INTERACTION BETWEEN ELECTRIC THRUSTERS AND COMMUNICATION SYSTEM INTEGRATED ON A SMALL SPACECRAFT

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A numerical multi-physics method is proposed in order to estimate the perturbation of an electric thruster's plume on the communication system of a CubeSat type spacecraft. A plume simulation model have been coupled with an electromagnetic simulation software. The far-field radiation characteristics of a UHF dipole are presented for a Hall effect thruster's plume on a 6U type platform for different integrations. Changes in radiated power are observed in the presence of the plume. This versatile method makes it possible to represent the communication system / thruster interactions for any antenna, thruster's plume or integration condition.

CONTEXT

CubeSat 1U
1999 – USA
10x10x10 cm
< 1,33 kg

NEW STANDARD, NEW SPACE …

Emergence of a **private initiative space industry** for the development of **low-cost** and public access to space exploration. [1]

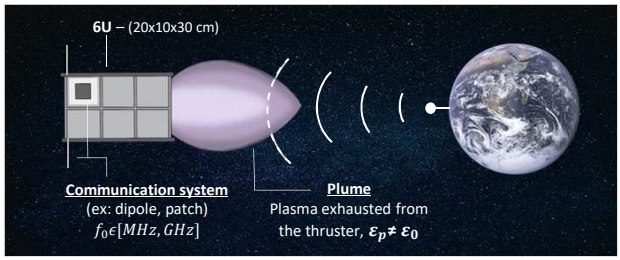
Reduced cost:
→ Reduced mass
→ Satellite miniaturization
→ **Miniaturized thruster**

… NEW CONSTRAINTS FOR THE THRUSTER

- In a miniaturization context, **electric propulsion** is preferred to chemical since its technology reduces the ergol mass on board
- Miniaturized electric thruster have to satisfy [2]:
  - good performance knowing low power available on board
  - low cost technology
  - **electromagnetic compatibility**

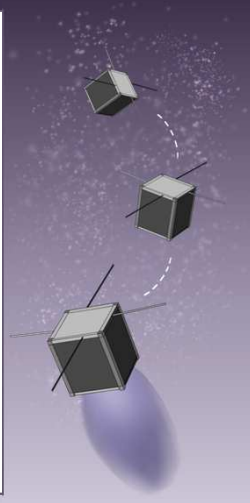
ELECTROMAGNETIC COMPATIBILITY

Ability of a system to function acceptably in their electromagnetic environment



The plume is an electromagnetically complex medium and has the potential to disrupt the proper functioning of integrated systems. [3]

Possible interactions between the communication system and the plume have to be anticipated

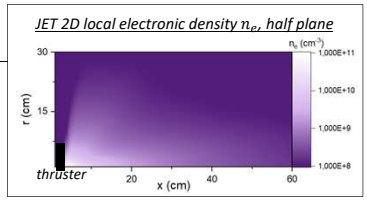


METHOD

Multiphysics method to study the possible interactions between the plume of a miniaturized Hall thruster and microwaves antennas

JET 2D

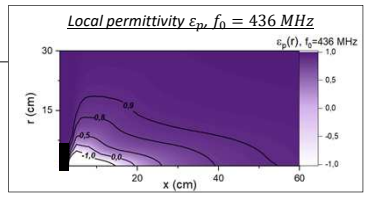
Plasma jet model [4] of a Hall thruster plume.
Provides local electronic density $n_e(r)$ within the plume.



Drude Model

Hall thruster plume = **dispersive medium**. Represented by its **equivalent local relative permittivity** $\boldsymbol{\varepsilon_p(r)}$ given by the Drude model, function of local electronic density $n_e(r)$ and of the operating frequency f_0:

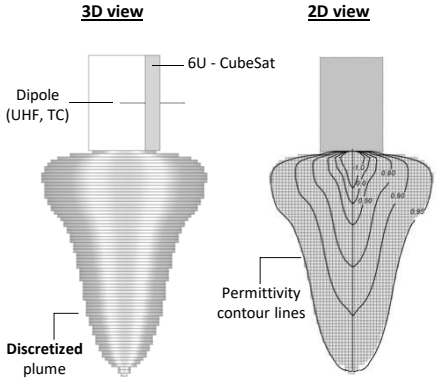
$$\varepsilon_p(r, f_0) = 1 - \frac{\boldsymbol{n_e(r)}\, e^2}{(2\pi \boldsymbol{f_0})^2 m_e \varepsilon_0}$$



Ansys HFSS

Finite element analysis of time harmonic Maxwell's equation software. Performs numerical analysis of the integrated antennas on a simplified CubeSat with **the discretized plume**. Provides **radiation and radioelectric characteristics** of the antennas.

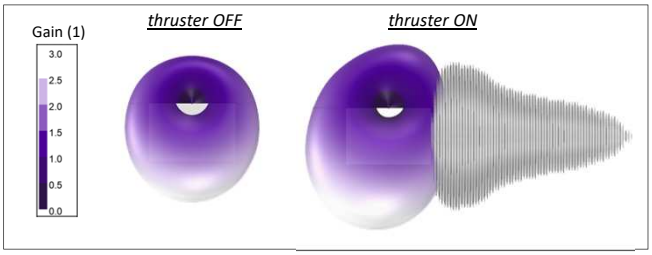
Representation of the problem in Ansys HFSS



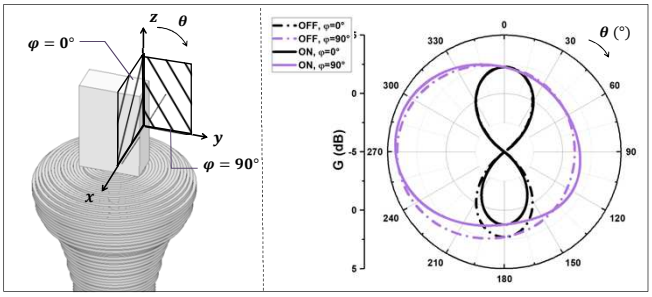
RESULTS

Comparison of the far field radiated energy distribution of a UHF dipole with and without the plume

- **Linear gain, 3D view**



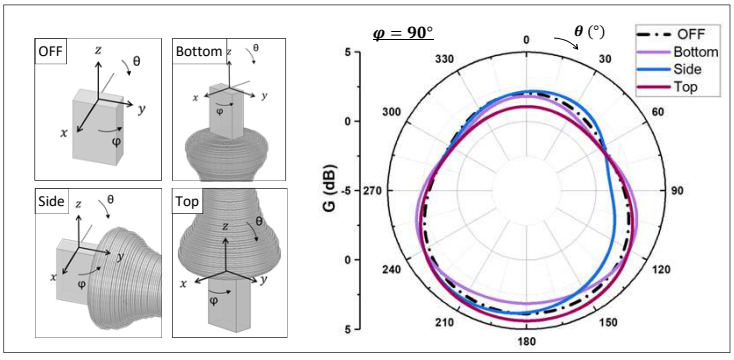
- **Gain, 2D view**



Permittivity gradient's plume = refracting medium
→ modification of the antenna far-field radiation characteristics with the plume

Far-field radiation characteristics, thruster's integration

- **Gain, 2D view, $\varphi = 90°$**



Modification of the radiated power depending on the antenna/plume relative position. Decrease of the gain in the area where the plume is located.

- A **method** have been developed in order to **estimate the interaction between antennas and a plume** integrated on a simplified **CubeSat**. This method is **versatile**. It can be used for other antennas, integration, type and power of a thruster
- The numerical approach proposed is not sufficient to answer the question of the electromagnetic compatibility between the communication system and the thruster . This work will be completed by **measurements** of antenna far-field radiation in the presence of a plasma in an anechoic chamber.

[1] H. Heidt et al., *Small Satellite Conference* **32** (2000)
[2] D. Lev et al., *Acta Astronautica* **159**, 213-227 (2019)
[3] E. Beiting et al., *International Electric Propulsion Conference* **120** (2013)
[4] L. Garrigues et al., *Journal of Applied Physics* **91**, 9521 (2002)