Psyche

Electric Propulsion Capstone Projects

Overview

Dr. Jason Frieman
NASA Glenn Research Center
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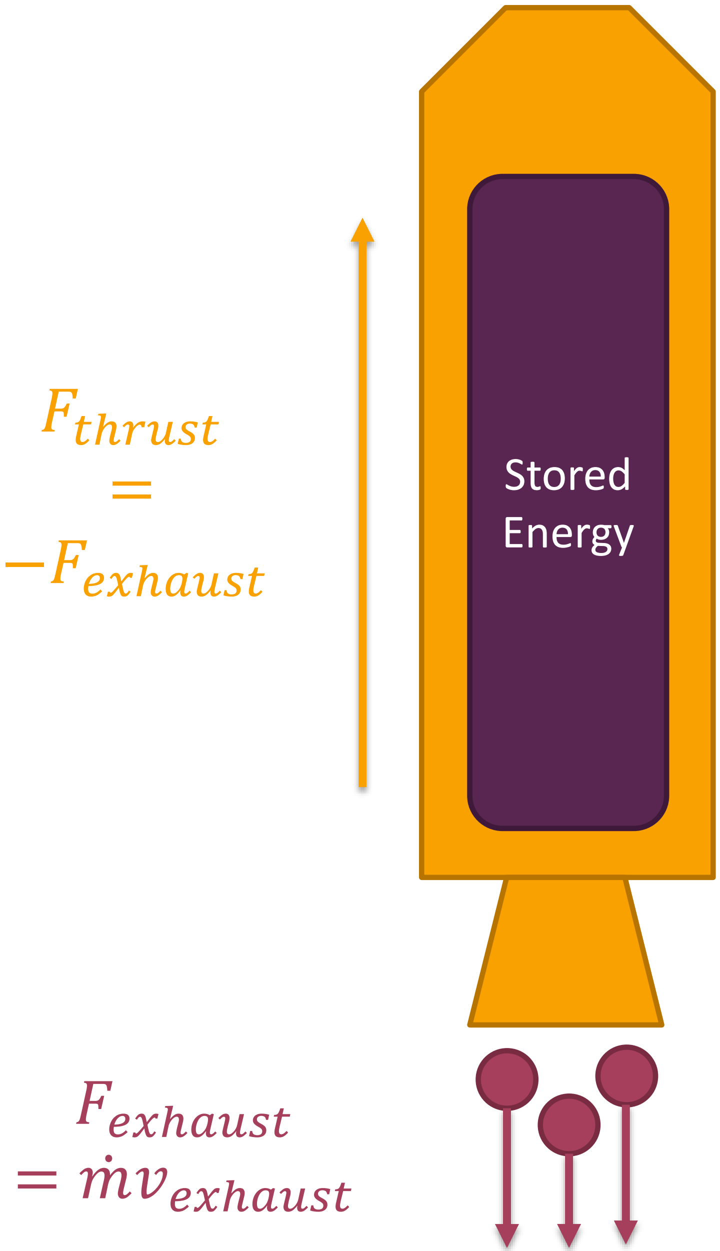
Introduction to Electric Propulsion

Introduction to Rocket Propulsion



- Newton's Third Law of Motion: For every action there is an equal and opposite reaction
- Rockets are devices that leverage this law in order to propel spacecraft:
  - Stored energy is used to accelerate and eject propellant ($F_{exhaust}$)
  - The ejected propellant produces an equal and opposite thrust force (F_{thrust}) on the rocket
- Rocket figures of merit:
  - Thrust: how quickly the rocket can accomplish a maneuver
  - Specific Impulse: rocket fuel efficiency

Types of Rockets

Chemical Rockets

Chemical Energy

Propellant | Oxidizer

↓

Thermal Energy

Combustion

↓

Kinetic Energy

Flow expansion through nozzle

High thrust: 1-1000+ N
Low specific impulse: <450 s

Electric Rockets

Electric Power

Solar Arrays | Batteries

↓

Electrical Energy

Ionization | Plasma

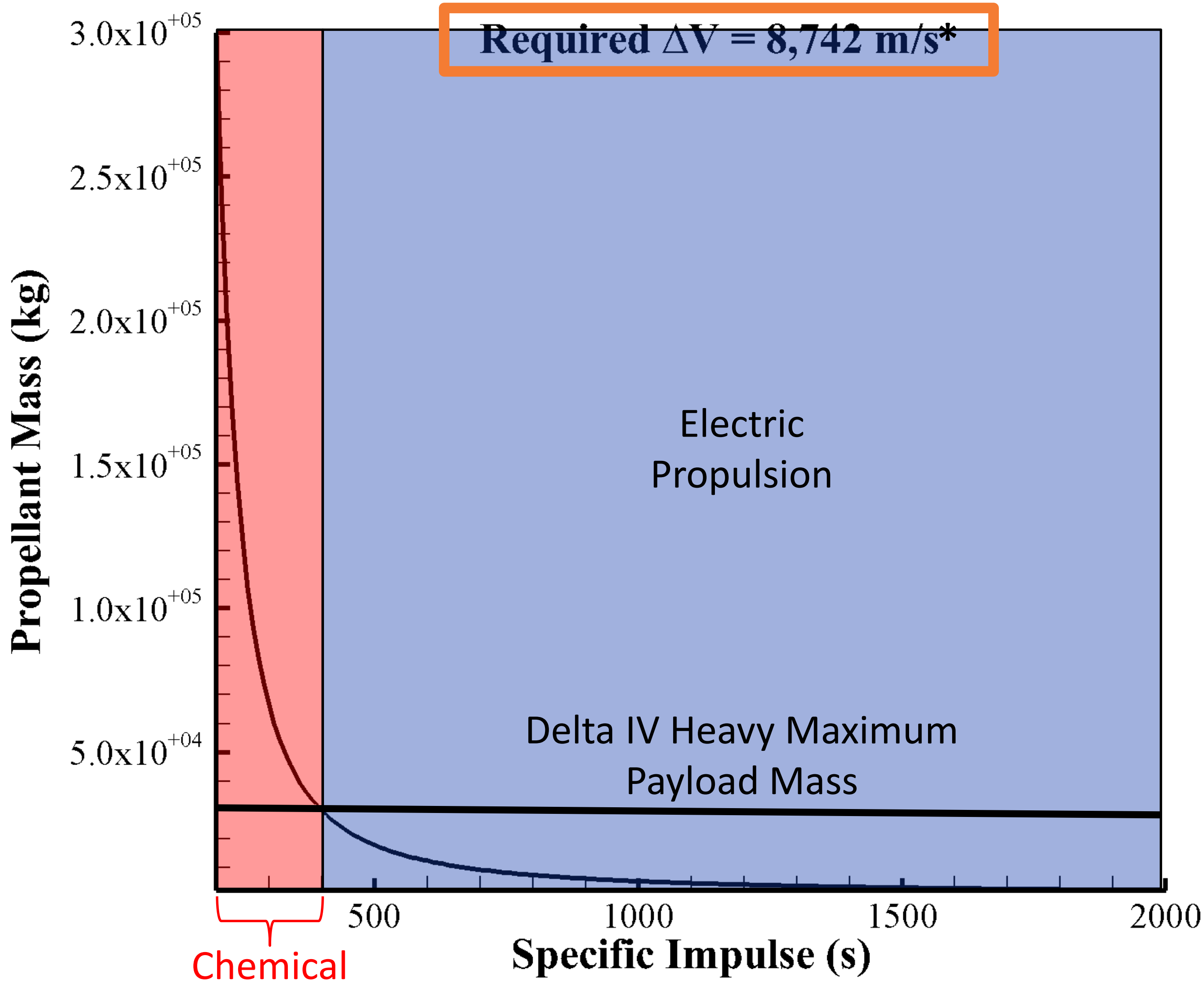
↓

Kinetic Energy

Electromagnetic acceleration

Low thrust: <1 N
High specific impulse: >1000 s

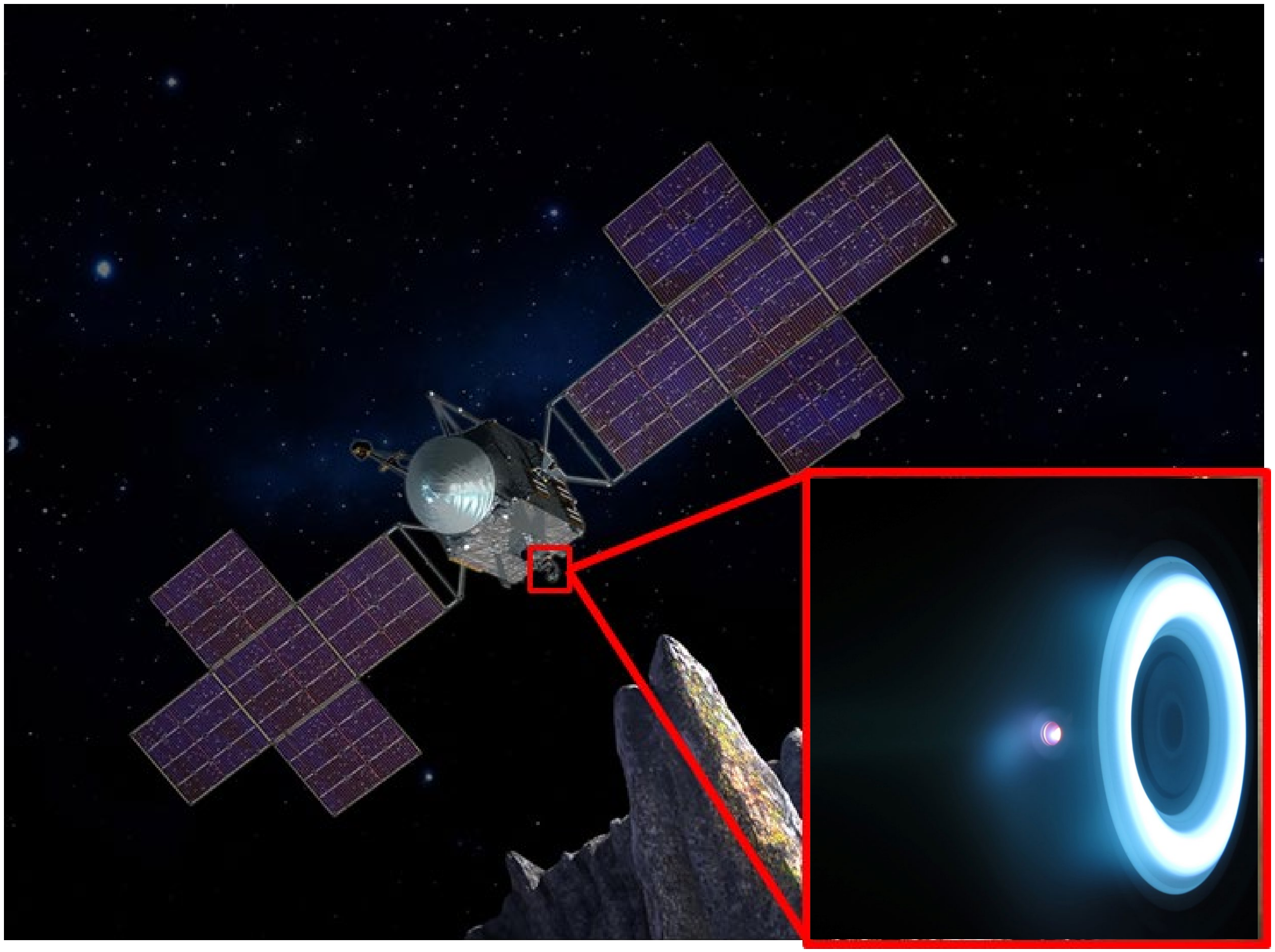
Why Use Electric Propulsion?



*For NASA Asteroid Robotic Redirect Mission (ARRM)

High Isp offered by Electric Propulsion required for system closure

Electric Propulsion on Psyche

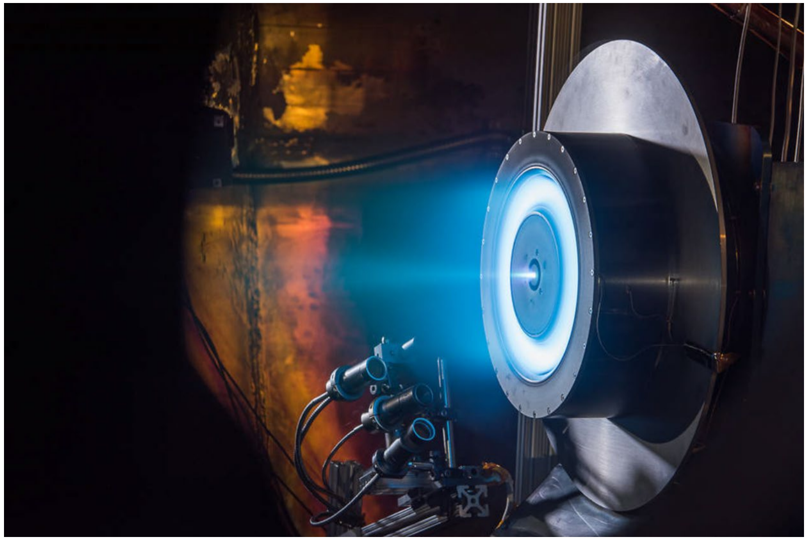


Images courtesy: https://www.jpl.nasa.gov/missions/psyche/
AIAA 2015-3720

Project Description

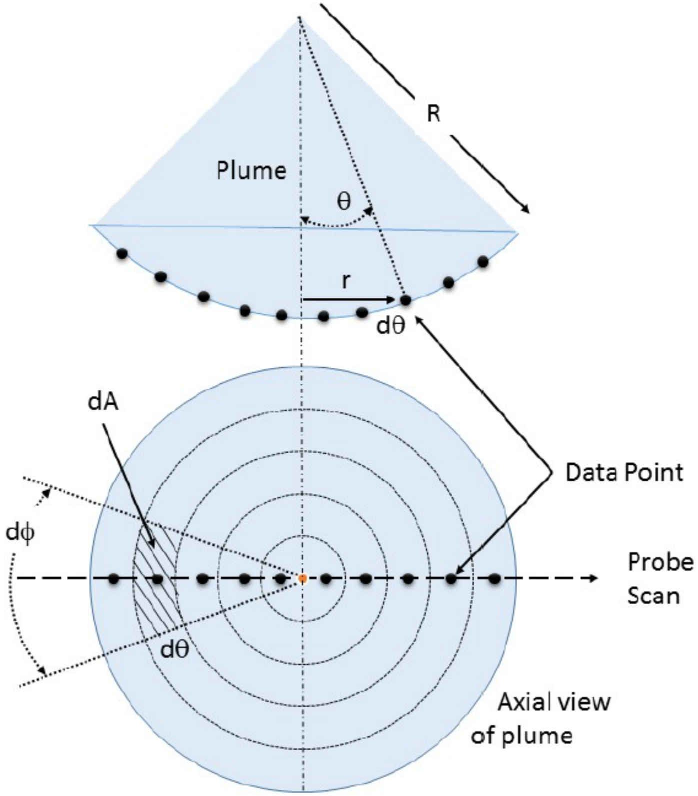
Thruster Plume

- During operation, Hall thrusters exhaust a hemispherical cloud of plasma known as a plume
  - This plume is composed of hot (>10,000°F) ions and electrons traveling at high speeds (>20,000 mph)
  - Ions have sufficient energy to damage surfaces they impinge upon
- Knowing the shape of the plume is important for two reasons:
  - Ensures other spacecraft surfaces are not damaged by ion impingement
  - Provides information on how efficiently the thruster is working



Thruster Plume Measurements

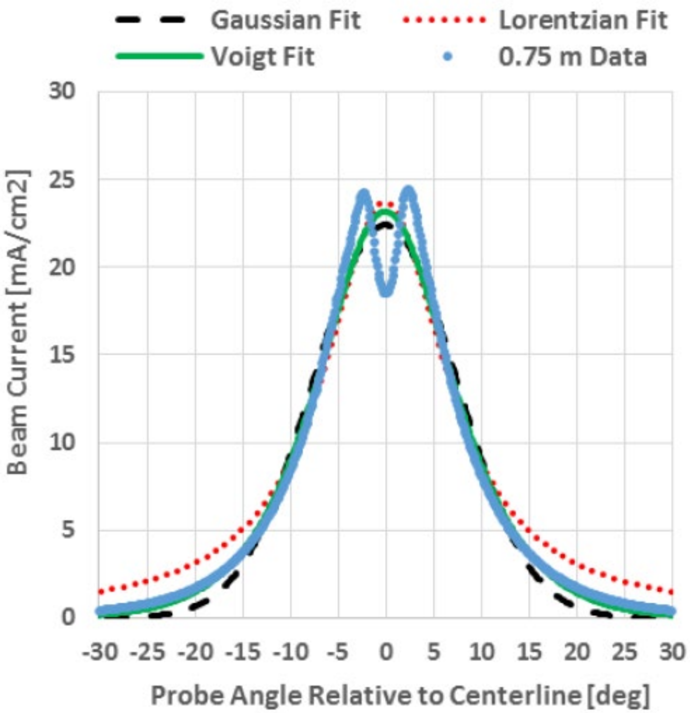
- During ground tests, probes are swept through the plume in order to measure the plume shape
- These probes are known as “Faraday probes” and collect ions (i.e., current) at discrete locations as they traverse the plume



Thruster Plume Measurements

- Ion current measured by the probes is interpolated in order to determine key plume shape parameters:
  - Distribution
  - Centroid

- Problem: key features of the probe measurements are not captured by fit functions used for the interpolation, which causes increased uncertainty in the key plume shape parameters



Project Description

Background

- Current fit techniques have proven inadequate to capture key features of Hall thruster plumes, which has lead to increased uncertainties in measurements of key shape parameters including the plume centroid
- These uncertainties have important impacts for integration of these thrusters on-board NASA spacecraft and understanding the efficiency of these devices

Goal

- The goal of this project is to apply machine learning or related techniques to NASA-provided plume measurements to devise a better technique for fitting the data and computing the plume centroid
- Teams must also quantify the uncertainties associated with the devised fitting technique and propagate them in order to provide an estimate for the uncertainty associated with computed centroid

References

Electric Propulsion and Hall Thrusters

- Goebel, D.M. and Katz, I., Fundamentals of Electric Propulsion: Ion and Hall Thrusters, Wiley, 2008, Chapters 7-8
- Frieman, J.D., Characterization of Background Neutral Flows in Vacuum Test Facilities and Impacts on Hall Effect Thruster Operation, 2017, Chapter 1

Plume Measurements

- NASA/TM-2018-219948: “Diagnostic for Verifying the Thrust Vector Requirement of the AEPS Hall-Effect Thruster and Comparison to the NEXT-C Thrust Vector Diagnostic”