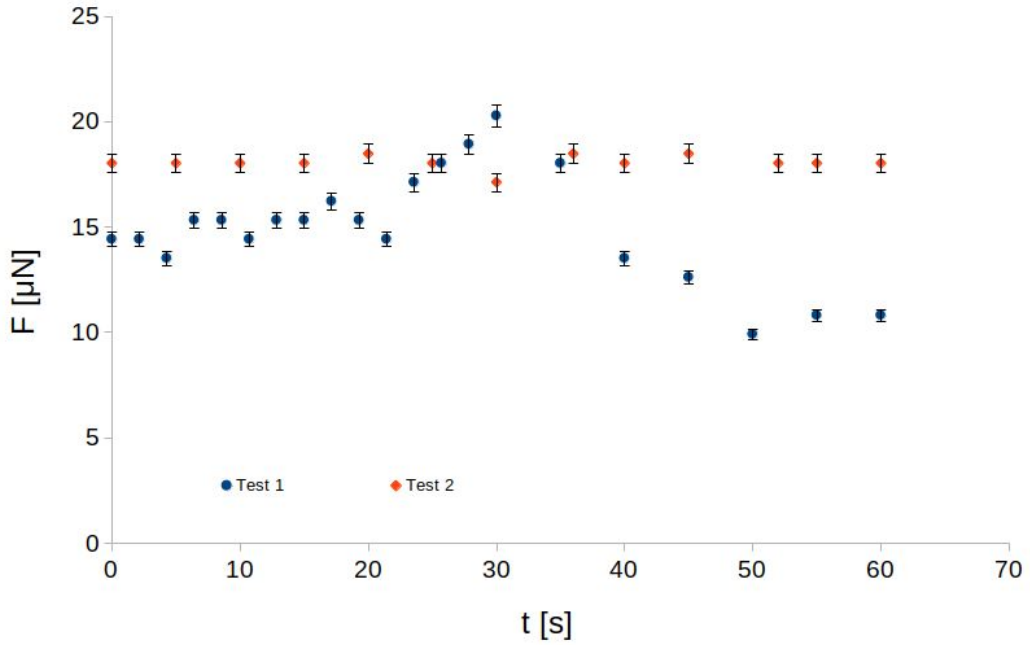



Average, Test 1: 15±8 µN

Peak: 20 µN

# Results

- Secondary test had better performance
- More steady thrust

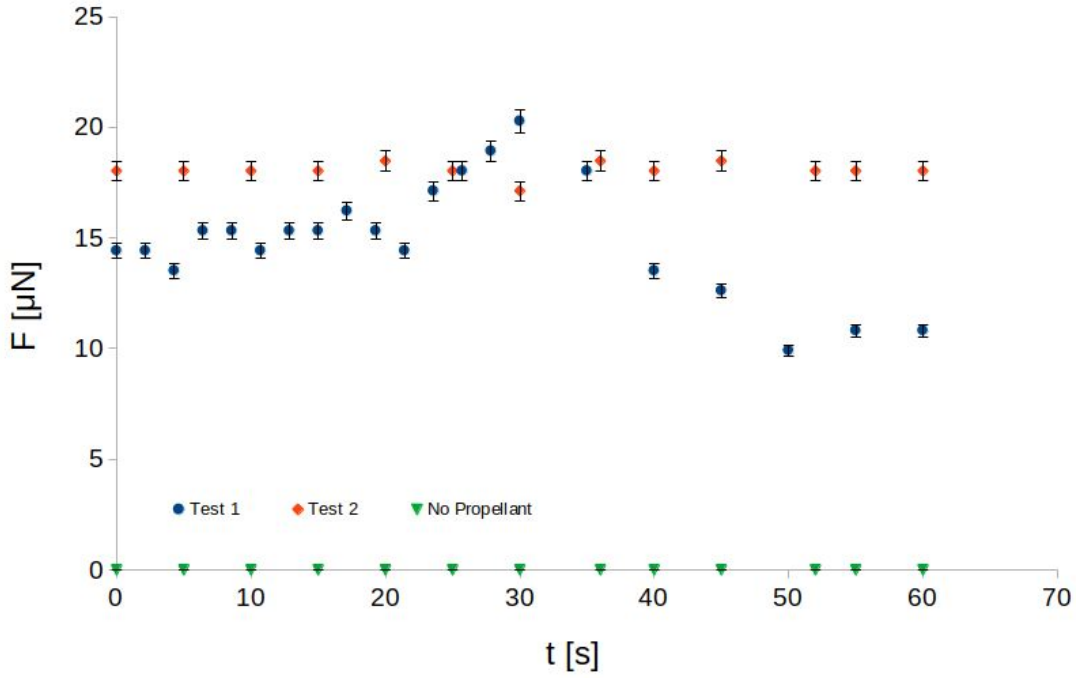



Average, Test 2: 18±3 μN

Peak: 19 μN

# Results

- Test was conducted with no adamantane in the thruster and resulted in no displacement of the pendulum
- Demonstrates no electrostatic attraction, i.e. no thrust without adamantane

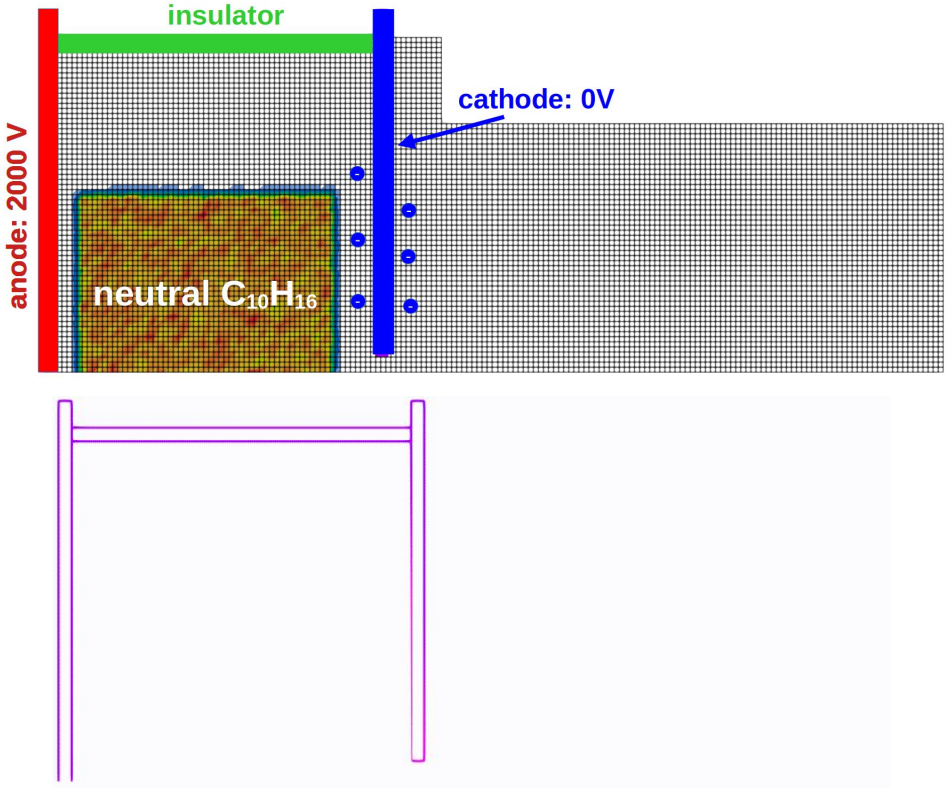



Average, No Propellant: 0±3 μN
Limited by instrument resolution

# Numerical Simulations

- Eventually to be used for thruster design optimization
- Using 2D ES-PIC code (Starfish) with all species modeled as particles
- Internal cavity filled with neutral adamantane molecules
- Kinetic electrons with artificially increased mass injected at cathode
- Using MCC algorithm to model ionization, cross-section given by Holste, et al.[1]
- Loss mechanisms not yet included

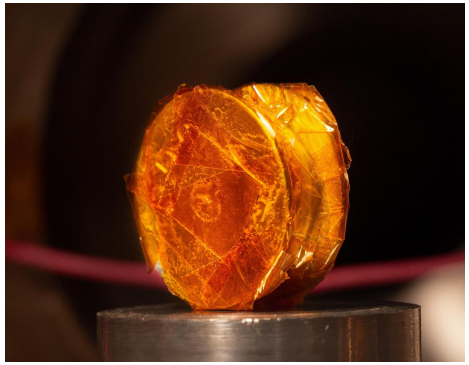
[1] K. Holste, et al.; Ion thrusters for electric propulsion: Scientific issues developing a niche technology into a game changer. *Rev. Sci. Instrum.* 1 June 2020; 91 (6): 061101. doi: 5.0010134

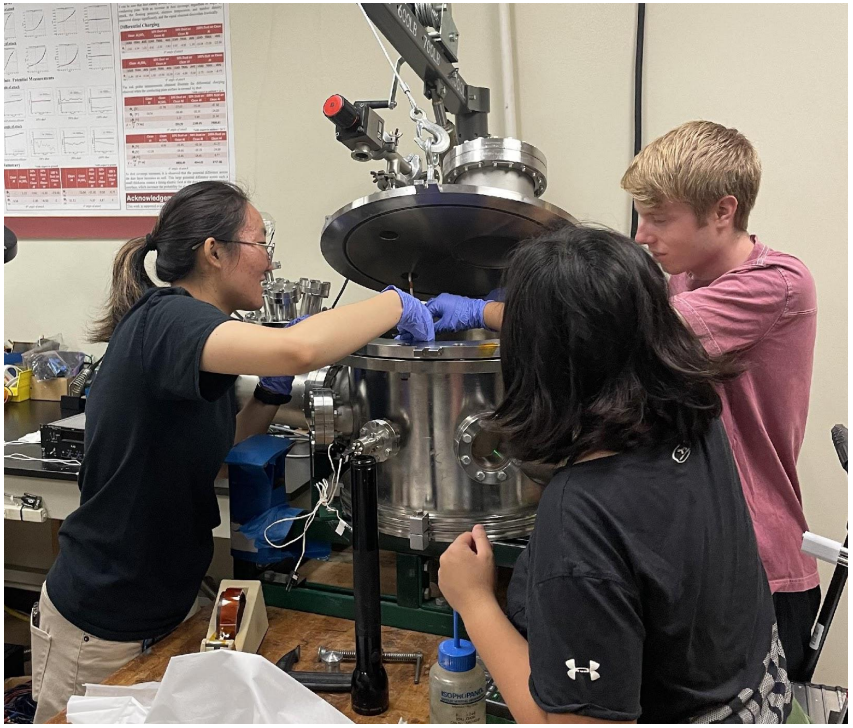



Adamantane ion density and plume velocity streamlines

# What We Accomplished

- Built up a vacuum lab for undergraduate use
- Learned to assemble, operate, and perform vacuum experiments
- Successfully demonstrated & indirectly measured thrust from a solid adamantane fueled  EP device





# Future Work

- Thrust Stand Improvements
  - Direct thrust measurement with inverted pendulum
- Instrumentation for V(t) and I(t)
- Thruster Redesign (short term)
  - Improve seal on end caps
  - Revision to reduce contamination from repeated testing
- Loss mechanisms included in larger scale simulations
- Full system design for integration on cubesat with ability to collect thruster data from ground (long term)
  - Miniaturization
  - Integrated power supply
  - Multi-thruster design
  - Hot wire filament for neutralization source
  - Valve/membrane for fuel storage

# Q & A

## Contact Information

elmersch@usc.edu ◆ okukar@usc.edu ◆ uscaspen@gmail.com