IAA-AAS-CU-17-02-05

MECSE: A CUBESAT MISSION AIMING TO MEASURE AND MANIPULATE THE IONOSPHERIC PLASMA LAYER

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4th IAA Conference on University Satellite Missions and CubeSat Workshop

Rome, 04th December of 2017

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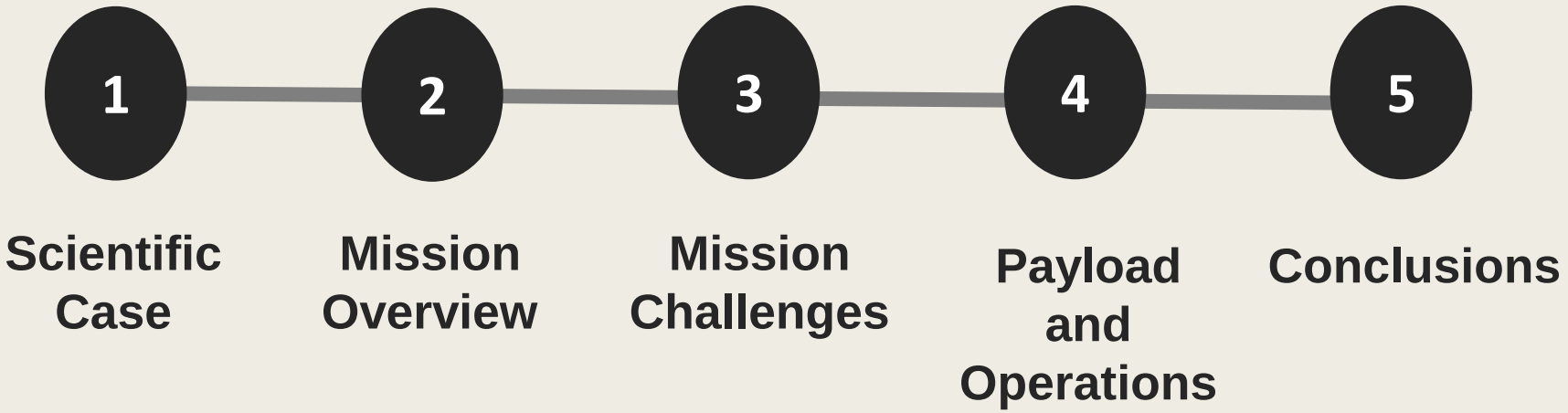
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Scientific Case
Mission Overview
Mission Challenges
Payload and Operations
Conclusions

Radio Frequency Blackout

Communication Cut-off:

$$\eta_{plasma} > \eta_{critical}$$

$$\eta_{critical} = \left(\frac{f_{radio}}{9\times10^3}\right)^2 \text{m}^3$$

At hypersonic velocities:

1 minute of blackout

<=>

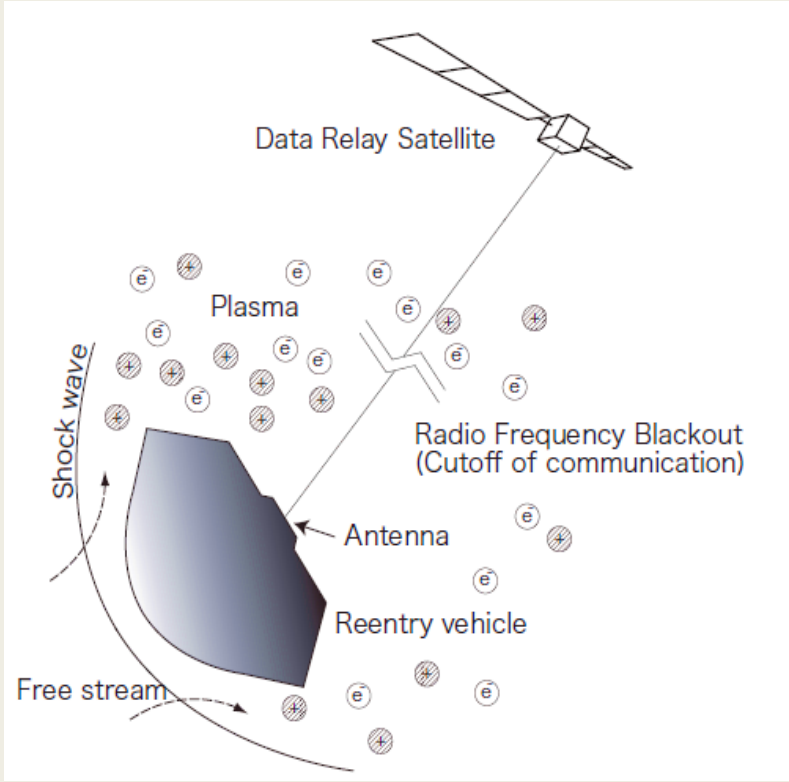
≈ 500 km of trajectory

GNSS Navigation

Vehicle Tracking

Real-time Data Telemetry

Voice Communication

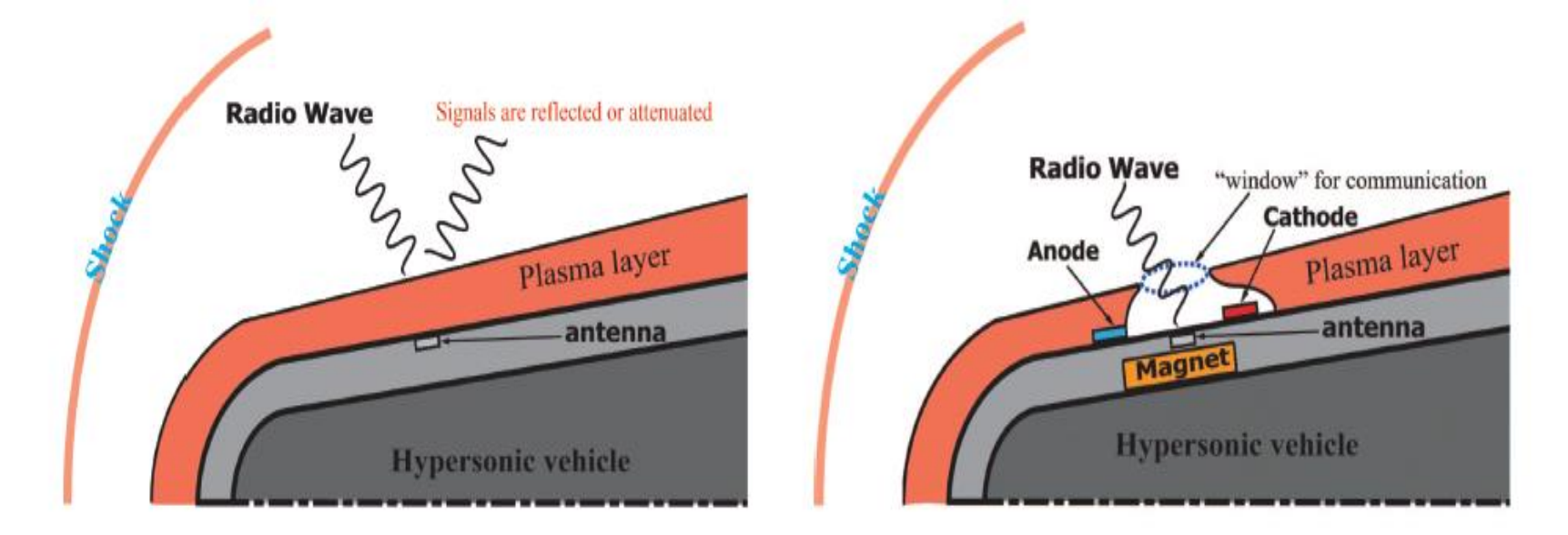


*Yusuke Takahashi, Reo Nakasato and Nobuyuki Oshima, "Analysis of Radio Frequency Blackout for a Blunt-Body Capsule in Atmospheric Reentry Missions", 2016

Solution: Decrease the Plasma Density

Magnetic Window – Review

- 1961: Hodora has shown that it is possible to alter the electromagnetic properties of the plasma by superposing a static magnetic field **(~0.0357 T);**
- Alternative to the constant magnetic field, **a time-varying magnetic field can be used** (Stenzel and Urrutia);



*M.K. Kim, "Electromagnetic Manipulation of Plasma Layer for Re-Entry Vehicles." PhD dissertation University of Michigan, 2009.

Magnetic Window – Review

- Experimental studies on reentry and hypersonic vehicles are extremely expensive and therefore few have been performed (RAM-C are an exception)
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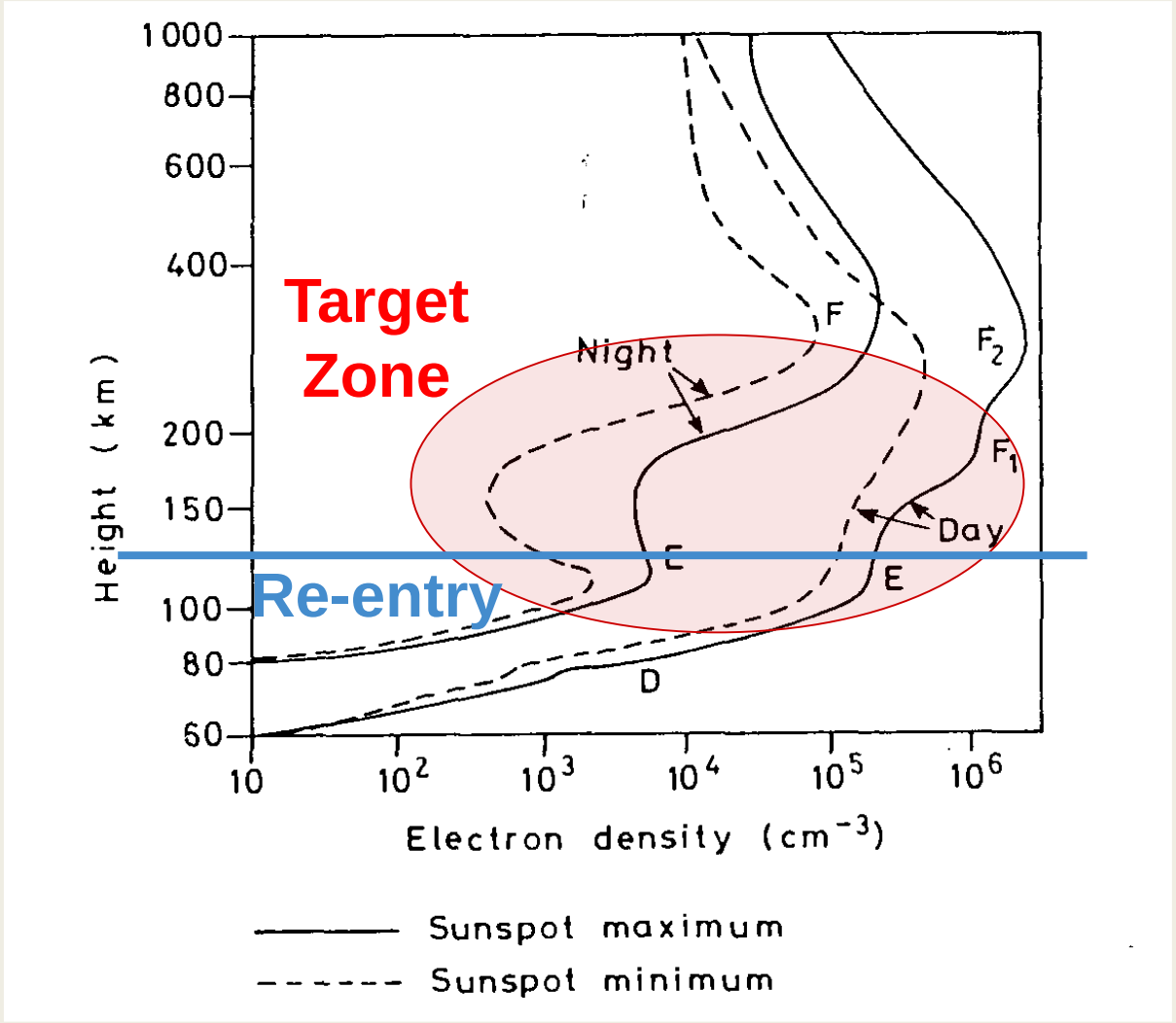
Low-cost flight experiment to investigate the effects of a magnetic field in the Ionospheric plasma.

Ionospheric Plasma

- Plasma density in Ionosphere ranges from 10^{9} to 10^{12} m^{-3}
- Vehicle reentering the atmosphere: from 10^{15} to 10^{20} m^{-3}
- Low Ionosphere (90 – 320 km altitude) is the least explored layer of the atmosphere.



MECSE Mission

Education

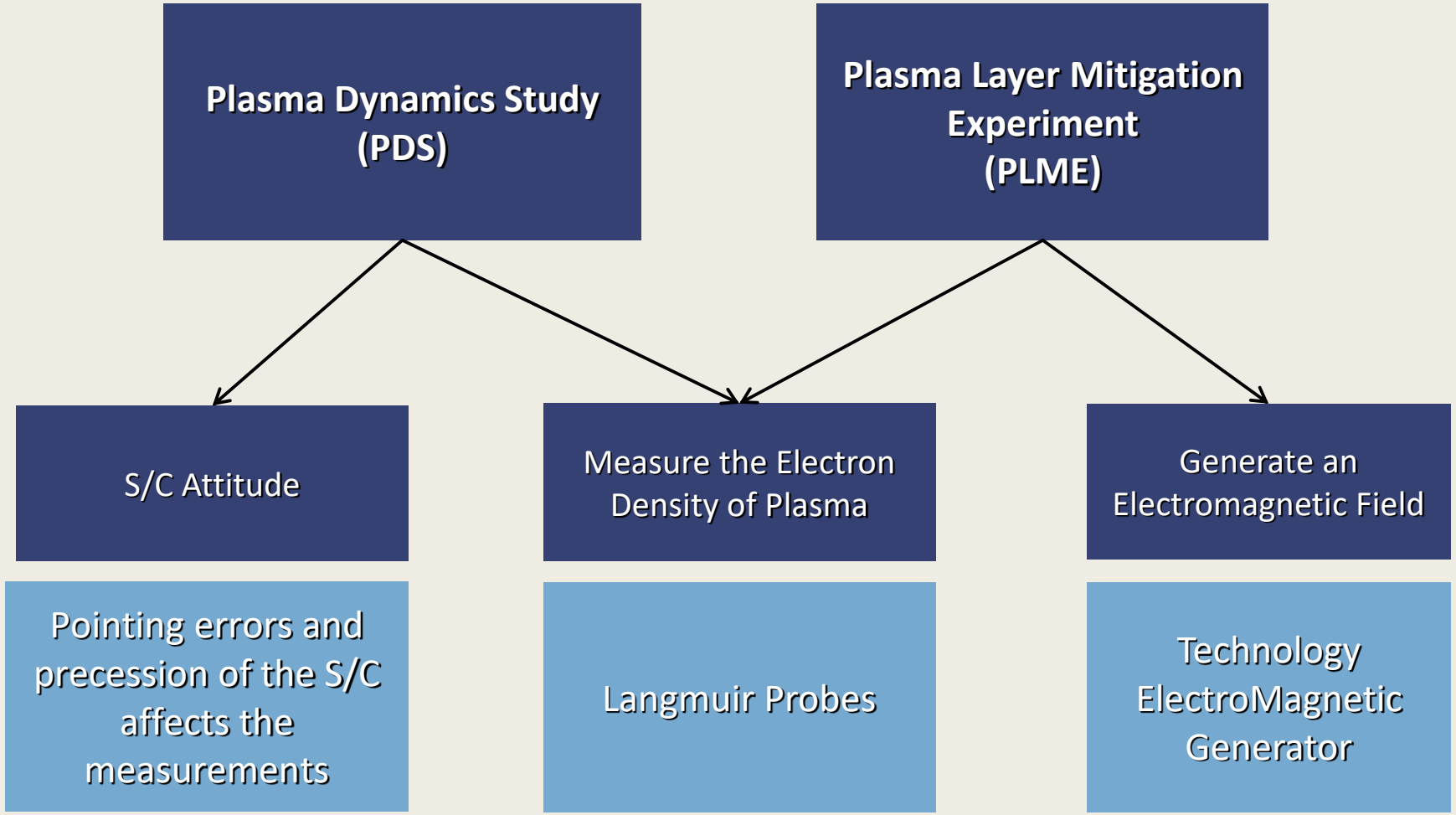
Science

PDS
Plasma Dynamics Study

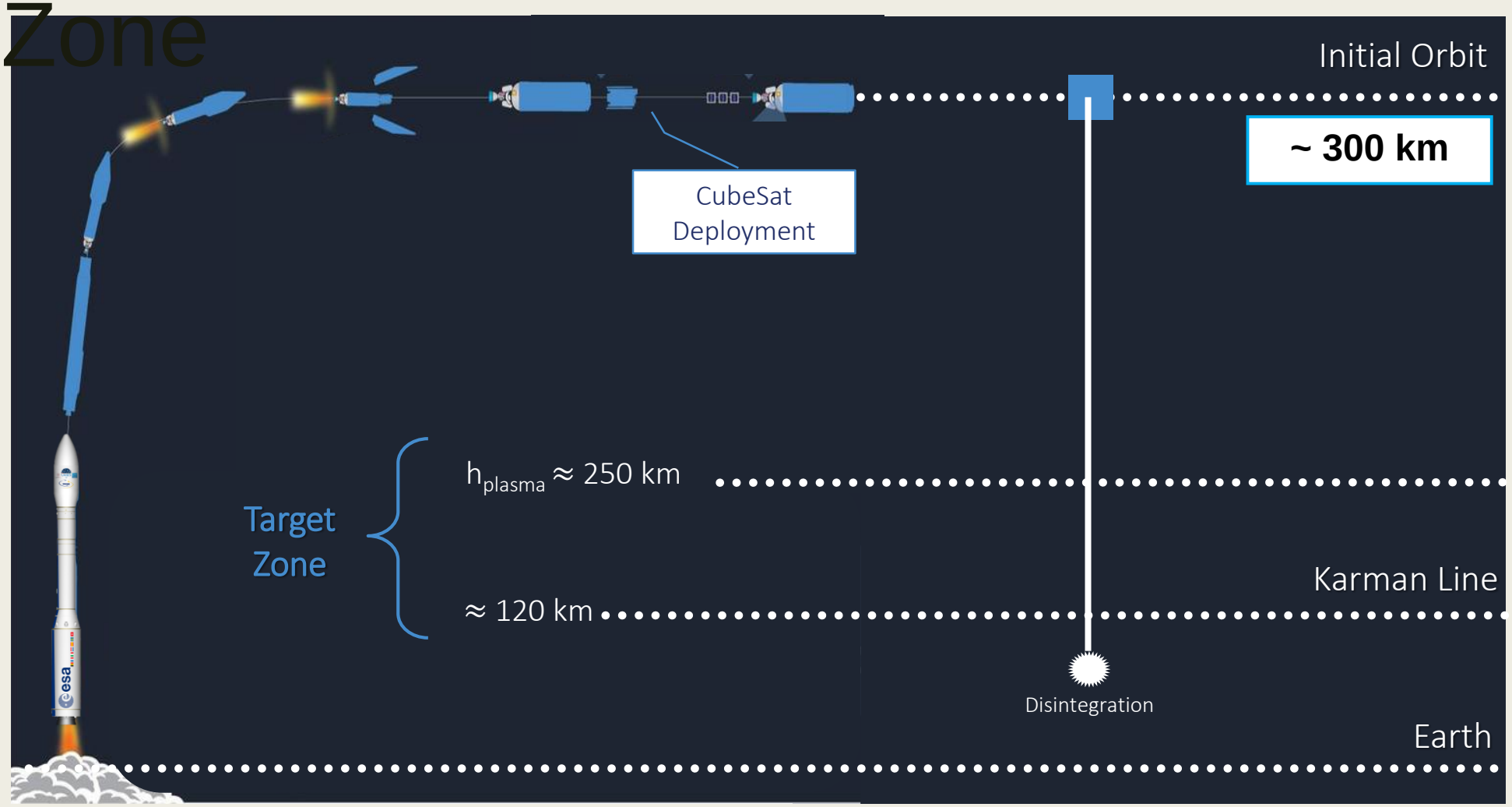
PLME
Plasma Layer Mitigation Experiment

MO1	Provide hands-on experience to university students on space projects
MO2	Study the formation of plasma surrounding the S/C in the Low Ionosphere
MO3	Assess the effects of the S/C attitude motion on the plasma layer
MO4	Study the effects of an electromagnetic field on the plasma layer

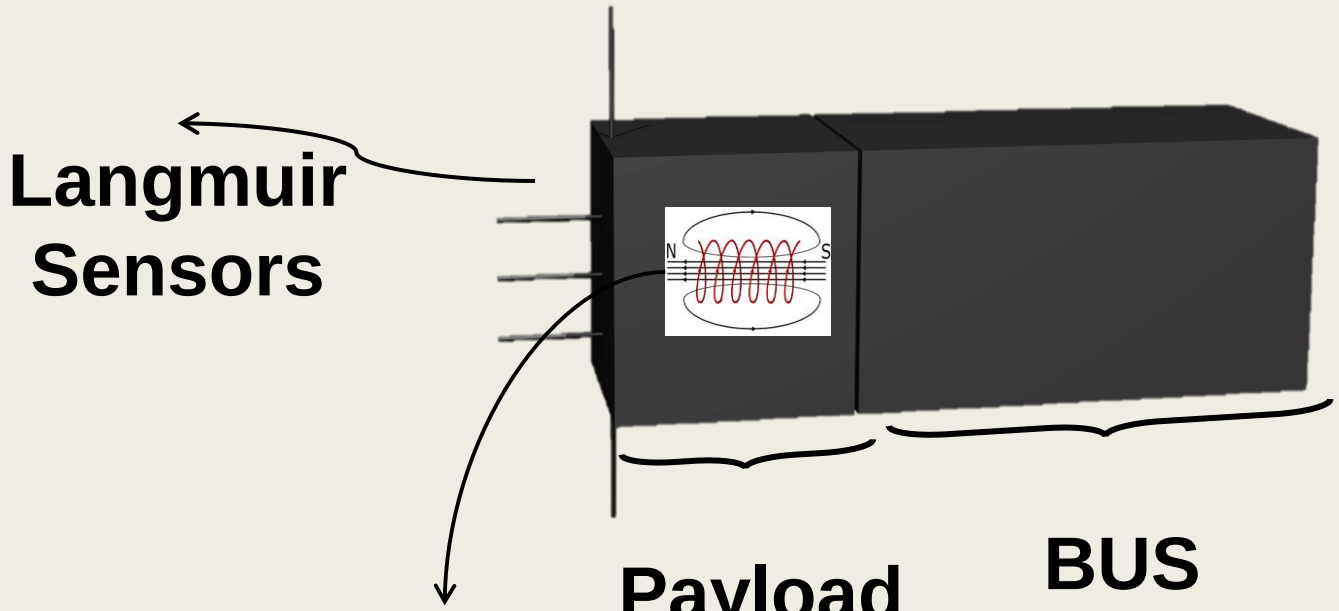
Mission Overview



Mission Challenge 1 – Get to Target Zone



Mission Challenge 2 – system drivers



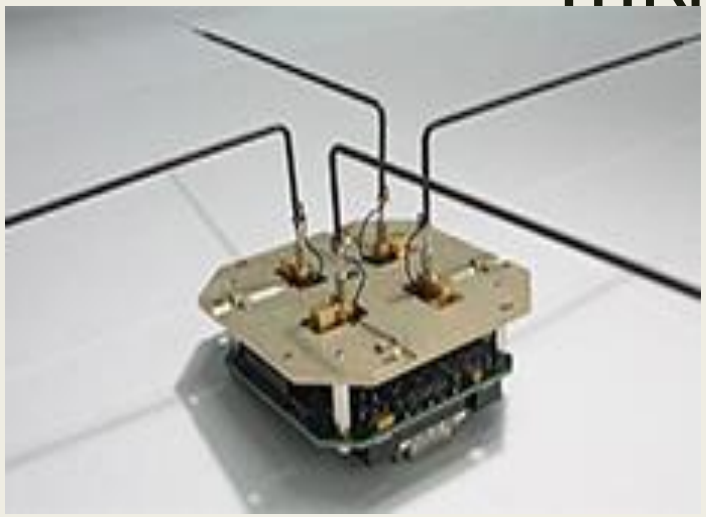
POWER

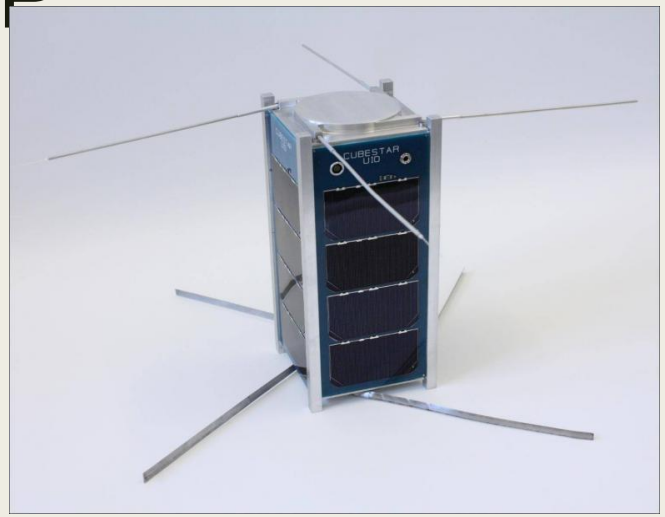
ATTITUDE

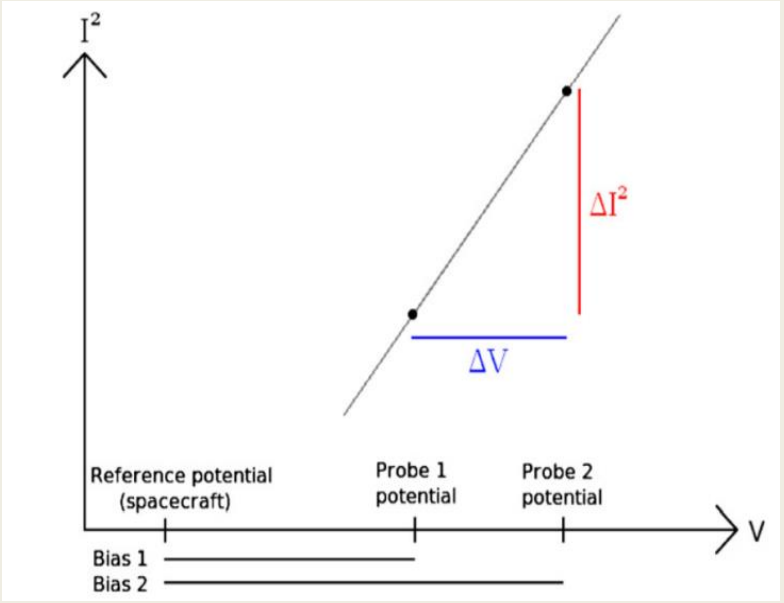
THERMAL / MAGNETIC PROTECTION

Mission Challenge 3 – Payloads

- Langmuir Probes -> mNLP







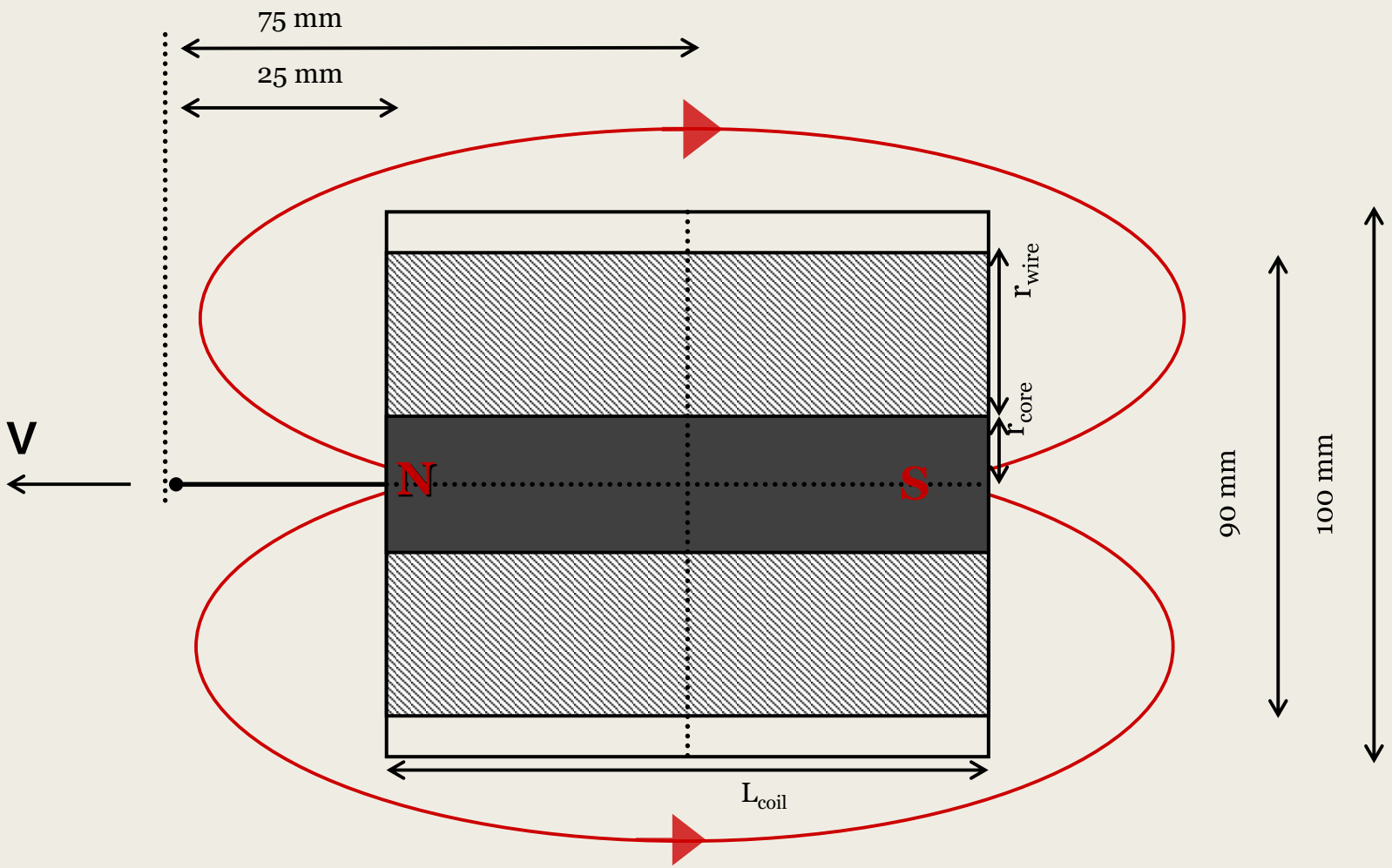
*multi-Needle Langmuir Probes (mNLP) CubeStar - University of Oslo

$$\eta_e = \sqrt{\frac{m_e}{2q(q2rl)^2}\frac{\Delta(I_c^2)}{\Delta V}}$$

m_e: mass of an electron
q: charge of an electron
r: radius of each probe
l: length of each probe

- EMG No technology available

Payload Configuration - Horizontal Dipole

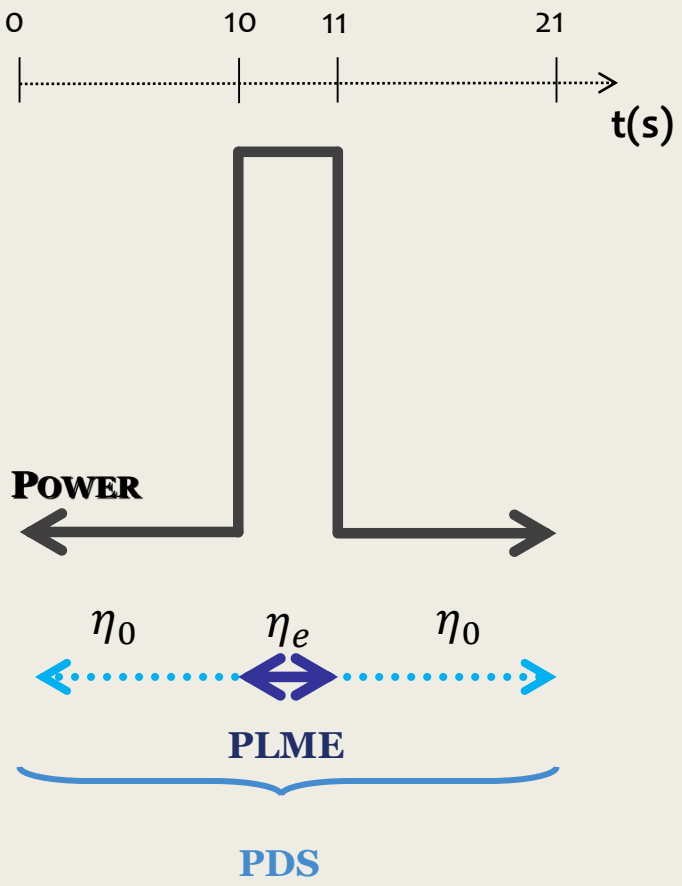


$$B = \frac{\mu N I}{L_{coil}}$$

- B: magnetic field intensity
- μ: magnetic permeability
- N: number turns
- I: current

LP position;
LP booms size;
EMG design (B).

Concept of Operations - Payload



$$EDR = \frac{\eta_e}{\eta_0}$$

ELECTRON DENSITY REDUCTION

Conceptual Design

AOCS: Attitude and Orbit Control System
EPS: Electrical Power System
CDH: Command & Data Handling
TCS: Thermal Control System
TTC: Telemetry, Tracking & Control
MSS: Mechanical System and Structures

TTC

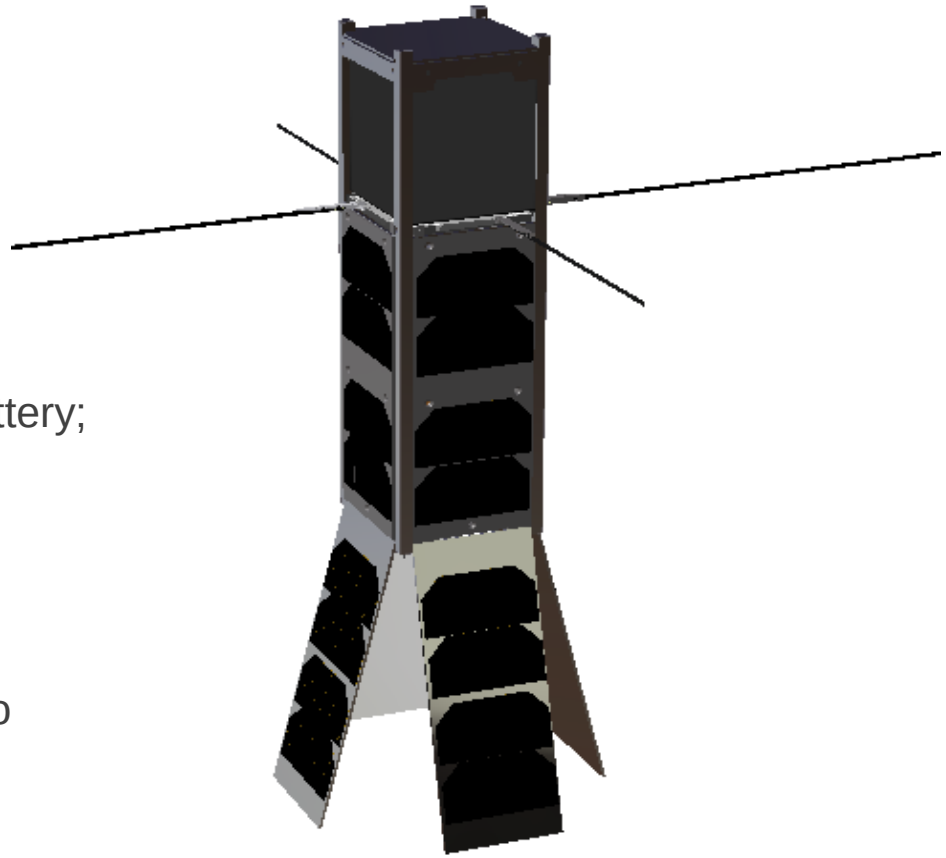
- 100% duty cycle of mNLP;
- Data volume ~ 18 Mb per day.

EPS

- High peak power (~100W);
- Storage: supercapacitors + battery;

AOCS

- Velocity-vector stabilization w/o magnetic parts;
- Attitude Control: Aerodynamic;



CDH

- COTS;
- Command the subsystem;
- Memory storage.

(housekeeping & scientific data)

MSS

- Develop a modular structure.

TCS

- Temperature of EMG (short time);

Conclusions

- The feasibility of performing a mission to manipulate plasma was assessed;
- The mission challenges were identified (power and EMG are the main ones);
- A conceptual design of the system was proposed;

- Stepping Stone for MECSE project;

SCIENTIFIC RESEARCH

MHD/EHD control of the plasma layer as a solution for RF blackout mitigation.

TECHNOLOGY DEMONSTRATION

Development of a tool for plasma layer manipulation.

EDUCATIONAL PROJECT

Hands-on project with the power to foster Portuguese space education.

COMMERCIAL VALUE

Strategies for the mitigation of RF Blackout are important for the design of future space vehicles.

Future Work

- ElectroMagnetic Generator:
  - Proceed the Feasibility Studies;
  - Simulations of magnetic decay with distance;
  - Impact of the sensor location in the magnetic field stregth;
  - Experimental tests (temperature, power and magnetic disturbances)

- Refine concepts ;
- Expand our team ;

Thank You!

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Questions?

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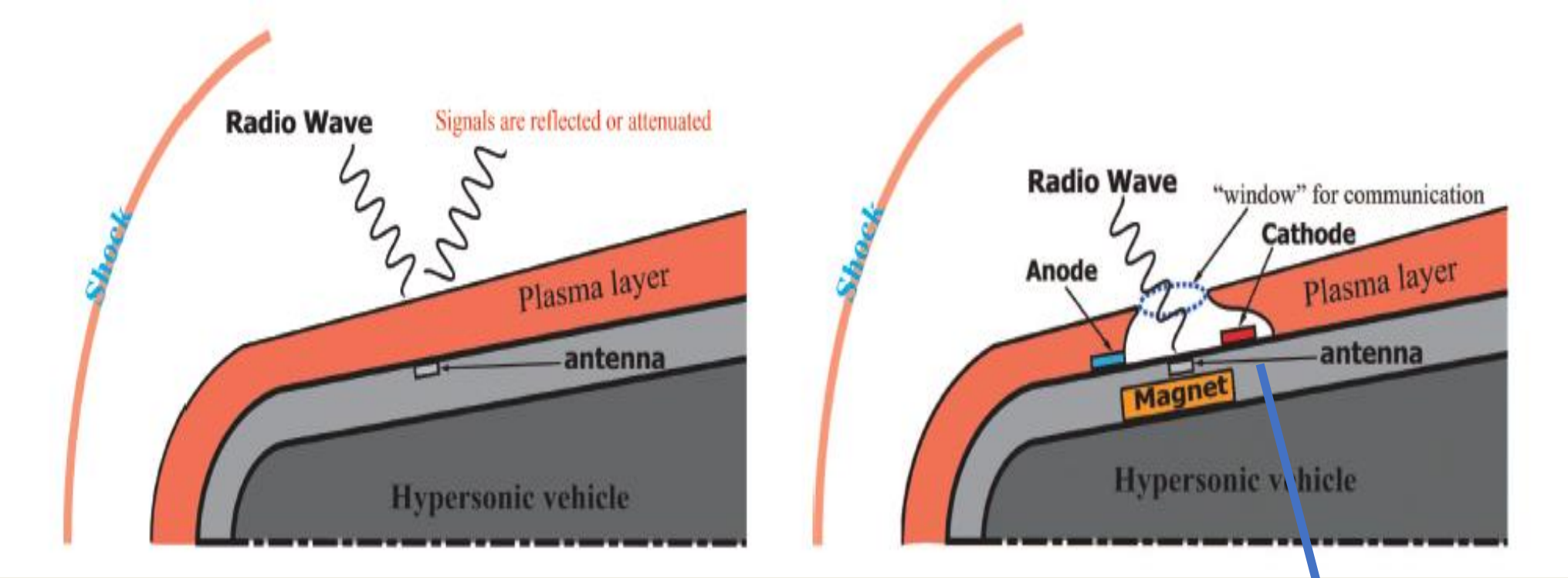
Magnetic Window



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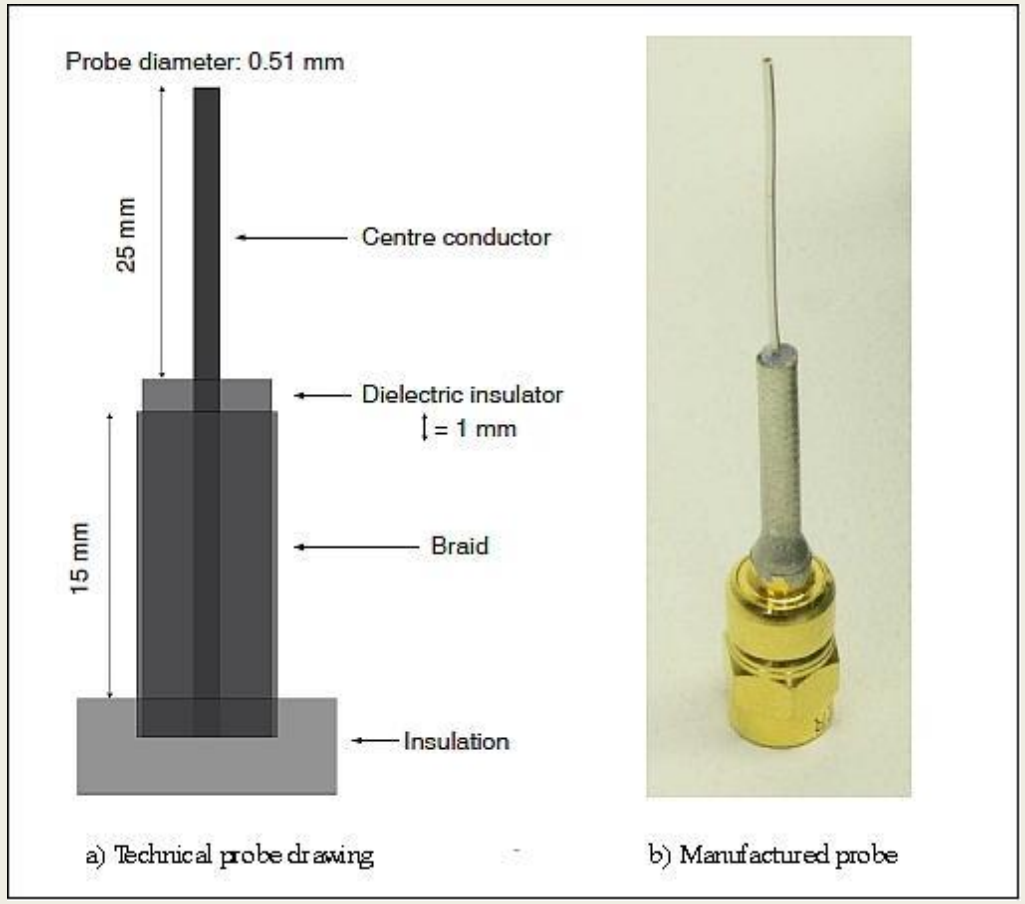
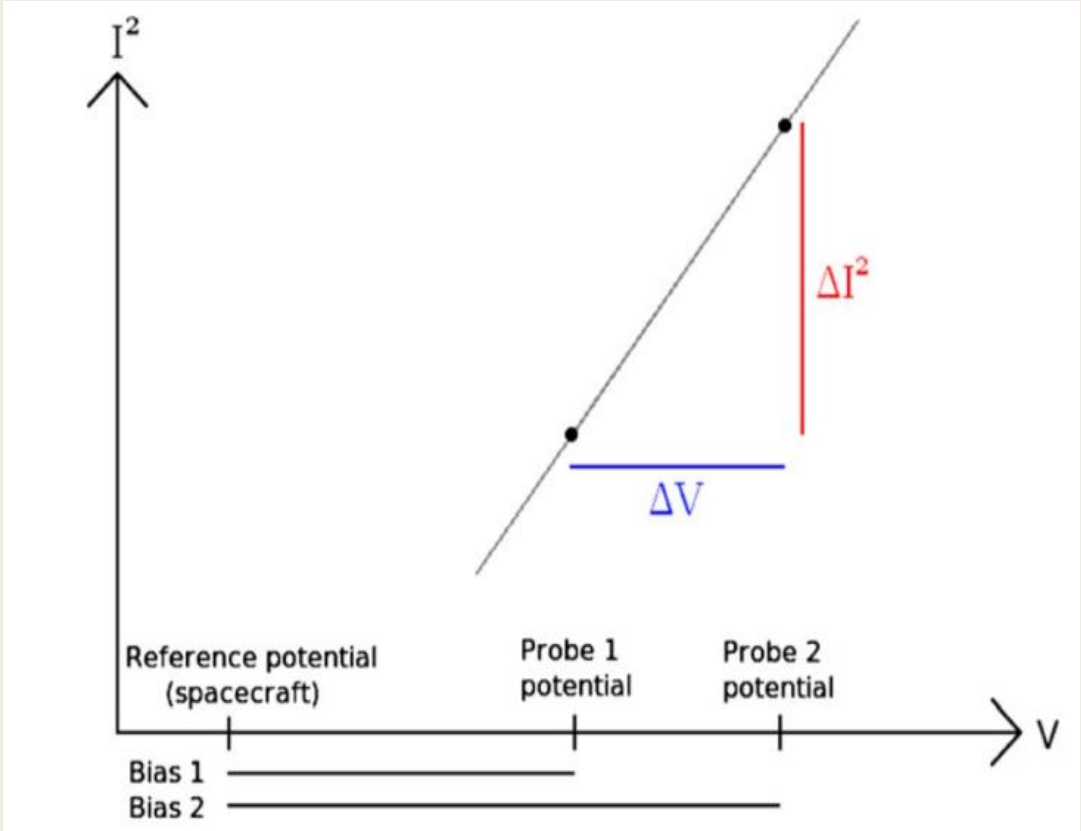
It makes use of a pulsed current flowing through an insulated conductor surrounded by plasma, generating variable magnetic fields, which magnetizes solely the electrons. These electrons are expelled from the field, creating a Hall electric field, and expelling the ions, thus decreasing plasma frequency in a small area, through which radio signals can pass .

E x B Drift

mNLP





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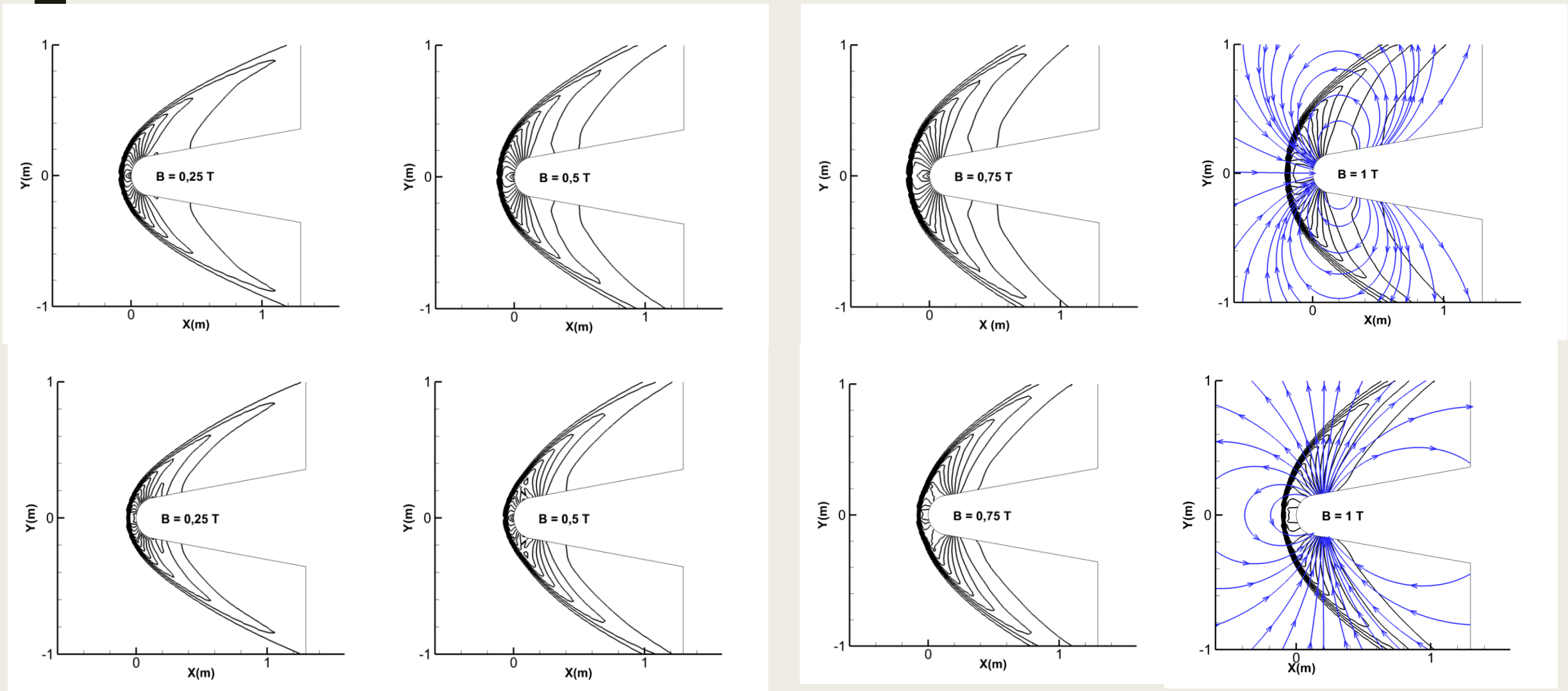
Previous Work

[7] Dias F., Xisto C., Páscoa J. (2016) "Numerical Computations of MHD Flow on Hypersonic and Re-Entry Vehicles", ASME Paper IMECE-2016-65676, pp.9.



Pressure contours around the RAM-C II blunt body for horizontal (top) and vertical (bottom) dipoles for magnetic field intensity of 0,25; 0,5; 0,75T and 1 T