

P17101: Prototype Arcjet Satellite Thruster

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Abstract—A tabletop prototype of an arcjet electrothermal propulsion system was developed to supplement ongoing exploratory spacecraft development conducted by RIT Space Exploration (SPEX). The arcjet thruster demonstrates the degree of practicality in implementing electrothermal propulsion systems. The arcjet assembly generates an electrical arc across the thruster nozzle's throat, ionizing argon propellant in order to achieve a greater specific impulse compared to cold gas propulsion.

I. NOMENCLATURE

II. INTRODUCTION

RIT Space Exploration (SPEX) provided a hypothetical use-case to serve as the foundation for this exploration into satellite propulsion. SPEX's hypothetical mission objective is to design a communications satellite that is capable of maintaining a polar geostationary orbit for 10 years.

In practice, satellites in Earth orbit for long-duration missions in excess of 5–25 years encounter perturbations to their trajectories over time from residual atmospheric and orbital particles, or from variations in Earth's gravity field. These spacecraft perform short station-keeping maneuvers periodically to compensate for drift and orbital decay.

An electrothermal rocket engine is a method of propulsion by which an inert gas stored at ambient temperature (cold gas) is released from a pressurized vessel or driven by a pump and heated electrically before being expelled out of a nozzle. Two proven methods of electrothermal propulsion are *resistojets*, which use conventional heat exchangers to heat the propellant, and *arcjets*, which pass the propellant through an electrical arc to heat the gas.

Electrothermal propulsion is advantageous over conventional chemical or cold-gas rockets for use by long-life satellites since the engines may be small in size, have no moving parts, and are more efficient at the expense of thrust. While resistojets and arcjets require more electrical power than chemical rockets, for example, the electrical energy may be recovered over time by photovoltaic panels, for example, whereas propellant fuel is a finite resource for these spacecraft.

A tabletop prototype thruster was designed and tested to explore the feasibility of this type of system with less strict requirements compared to the limitations of building a flight-worthy system. A tabletop version does not require integration with a spacecraft, and mass and spatial limitations are relaxed.

III. DESIGN METHODOLOGY

In low power (1 kW) applications, an arcjet offers up to 200% gains in efficiency over a resistojet thruster [1]. Figure 1

identifies the typical use cases and performance characteristics of arcjets compared to various other types of electrothermal thrusters. Arcjets achieve a greater specific impulse compared to resistojets but produce less thrust. Thus a maneuver would take a longer amount of time using an arcjet but would consume less propellant overall for the same maneuver as compared to a resistojet.

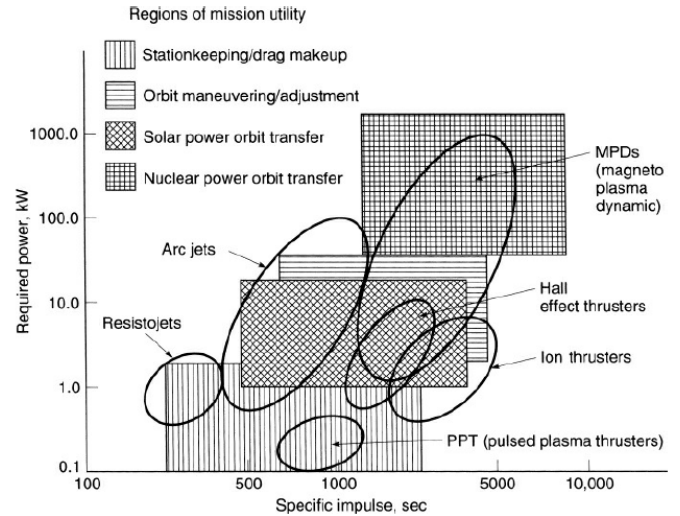


Fig. 1. Types of electrothermal propulsion with respect to typical performance and mission utility. In the 1 kW range, arcjets typically have a higher specific impulse than resistojets. (Sutton 2010)

A. Gas Dynamics

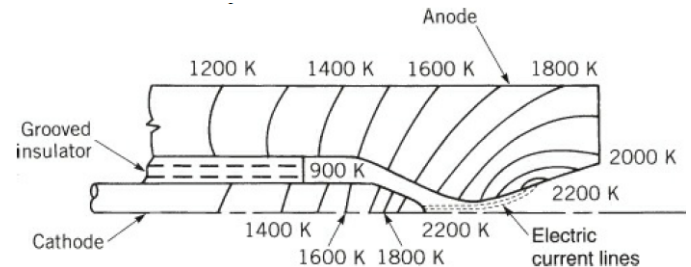


Fig. 2. A cross sectional view of a typical arcjet shows the expected thermal profile in the anode (nozzle) and the expected location of the electric current. (Sutton 2010)

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B. Power Conditioning

C. Test Signal Amplification

IV. SYSTEM OVERVIEW

A. Thruster Design

B. Power Conditioning Unit

V. TESTING

A. Test Stand

B. Data Acquisition

C. Safety Measures

VI. RESULTS

VII. CONCLUSIONS AND RECOMMENDATIONS

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REFERENCES

- [1] G. P. Sutton and O. Biblarz, *Rocket Propulsion Elements*, 8th ed. Hoboken, NJ: John Wiley & Sons, 2010.