Study and Development of a Fluidic System for Iodine-fed Magnetically Enhanced Plasma Thruster (MEPT)

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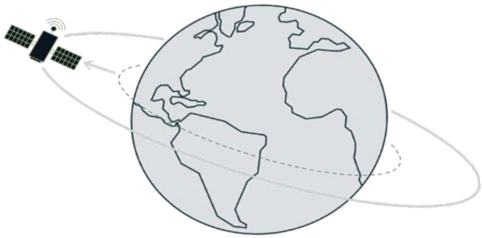
FRAMEWORK AND STATEMENT OF THE PROBLEM

The Magnetically Enhanced Plasma Thruster (MEPT) is an innovative low-cost electric propulsion system able to increase small spacecrafts mobility, opening new unconventional mission scenarios.

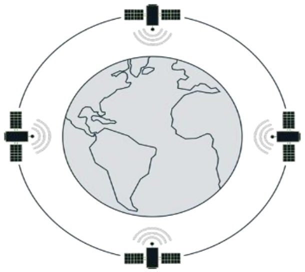
T4i is engaged in the design and development of **REGULUS**, a complete propulsion module based on the MEPT. The module is intended for CubeSat platforms ranging in size from 6 U to 24 U, providing:

- 0.25-0.65 mN of Thrust
- Isp up to 650 s
- input power lower than 60 W

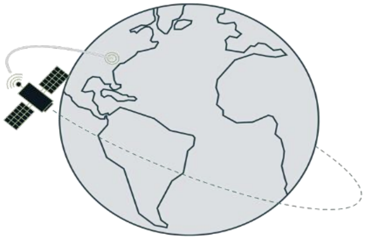
T4i THRUSTING A DIFFERENT FUTURE



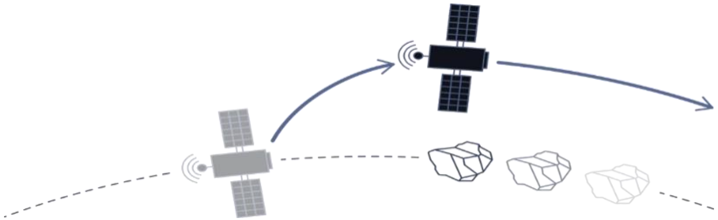
Altitude-changes



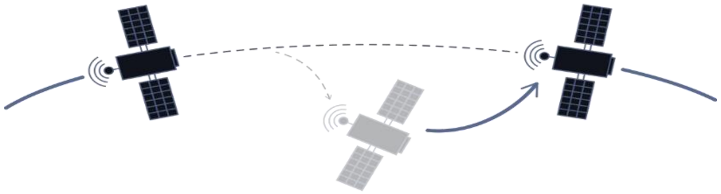
Formation flight continuous operations
Station keeping



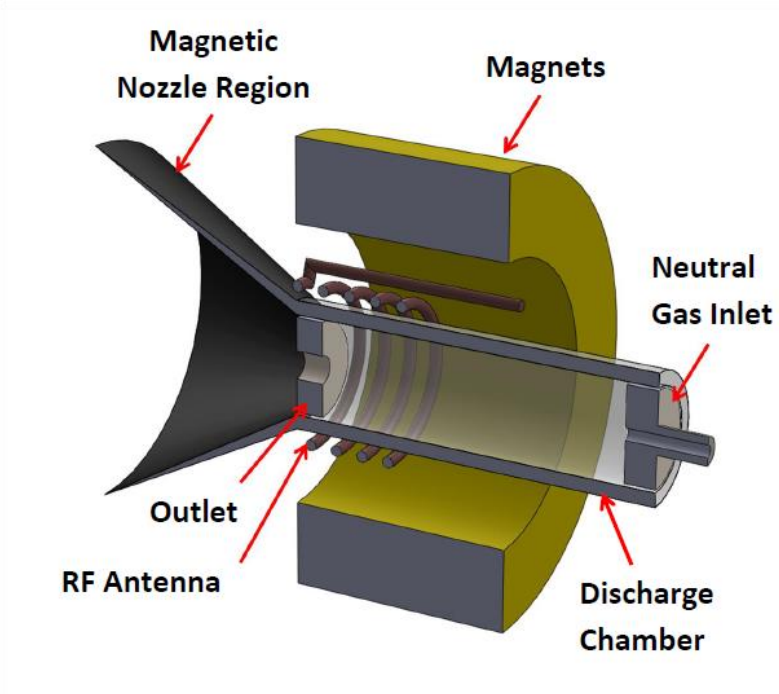
Decommissioning



Collision avoidance

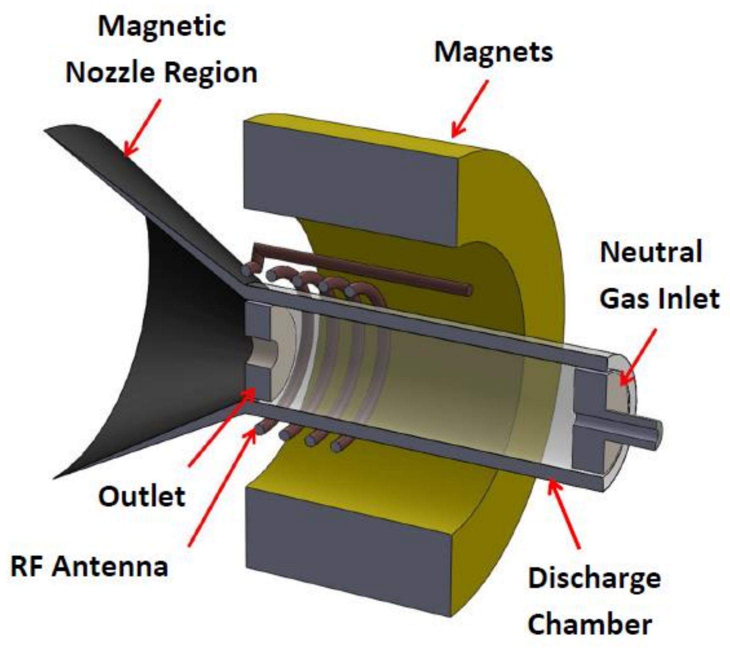


Continuous drag compensation



The main components of MEPT, the core technology of REGULUS, are:

- A **fluidic line** which transfers the neutral gas propellant from a storage tank to the **discharge chamber**.
- A **discharge chamber** inside which the neutral gas is ionized
- A **RF antenna**, in the MHz frequency range, which generates the electromagnetic (EM) fields for gas ionization
- **Magnets** producing a magnetostatic field to enhance the plasma confinement and provide the magnetic nozzle effect.



Advantages:

- Absence of electrodes immersed in the plasma
- Good power scalability
- Adaptability to different propellants
- No need for a neutralizer

Disadvantage:

- High thermal load

MEPT: Iodine Propellant

MEPT can work with different propellants (such as Ar, Kr, Xe, Air, CO2). Because of this last feature it seems extremely promising to investigate the employment of Iodine as a propellant, which is particularly appealing for space applications.

Why Iodine Propellant?

- It costs only 1/5 compared to Xenon
- It can be stored as solid
- No pressurized tank

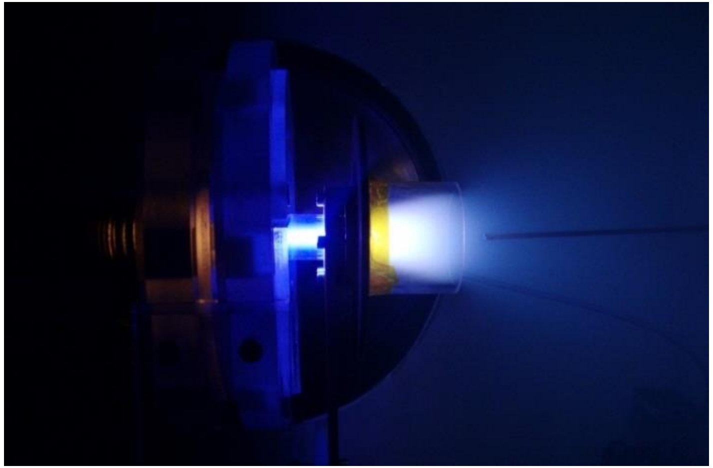
Disadvantages:

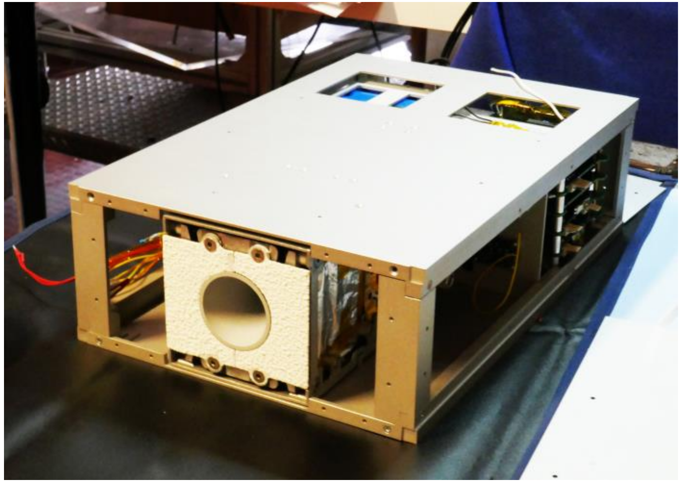
- Chemically reactive
- Non-trivial thermal control

RESEARCH PROJECT

Aim of the Project

The research program was focused mainly on the design of an innovative low cost fluidic system for Iodine fed Magnetically Enhanced Plasma Thruster, in order to use it on a smallsat platform.





The fluidic subsystem must provide a **fixed mass flow rate of 0.1 mg/s ±10%** to the thruster.

Research Activity

1. Study and development of the **mass flow control system** by means of thermal management strategy, in order to grant the proper **sublimation rate** and to avoid the **re-condensation**.

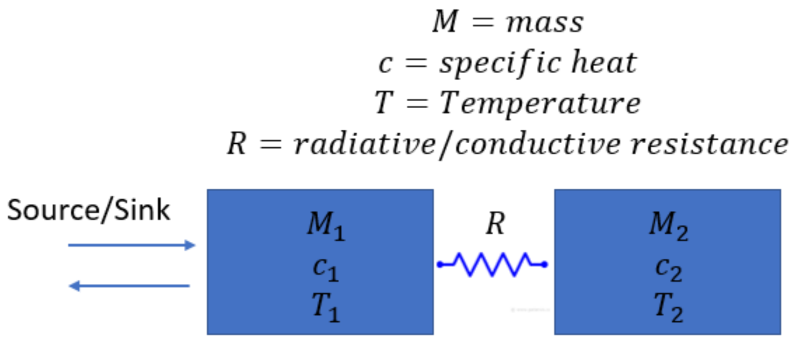
2. Development of a proper **software tool** to design and study the system from a thermal and fluidic point of view.

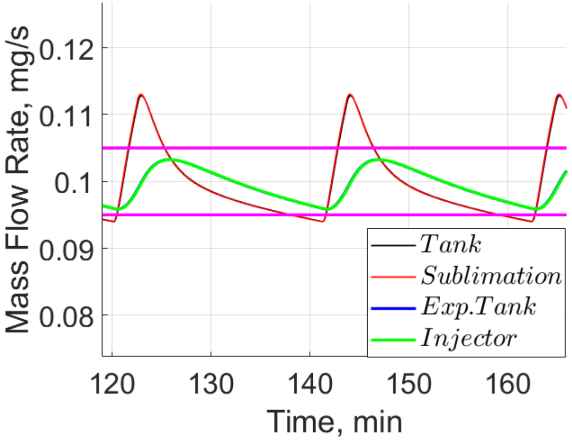
3. Testing of **the mass flow control system with Iodine propellant.**

PERFORMED ACTIVITIES

Numerical Approach

A Thermal Lumped Parameter Model was developed in order to simulate the thermal behaviour of the system.



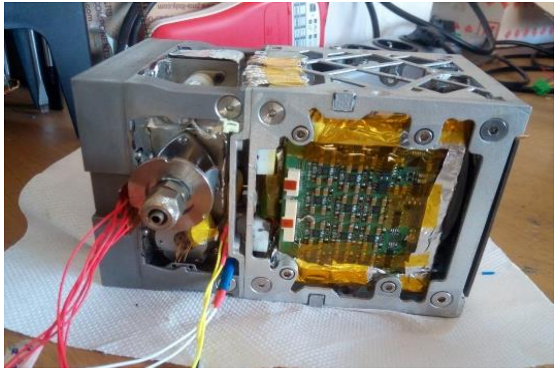


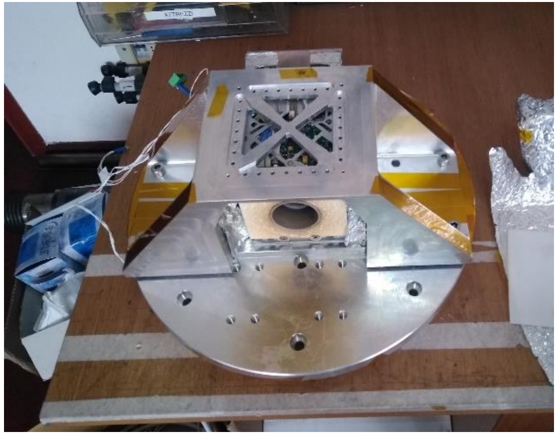
A Fluidic Model, coupled with the thermal one, was developed and was used to study the mass flow control system.

Tests

The following tests have been performed:

- Validation of the numerical model
- Tuning of the thermal control loop
- Calibration of the sensors
- Functional tests in vacuum with the thruster module (heating, ignition, thrusting and cooling)
- TVAC

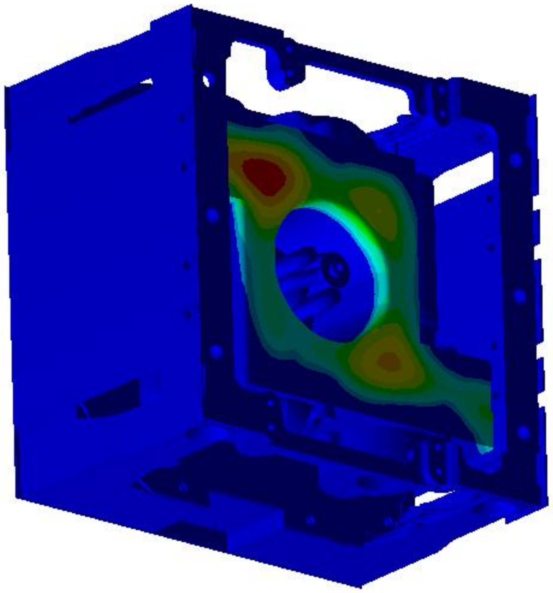




Re- Design of the Fluidic Module

The experimental campaign showed the limits of the actual fluidic system:

- Manifold and tank shall **be thermally decoupled** in order to reduce re – condensation spot of iodine
- **Pressure control** can be speed up acting both on valves and heaters
- **Total impulse** shall be increased in order to meet the Cubesat market requests.
- **Power consumption** shall be reduced



Re- Design of the Fluidic Module

Due to the high compactness of the fluidic system driven by the tight volume budget, the system suffers from a severe case of “butterfly effect": ***a small change in the design can cause dramatic unwanted changes to the system.***

In other words, the **thermal, mechanical, fluidic, and functional requirements** of the fluidic system must be addressed in a holistic way - tank and manifold altogether.

Re- Design of the Fluidic Module

Parameter	Before	After
Stored iodine [kg]	0.5	2
Dry Mass [kg]	0.7	1
Volume [U]	0.5	1
Normalized power consumption [-]	1	< 0.5

CONCLUSIONS

Summary of Activities

- ✓ **Bibliography Research**
  - ✓ **International Papers**
- ✓ **Numerical Models**
  - ✓ **Thermal Model**
  - ✓ **Fluidic Model**
  - ✓ **Coupling**
  - ✓ **Validation**
- ✓ **Design and Development**
  - ✓ **Mass Flow Control System**
  - ✓ **Re - Design**
- ✓ **Calibration and Test**
  - ✓ **Thermal Control**
  - ✓ **Mass Flow Control**

Legend

- ✓ **Finished**
- ▪ **In progress**
- ❑ **To start**

Future works

Future works could be focused on:

Testing

Of the new fluidic module.

New instruments

To work with iodine, like a flight mass flow meter.

Chemical compatibility

Improve the know-how on iodine and its compatibility with metals/plasics.

Thanks for the attention

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