ASTROPULSE

Group 17

Electric Propulsion Thruster for Nanosatellites

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Contents

Acknowledgments

Shoutouts to people who helped us

List of Abbreviations

GEO Geostationary Orbit

MEO Medium Earth Orbit

LEO Low Earth Orbit

EP Electric Propulsion

CSA Canadian Space Agency

NOMANCLATURE

A_e Thruster exit area [m^2]

1 Project Overview

1.1 Introduction

1.1.1 Background

The first satellite, Sputnik 1, was launched by the Soviet Union on October 4, 1957. This event marked the start of the space race, leading to new technological, scientific, and political developments [7]. Since then, 23030 satellites have been launched [3]. Satellites orbiting Earth can be split into 3 catagories:

- Low Earth Orbit (LEO) : 160 km - 2,000 km
- Medium Earth Orbit (MEO) : 2,000 km - 35,786 km
- Geostationary Orbit (GEO) : 35,786 km

For decades interest lied in GEO satellites, with Syncom becoming the first GEO satellite in 1963 [8]. Being in geosynchronous orbit meant that satellites could stay at a specific position above Earth, allowing for constant communication with a specific area on Earth. This made these satellites ideal for communication and weather monitoring. However, GEO satellites have high latency due to their distance from Earth, making them less suitable for real-time applications.

Since then the most significant change in satellite technology has been the development of LEO satellites. Although they were first developed in the 1990s, these satellites have only really become widely used in the last decade. Companies like OneWeb and Starlink have launched constellations of LEO satellites to provide low-latency internet access across the globe [10]. These developments denoted a transition in the commercial communication satellite business from small numbers of large geostationary satellites towards constellations of hundreds of smaller lower satellites in low earth orbit.

Fueled by this new idea, the global space industry accelerates as the number of satellites launched annually continues to rise. Both governments and private entities are allocating significant resources to satellite research and development for applications such as communication, navigation, Earth observation, atmospheric characterization, and military purposes.

1.1.2 Project Motivation

With the increasing complexity of mission requirements, the need for more advanced satellite technologies has increased. Specifically, the need for efficient and reliable propulsion systems has become crucial for satellite operations. Satellites require propulsion for various reasons, including orbit insertion, station-keeping, attitude control, deorbiting at the end of their operational life, and formation flying. Additionally, as spent rockets, satellites and other space trash accumulate in orbit, the likelihood of collisions with debris has increased. Unfortunately, collisions create more debris creating a runaway chain reaction of collisions and more debris known as the Kessler Syndrome [4].

There are two main types of propulsion systems used in satellites: chemical propulsion and Electric Propulsion (EP). Satellites have traditionally used chemical propulsion systems, although there is now a huge shift towards EP systems with Space X's Starlink constellation being the largest adopter of EP technology.

Chemical propulsion uses a fuel and an oxidizer, converting energy stored in the chemical bonds of the propellants, to produce a short, powerful thrust, or what we see as fire. It's loud and exciting, but not all that efficient. Chemical propulsion is said to be "energy limited" because the chemical reactants have a fixed amount of energy per unit mass, which limits the achievable exhaust velocity or specific impulse.

Electric propulsion systems use energy collected by either solar arrays or a nuclear reactor to generate thrust by using electric, and possibly magnetic, processes to ionize and accelerate a propellant. It is a technology aimed at achieving thrust with high-exhaust velocities, which results in a reduction in the amount of onboard propellant required for a given space mission or space-propulsion application compared to other conventional propulsion methods. Reduced propellant mass can significantly decrease the launch mass of a spacecraft or satellite, leading to lower costs from the use of smaller launch vehicles to deliver a desired mass into orbit or to a deep space target. [1] It can reduce the amount of fuel, or propellant, needed by up to 90% compared to chemical propulsion systems, saving millions in launch costs while providing greater mission flexibility. [9]

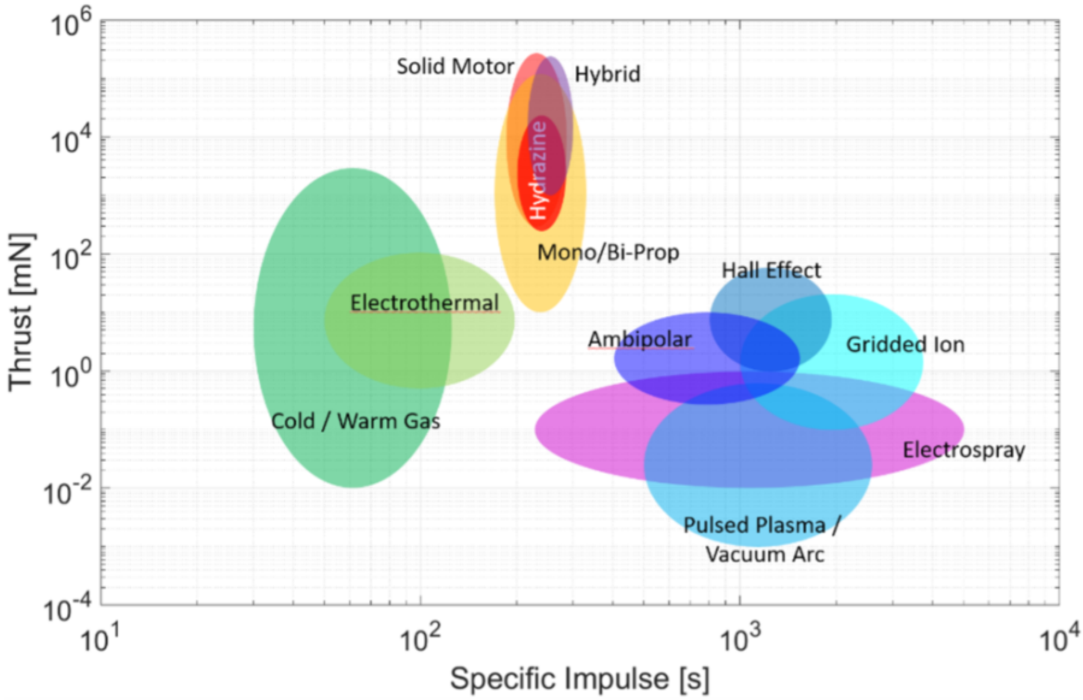

Figure 1: Typical small spacecraft in-space propulsion (thrust vs specific impulse)
Chemical Thrusters shown in shades of red and Electric Thrusters shown in shades of blue[6].

1.1.3 Relevance

As the technology matures and becomes more widely adopted, we can see an increasing interest in the space and satellite industry by the goverment of Canada. The Canadian Space Agency (CSA) has been actively encouraging development in the industry through initiatives such as the "Call for Ideas - Science and technology small payloads for space missions" [2]. The CSA also initated a "Consultation on Changes to Licensing Requirements and Conditions of Licence on Space Debris Mitigation" [5], which aims to address the growing concern of space debris. It proposes mandating active propulsion systems, with redundancy, for all Non-Geostationary Satellite Orbit (NGSO) satellites operating at or above 400 kilometers. This can severley increase the system and integration complexity for small satellites. Hence, now more than ever, there is a need to develop modern, efficient, and reliable propulsion systems for satellites. This shows that the goverment of Canada is aware of the increasing importance of the space industry and is taking steps to ensure its growth and sustainability.

1.2 Deliverables

1.3 Objectives

Remove this section if it has too much overlap with Deliverables

Maybe add a Requirements section

2 Conceptual Design

In this section make sure to:

- Explain Past Methods (eg. from reseach papers)
- Your concept
- Why your concept

2.1 System Overview

Einstein's work on relativity changed physics forever **einstein1905**. Knuth's book is a classic in computer science **knuth1984**.

2.2 Thruster Design

2.2.1 Hall Thruster Types

This section will go over Mechnical/Physics Design

2.2.2 Propellant Selection

2.2.3 Propellant Feed System and Anode

storage tank feed plumbing injector

talk about anode

2.2.4 Magnetic Field Design

2.2.5 Cathode

2.3 Avionics Overview

Explain high level what is needed in the avionic substem

Include high level / block diagrams

Explain that real time software control will be needed

2.3.1 Electrical System

block diagrams reference to existing designs explanation of the goal of the system how it will be run from soalr panels etc

2.3.2 Software

reference to existing use of real time system in rockets Exaplin the RTOS and using MCU peripherals like PWM How this choice of software architecture will help achieve the final goals Explain that low power feature will be used to minimize power consumption in space

2.4 Test Stand

explain existing methods

why you chose yours

touch on initial concept

change dues to chamber sizes

final concept

data acquisiton needed

2.5 Final Concept

Just a system diagram and CAD or smth

3 Design Development

4 Prototypes and Design Verification

5 Testing

6 Closing Remarks

7 Project Management

A List of Figures

Here you can include additional figures, tables, or explanations.

B List of Tables

Detailed derivations go here.

C Code Snippets

```
for i in range(10):
    print(i)
```

References

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