Overview and outlook of CIRA activities on Electric Propulsion

EPIC Workshop 2023, Naples, IT

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CIRA (Italian Aerospace Research Centre) - Via Maiorise, 81043 Capua (CE), Italy, www.cira.it

Outline

- CIRA company overview
- CIRA research activities in EP
  - ✓ New development projects
  - ✓ Current status of the activities
    - o Facilities description: status and features
    - o Diagnostics and Experimental Thrusters
- Conclusions and Outlook

Internal view of the MSVC simulator

CIRA Key Features

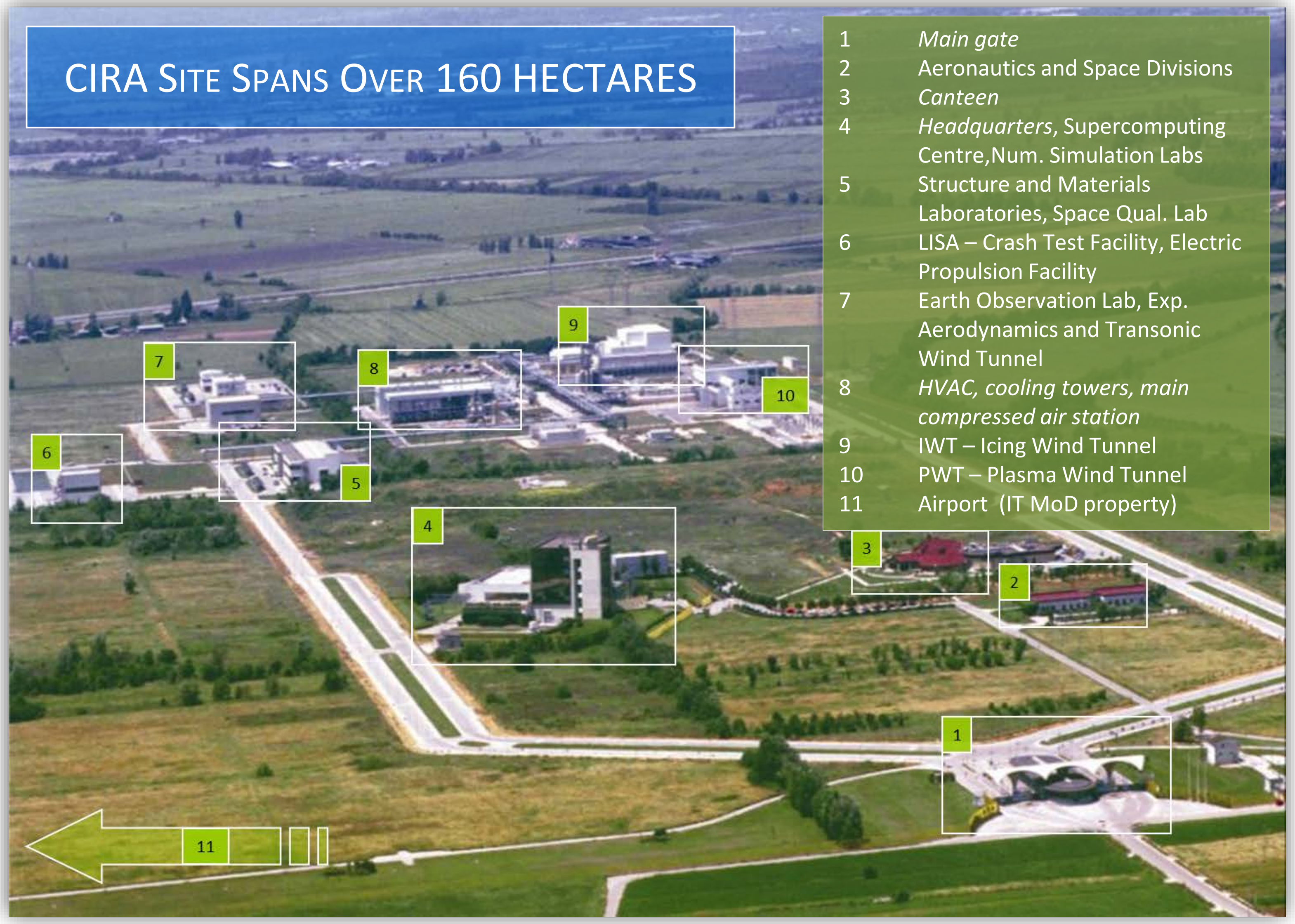
A NO-PROFIT PUBLIC-PRIVATE PARTNERSHIP AMONG:

CNR (NATIONAL RESEARCH COUNCIL) 52%

ASI INDUSTRIAL AREA OF CASERTA 16%

ITALIAN AEROSPACE INDUSTRIES 32%

ALMOST 350 EMPLOYEES (211 RESEARCHERS ; 108 PHD) AND APPROXIMATELY 50 UNIVERSITY STUDENTS AND PHD CANDIDATES A YEAR



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PRO.R.A. National Aerospace Research Program

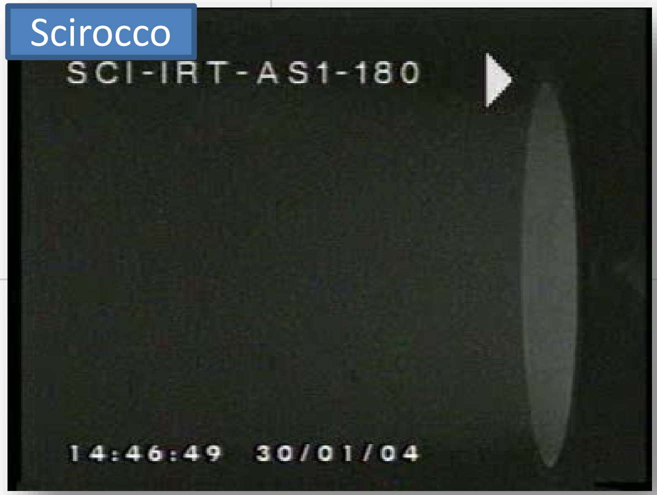
IN 1989, THE ITALIAN GOVERNMENT ENTRUSTED CIRA OF THE ITALIAN AEROSPACE RESEARCH PROGRAM (PRO.R.A.) MANAGEMENT.

PRO.R.A. AIMS TO SUPPORT THE COMPETITIVENESS OF THE ITALIAN AEROSPACE COMMUNITY BY:

- ✓ DEVELOPMENT AND OPERATION OF STRATEGIC TESTING FACILITIES
- ✓ DEVELOPMENT OF STRATEGIC RESEARCH PROGRAMS
- ✓ ENHANCEMENT OF SCIENTIFIC COMPETENCES AND EXPERTISE

CIRA PERFORMS PRO.R.A. MANAGEMENT UNDER THE CONTROL OF MINISTRY OF UNIVERSITY AND RESEARCH (**MUR**)

MUR
Ministero dell'Università e della Ricerca



Research Thematic Areas

Know How

Knowledge

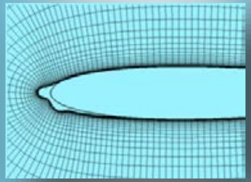
Competences


Systems Integration


Vibro Acoustics

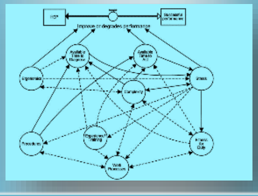

Aerodynamics


Structures & Materials


Icing Simulation


Propulsion

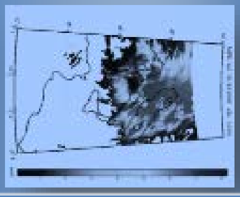

Earth Observation


RAMS & Safety

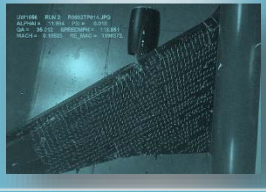

Aerothermodynamics

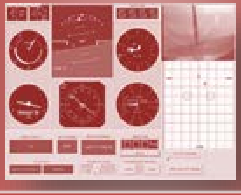

Aeroacoustics


Adaptive Structures


Meteorology

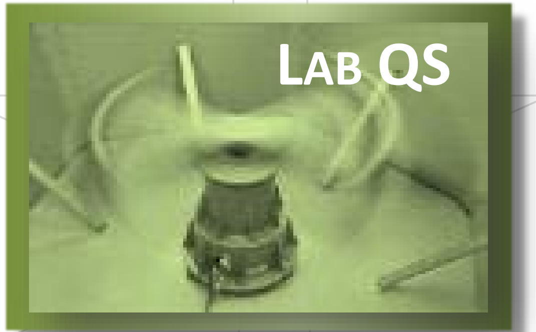

Electronics & Communications


Measurement Techniques


GN&C On-Board Systems

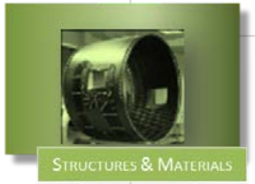
Main Research and Qualification Infrastructures

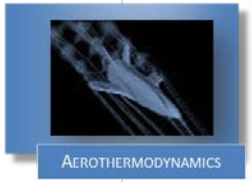
FEEL
INTEGRATE
EXPERIMENT

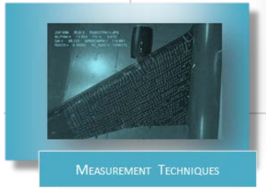


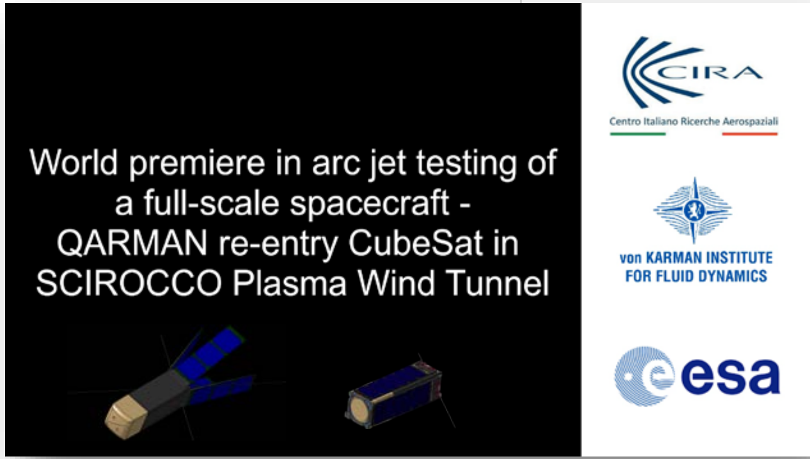
MORE IS COMING…

PWT – Plasma Wind Tunnel









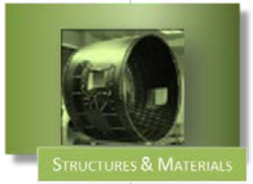
GOAL: IMPROVE SAFETY OF RE-ENTRY SPACE VEHICLES

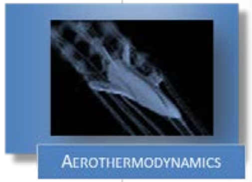
USE: DESIGN AND TEST THERMAL PROTECTION SYSTEMS FOR SPACE VEHICLES

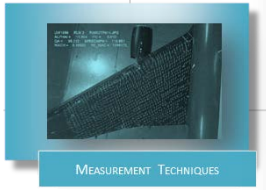
- OPERATIVE SINCE: 2002
- TESTING FLUID: AIR
- MAX SPEED: UP TO MACH 12
- STAGNATION TEMPERATURE: ~ 10.000 °C
- MAX TEST DURATIONS: < 25 MINUTES
- NOZZLE EXIT DIAMETER: 2.0 M
- NOMINAL DIMENSION OF TEST SPECIMEN: 0.6 M
- MAX POWER OF ARC HEATER: 70 MW

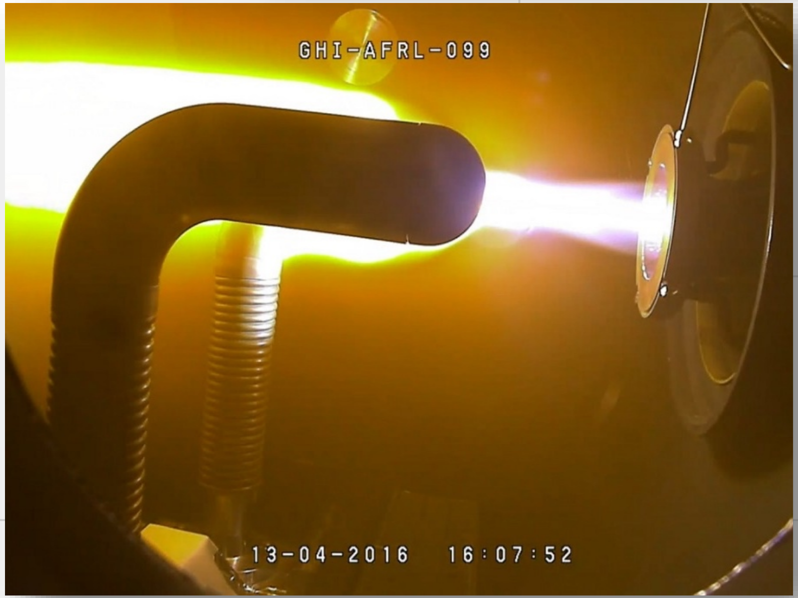
NASA · esa · NASDA National Space Development Agency of Japan · ThalesAlenia Space · Snecma Moteurs groupe snecma · DLR · asi agenzia spaziale italiana · AERO SEKUR · ISRO · ALI

GHIBLI – Small Plasma Wind Tunnel









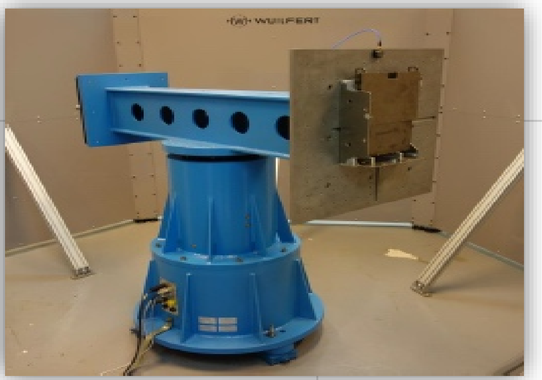
GOAL: IMPROVE SAFETY OF RE-ENTRY SPACE VEHICLES

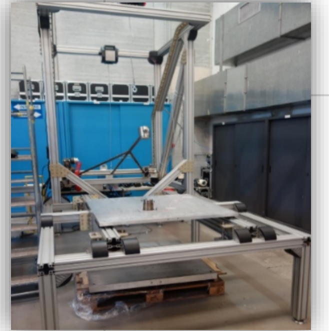
USE: DESIGN AND TEST SMALL SPECIMENS OF MATERIALS TO BE USED FOR THERMAL PROTECTION SYSTEMS OF SPACE VEHICLES

- TESTING FLUID: AIR (CO_2 IS UNDER DEVELOPMENT)
- MAX SPEED: UP TO MACH 10
- STAGNATION TEMPERATURE: ~ 10.000 ° C
- MAX TEST DURATIONS: < 25 MINUTES
- NOZZLE EXIT DIAMETER: 150 MM
- NOMINAL DIMENSION OF TEST SPECIMEN: 80 MM
- MAX POWER OF ARC HEATER: 2 MW

Space Qualification Laboratory

Test & Qualify

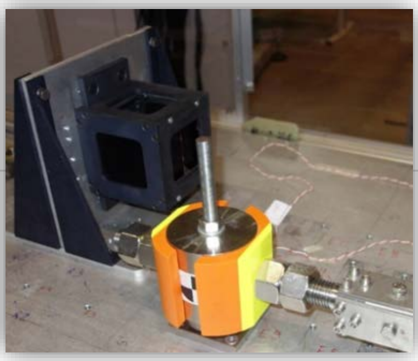


STANDARD ESA, ECSS-E-10-03C, MIL-STD-810G

QUALIFICATION CAPABILITIES FOR:

- PHYSICAL PROPERTIES MEASUREMENTS
- ACCELERATION TEST
- PYRO-SHOCK TEST
- COMBINED VIBRATION, HUMIDITY, TEMPERATURE AND ALTITUDE TEST
- ENVIRONMENTAL STRESS SCREENING
- THERMAL SHOCK TEST, THERMAL VACUUM TEST
- PLATFORM FOR MEASUREMENT
- VIBRATION TABLE
- MECHANICAL SHOCK TEST FACILITY






Space propulsion at CIRA

Cryogenic rocket propulsion (LOX/LCH4)

CIRA DEMO0A LOX/CH4 tests

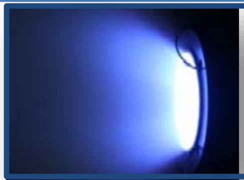
Hybrid rocket propulsion

CIRA 1kN paraffin based thruster

Electric propulsion

CR-HET 250 firing

SPACE ELECTRIC PROPULSION: BASIC CONCEPTS



*«**Electric Propulsion (EP)** is a class of space propulsion which makes use of electrical power to accelerate a propellant by different possible electrical and/or magnetic means.»*

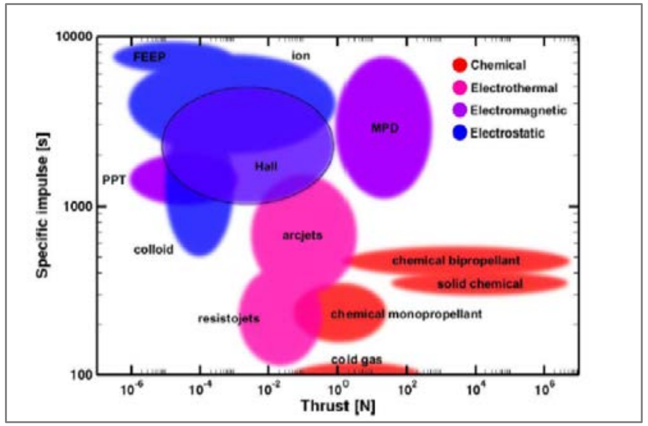
EP is considered one of the most promising technology for the application of present and **next future** space systems

Main advantages

- High specific impulse
- High efficiency (fuel and mass savings)
- Long running times or large radii of action
- Multiple ignitions
- High accuracy of thrust, modulation
- Re-usability
- Easiness of thrust distribution
- Compactness of lay-out

Main disadvantages

- Very low thrust
- Acceleration takes time
- Potential life time issues
- Fairly complex lay-out



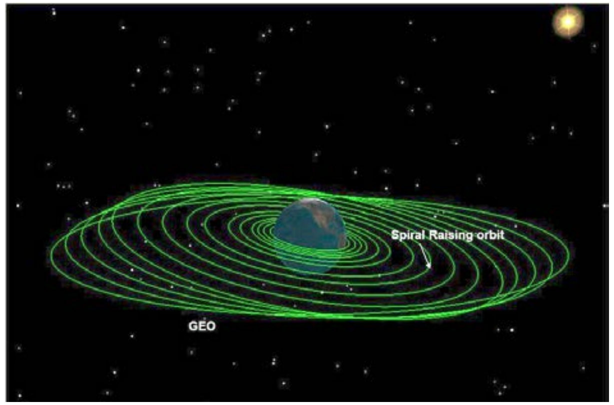
John Tamin Yim,"Computational Modeling of Hall Thruster Channel Wall Erosion", PhD thesis, University of Michigan, 2008.

Propulsori	Processo accelerativo	Energia utilizzata	Isp [s]	T [N]	W/F [kW/N]
Monopropellenti (N_2H_4)	gasdinamico	chimica	230	0.5-100	-
Bipropellenti (N_2H_4/ N_2O_4)	gasdinamico	chimica	310	0.5-1000	-
Bipropellenti criogenici LH_2/LOX	gasdinamico	chimica	450	$0.5\text{-}10^6$	-
Resistogetti (N_2H_4/RCC)	gasdinamico	elettrica	300	0.4	5
Arcogetti (N_2H_4)	gasdinamico	elettrica	420	0.16	10-15
Effetto Hall: SPT 100	elettromagnetico	elettrica	1600	0.086	30
MPD	elettromagnetico	elettrica	2000	100	35
Elettrostatici (EB): UK 10	elettrostatico	elettrica	3250	0.018	25-30
Elettrostatici (EB): NSTAR	elettrostatico	elettrica	3170	0.092	25-30
Elettrostatici (RF): RIT 10	elettrostatico	elettrica	3150	0.015	25-30
FEEP: μ FEEP-100	elettrostatico	elettrica	8000	0.0001	55

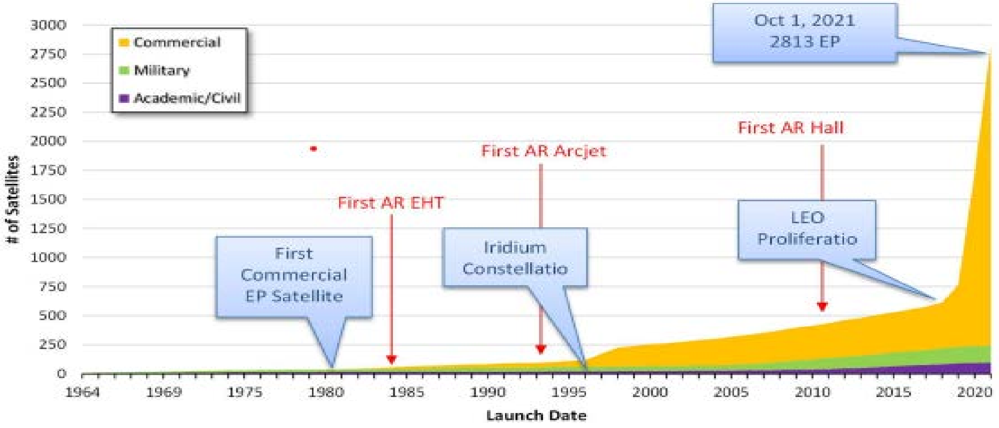
Comparison of different propulsion systems performances

Main Applications

- Station keeping
- Attitude control
- Orbital change LEO to GEO
- Primary propulsion



Example of a orbit raising mission with EP



Cumulative number of spacecrafts launched with electric propulsion

SPACE ELECTRIC PROPULSION: MARKET POTENTIAL

➢ One of the main drivers of the **space electric propulsion market** is the growing demand for reliable and efficient propulsion systems regarding satellite constellations, which provide a range of services:

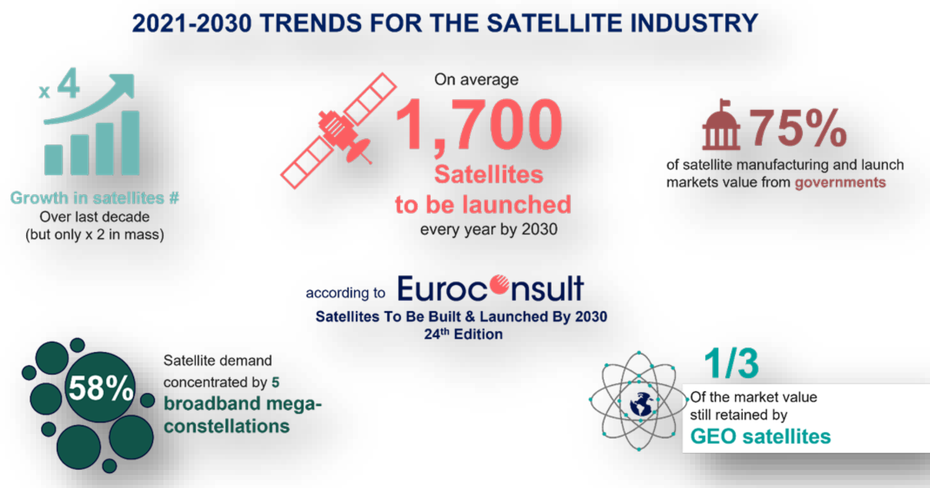
- Communication
- Earth observation
- Navigation

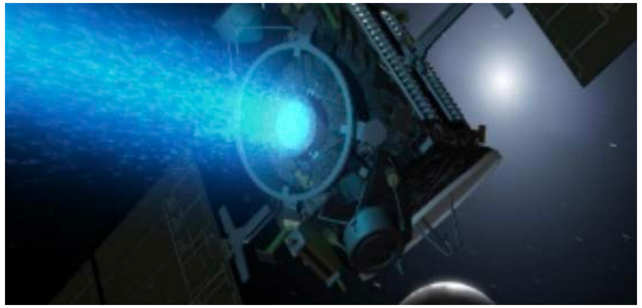
In addition to satellite applications, **space electric propulsion** is also being increasingly explored for deep space exploration missions.

➢ According to a report by *«MarketsandMarkets»,* the global space propulsion **market size is expected to reach $14.2** billion by 2025, growing at a **CAGR of 12.67%** during the forecast period.

➢ The report also highlights the increasing demand for electric propulsion systems, which is expected to drive the growth of the market.

➢ As technology continues to advance, we can expect to see further development and refinement of space electric propulsion systems, leading to even **greater opportunities** for the space industry.



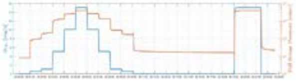


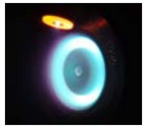
CIRA in Electric Propulsion: a recent story

- CIRA, endorsed by ASI, launched a detailed development plan regarding an **electric propulsion research program** in 2015-16
- **Aims**: to **support National companies in R&D activities, integrate availability of current test facilities** (commercially oriented), cooperate with academic and research Italian Institutions as well with the European scientific community
- A first stage of development has been carried out with the **IMP-EP** project from late 2015 to 2021
- Currently the activities are in CIRA **Innovative Propulsion** program and divided in three new projects
- The cooperation with national and international scientific community will be encouraged and the participation to the most important programs will be promoted







T0

IMP-EP

09/2015 - Project Concept Review

2017 - Final design MSVC – CR HET preliminary design

2019 - Facility installation and acceptance – Thruster Manufacturing

2020 - Laboratory set-up – Preliminary version of the HYPICFLU code

2021 - Commissioning and full operation

Innovative Propulsion

04/2022 - HW Cathode characterization

06/2022 - CR-HET 250 Tests

12/2022 - Thrust balance calibration

Today

Small Scale Vacuum Chamber bid
CR-CAT tests

CIRA current investments in electric propulsion

In order to front the challenges of **novel missions enabled by Electric Propulsion** CIRA made new research investments.

Three Project on Electric Propulsion have been founded with a total investment (PRORA*) of 18 M€ in 9 years.

High level objectives are:

- ✓ **Support** low power systems development → Low Power Electric propulsion (LPEP)
- ✓ **Enable** high power thrusters evolution → High Power Electric propulsion (HPEP)
- ✓ **Increment** TRL of innovative solutions → Innovative Technologies (MATI)

* Programma Nazionale Ricerca Aerospaziale (MUR) https://www.istruzione.it/archivio/web/ricerca/enti-di-ricerca/elenco-enti/prora.html
(National Aerospace Research Program)

CIRA current investments in electric propulsion

Low Power Electric propulsion (LPEP)

* *images from open literature

Facility upgrades

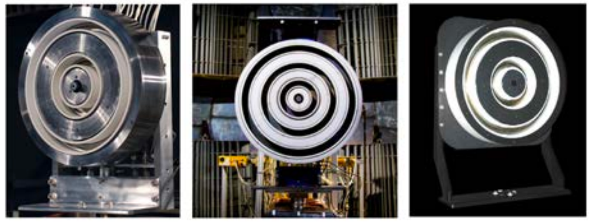
Upgrade of MSVC facility capabilities and availability
Small vacuum chamber for subsystem development
New closed clean area for integration

Diagnostics

Cavity Ring Down Spectroscopy
DLIF system
New Thrust stands
New Probes

Design & Analysis

Consolidation of thruster testing activities
New experimental thrusters
Advanced numerical code



*The X2, X3, and N30 nested Hall thrusters * * *.*

Design and realization of a brand new simulator devoted to high power thrusters (>10 kW)

Development of experimental thrusters and diagnostic for research purposes

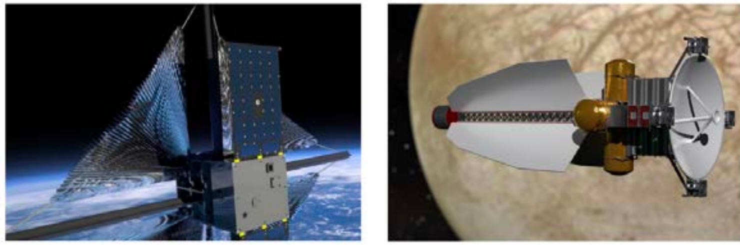
High Power Electric propulsion (HPEP)

** * *Future Directions for Electric Propulsion Research, Aerospace 2020, 7, 120; doi:10.3390/aerospac*

Innovative Technologies (MATI)

*«In such mature market **disruptive innovation** is crucial to increase market uptake and should therefore be promoted» **

** Case study 65 EC Business Innovation Observatory*



Trade off of innovative concepts

- Alternate concepts to Electric Propulsion
- Disruptive technologies in Electric Propulsion

MSVC Test Facility
Main features

The **Medium Scale Vacuum Chamber (MSVC)** is test facility located at **CIRA** premises in Capua.

AIMS

- Enabling the start of planned **R&D activities** on engines up to **5 kW** (*improvement of analysis, theoretical and numerical modeling, design and fabrication competences*)
- Integrating test infrastructures, currently available in Italy and commercially oriented, with an advanced facility
- Promoting the **Cooperation** with other National and International actors

MSVC simulator

MAIN FEATURES

- **Pumping speed** up to about **80,000 l/s** (Xe) and fully **cooled**
- **Dimension**: 2-m-diameter x 4.5-m-long
- **Performance** evaluation, **plume** characterization and **lifetime** tests
- Key to improve **experimental**, **design** and **analysis capabilities**
- First implementation of **advanced diagnostics**
- **Research** on innovative materials, propellants, technologies

Medium Scale Vacuum Chamber (MSVC)	
Dimensions	(ab.) 1.9 m D (inner) x 4.5 m length
Vacuum	Up to 5e^{-8} mbar (ultimate pressure)
	Lower than 4.0e^{-5} mbar (working)
Applications	R&D purposes, equipped with advanced diagnostics
Reference test article	HET (up to 5 kW) fed up by Xenon (up to 15 mg/s)

MILESTONES

- ✓ **Medium Scale Vacuum Chamber (MSVC)** preliminary design was completed by CIRA in **April 2016** and Final design, manufacturing and installation activities were entrusted to Angelantoni Test Technologies (Massa Martana, Italy)
- ✓ Delivery, assembly and installation of the simulator at CIRA premises were accomplished in **Sept 2019**
- ✓ **Functional** and **Acceptance Tests** were accomplished in **December 2019**
- ✓ **Completed the laboratory area in 2020**
- ✓ **Commissioning and full operation of simulator have been accomplished in 2021.**
- ✓ **Facility operative since January 2022.**

MSVC Test Facility
Subsystem details

Multistage pumping system (up to 10^{-8} mbar) composed by:
- ***primary pumping system*** – one dry pump (Oerlikon Leybold LEYVAC LV140 - 100 m^3/h) and one root pump (ROOTS WAU 501 - 500 m^3/h)
- ***High** and **ultra-high vacuum system*** – one turbo-molecular pump (Oerlikon Leybold TURBOVAC MAG 700 - 700 l/s on N2), one cryo-pump (Oerlikon Leybold COOLVAC 10000- 10000 l/s on N2), 4 single-stage cold heads (CHDs – 74000 l/s on Xe)

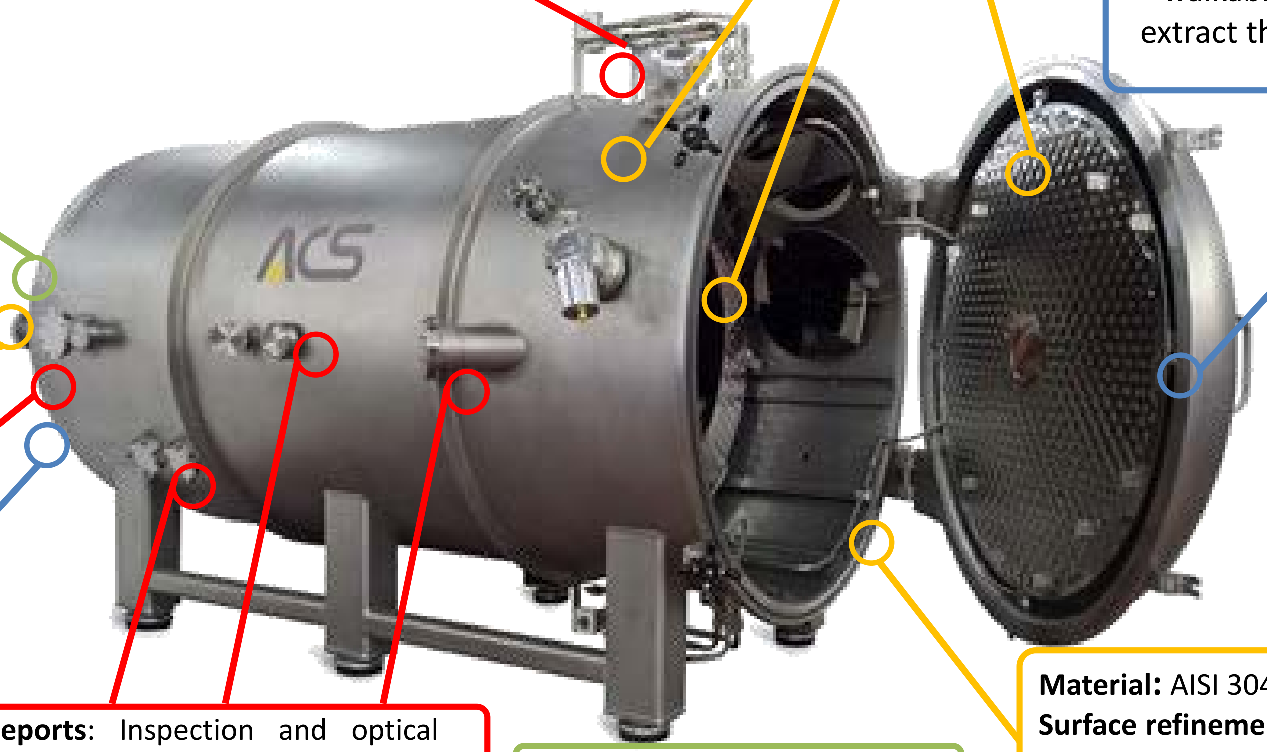
Refrigeration: three independent sections (cylindrical section, annular shroud - plume expansion zone- and end-cap cooling system)

Beam Target: provided with graphite plates

Access: through full size door - walkable panels and rails to extract the thrust stand sled

Flow controllers: for anode and cathode feeding

Main Electrical connections



Thrust stand: located at 700 mm from the front cap and mounted on a dedicated sled

Access to thrust stand zone: front cap (DN 900)

Vieweports: Inspection and optical feedthroughs
Fiber feedthroughs

Antivibration feet

Material: AISI 304L stainless steel
Surface refinement: by micro-peening process
Lined with graphoil sheets

MSVC Test Facility Equipment

MSVC is equipped with:

- 4 chamber pressure transducers
- 1 mass spectrometer *Residual Gas Analyzer*
- 3 pumping system pressure transducers located on the turbo and cryo-pumps
- cold heads and target temperature sensors (type-K thermocouples and PT100)
- Skid including electronics/control rake, pump accessories and helium compressors
- 4 power supply units (by Magna Power)
- Support facilities – dedicated **soft-wall clean room**, UPS system and chiller, integration area.

Side view including the skid

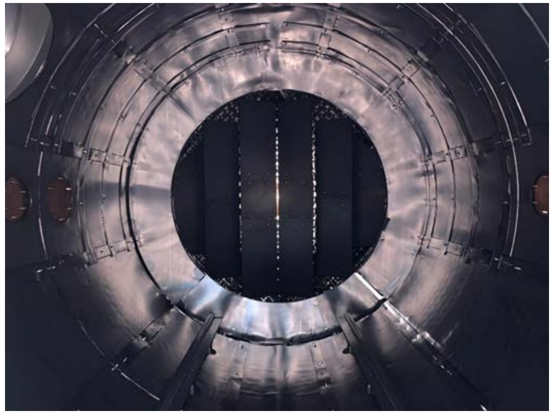
34 feedthroughs, including:

- measurement instrumentations
- baking and venting (automatic or manual)
- electrical (in front and side parts)
- fluidic supplies (2 mass flow controllers)
- inspection viewports
- optical viewports (Fused Silica UV GRADE and ZnSe optics) – 2 ports with inclination of 45 degrees and 1 port on the back door
- optical fiber feedthroughs
- 1-axis rotating rake, dedicated to the intrusive diagnostics

Side view of MSVC simulator

View of end-cap

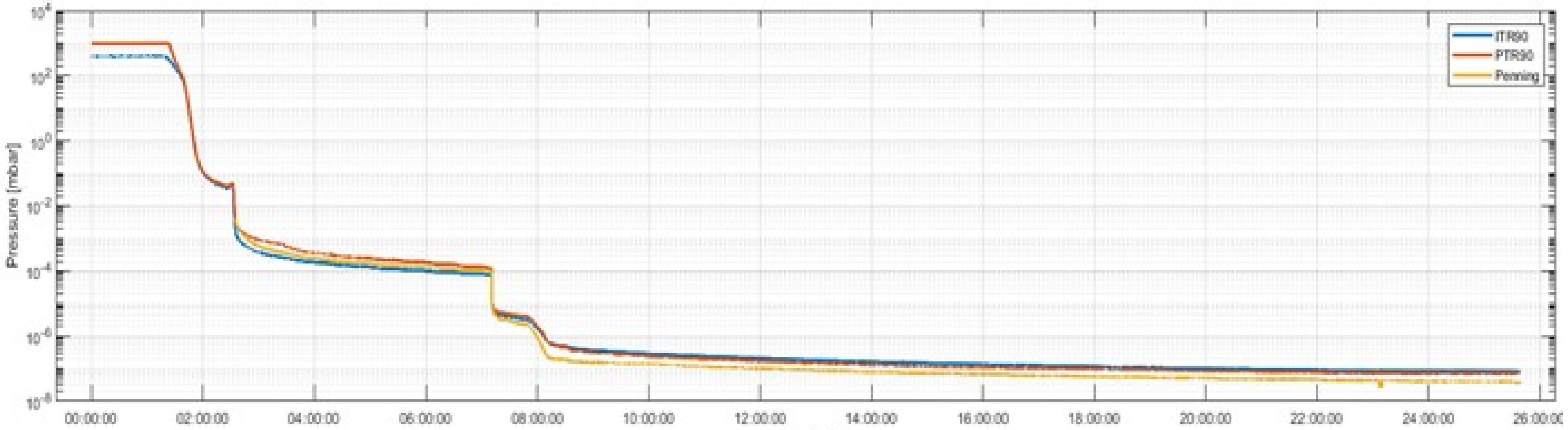
Internal view from end cap



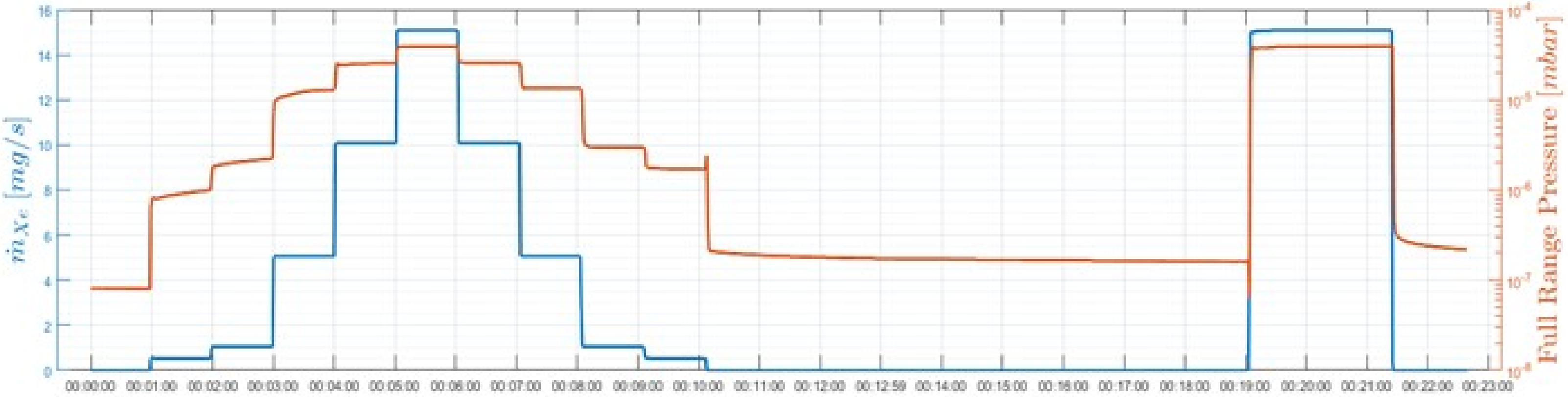
Internal view from thrust stand

Final performance Tests
Xenon injection tests

- After the installation several performance tests at subsystem level have been accomplished
- A final dynamic pumping test has been carried out to verify that the **pumping capability** of the facility was in line with requirements
- Xenon mass flow rate (ranging from 1 to 15 mg/s) has been injected into the facility and the pressure measured has been recorded by full range pressure sensors



Ultimate Pressure



Operating Pressure vs injected Xenon mass flow rate

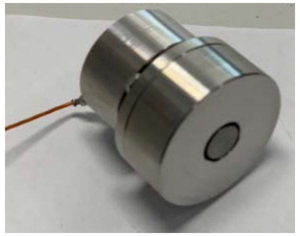
Non-intrusive diagnostics

High Speed Imaging Camera

Thermography

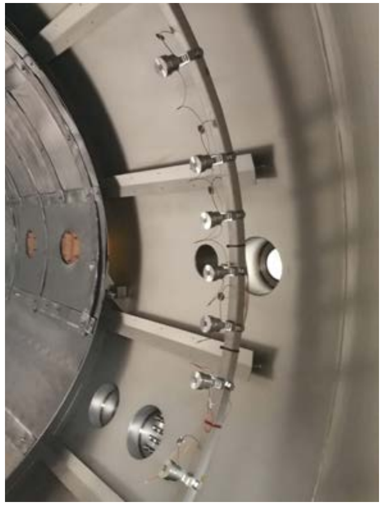
Intrusive diagnostics

Langmuir probe

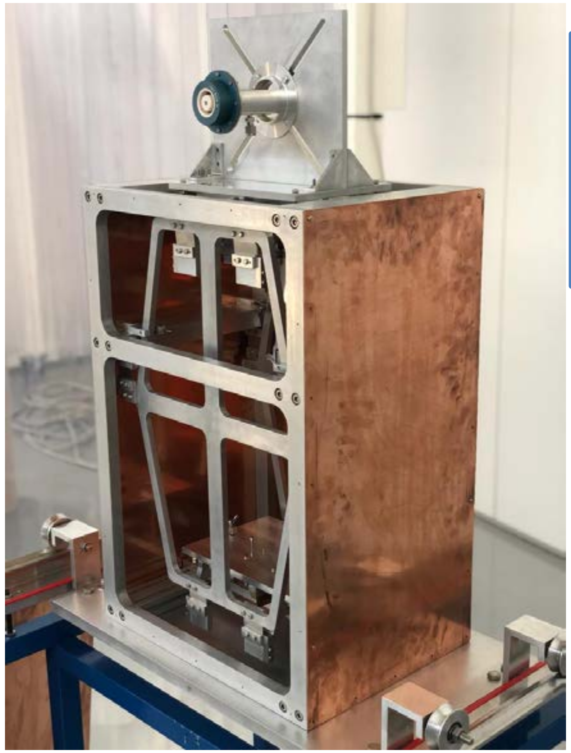


Faraday probe

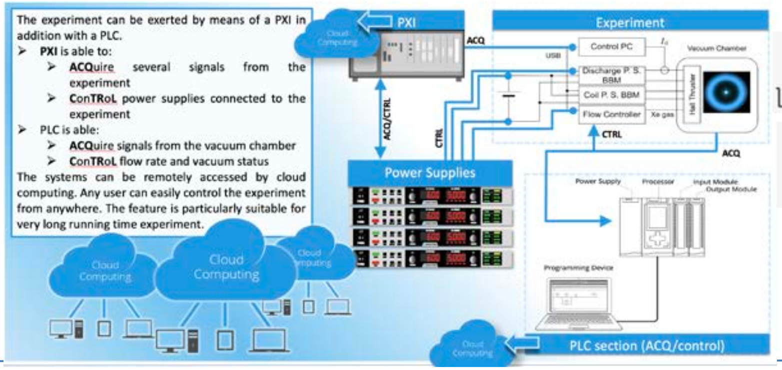
Langmuir stand and rotating arm



Detail of Faraday probes rake on the rotating arm

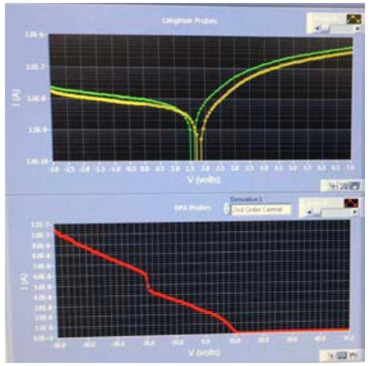


Thrust stand features
Maximum thruster weight <7 kg
Measurable thrust range 0-100 mN
Accuracy 1 mN
Repeatability 0.5 mN
Resolution <0.15 mN



Command control and Data Acquisition System Architecture

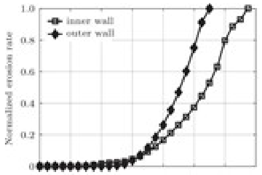
Calibration activities has been completed on Faraday and Langmuir probes in IAPS with a ion source.



ISTITUTO NAZIONALE DI ASTROFISICA
ISTITUTO DI ASTROFISICA E PLANETOLOGIA SPAZIALI DI ROMA

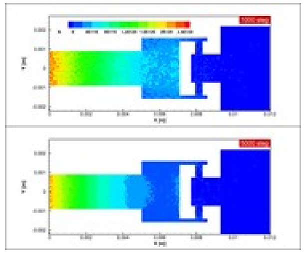
Development of Laboratory Thrusters

The **Experimental Thrusters** line has been established in order to improve CIRA knowledge on design and modeling aspect of electric propulsion. Hardware has been designed and manufactured in order to verify design and manufacturing process. Proprietary numerical tools have been developed.

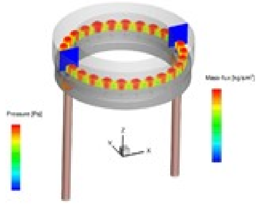


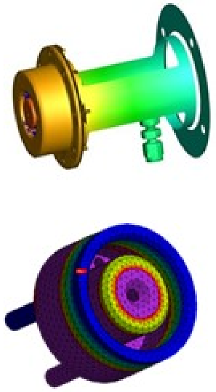
Testing

Gas Dynamic design

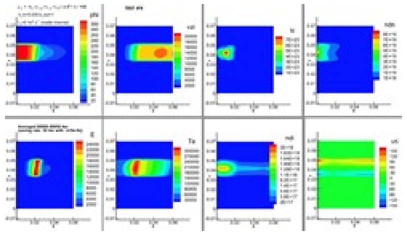


Erosion phenomena modeling





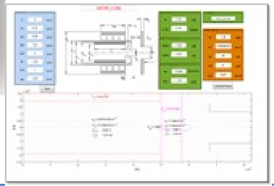
Thermo-structural modeling

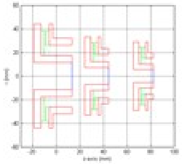


Assmbly Manufacturing and integration

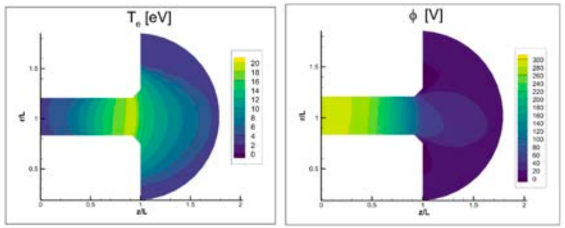
Magnetic field modeling and optimization

Scaling and pre-design

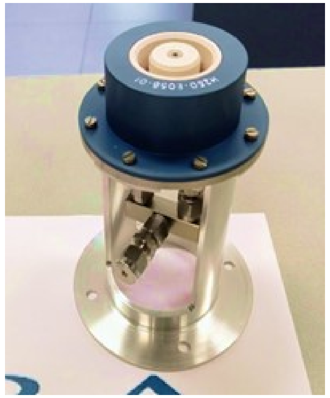




Plasma modeling



CRHET-250	
Discharge Power	250 W
Specific Impulse	1250 s
Propellant	Xenon
Cathode Location	External
Thruster Mass	0.45 kg



CRHET mark 3 unit

CRHET mark 1 In MSVC

A supporting project «MEMS» has been established with internal funds in order to better focus EP modeling aspects

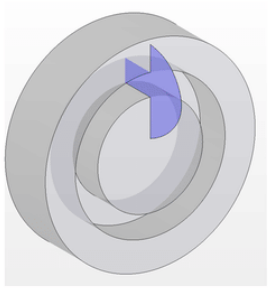
Methodologies and Models for Electric Propulsion (MEMS) project

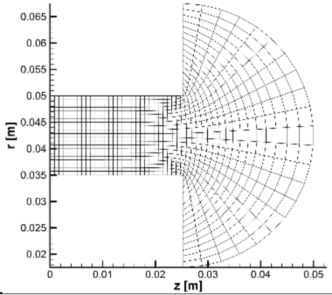
Main Tasks

- Development of plasma code for HETs
  - Magnetic field optimization in HETs
- Modeling of erosion phenomena in HETs

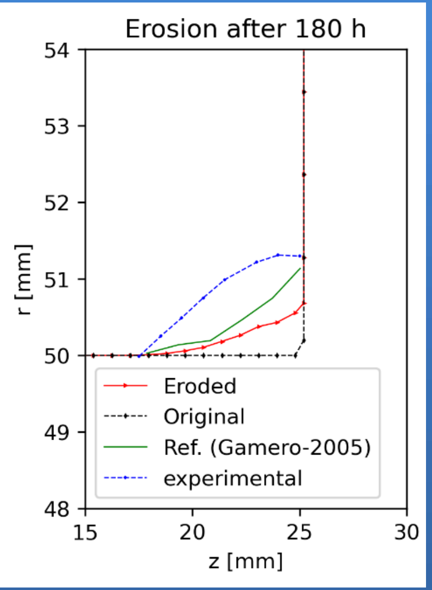
HYPICFLU (Hybrid Particle-In-Cell + Fluid)

- 2D axis-symmetric
- Domain: channel + near plume
- Particle in Cell: neutrals and ions
- Fluid approach: Electrons

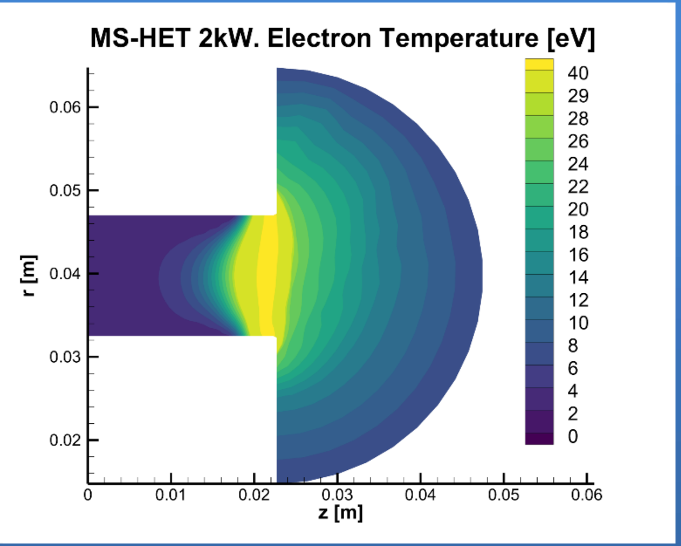




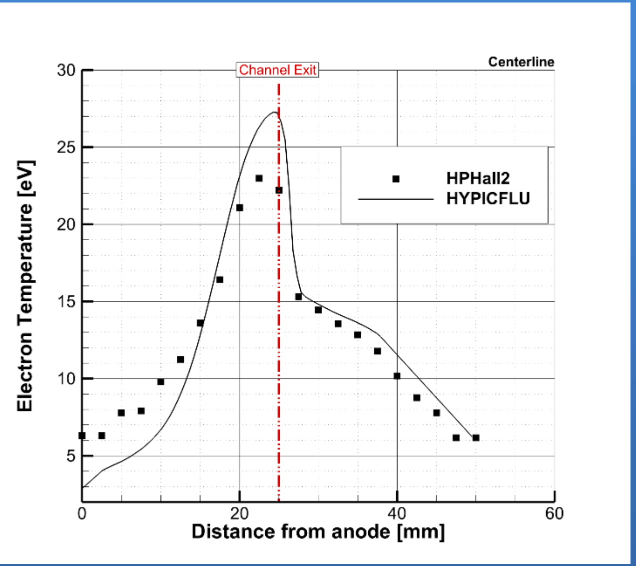
Erosion of SPT100 channel wall



Application of HYPICFLU



Validation of HYPICFLU (SPT100)



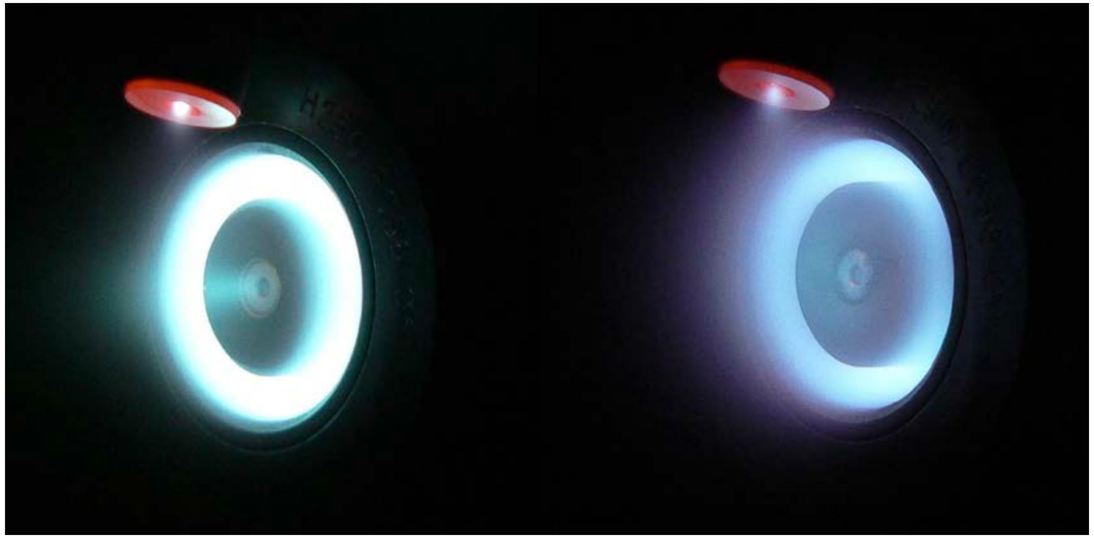
Preliminary experimental activities

Objectives: -verify MSVC facility performances in a plasma environment.
- characterize the behaviour of the thruster at different regimes

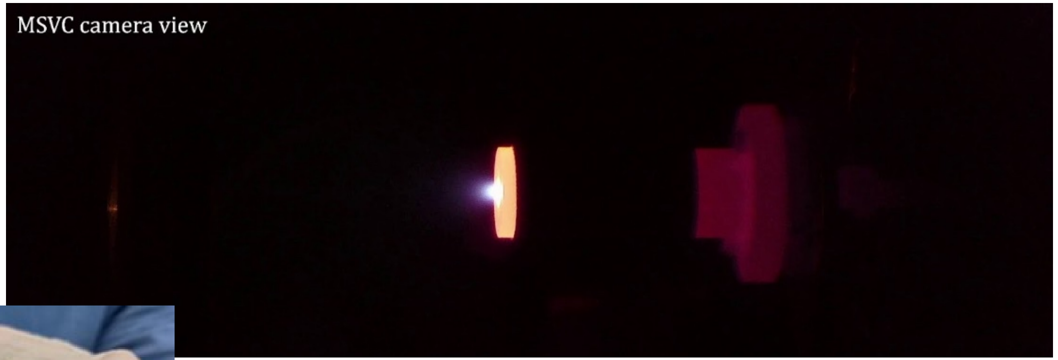
-Preliminary tests on CR-HET thruster unit 1 coupled with the electronic source by Heat Wave Lab have been performed.

-The level of the pressure has been monitored and verified during testing.

-The thruster performed about 40 hours of firing with multiple ignitions at different power levels (80 to 600 W) and the status is good.



CR HET during firing at high and low power level



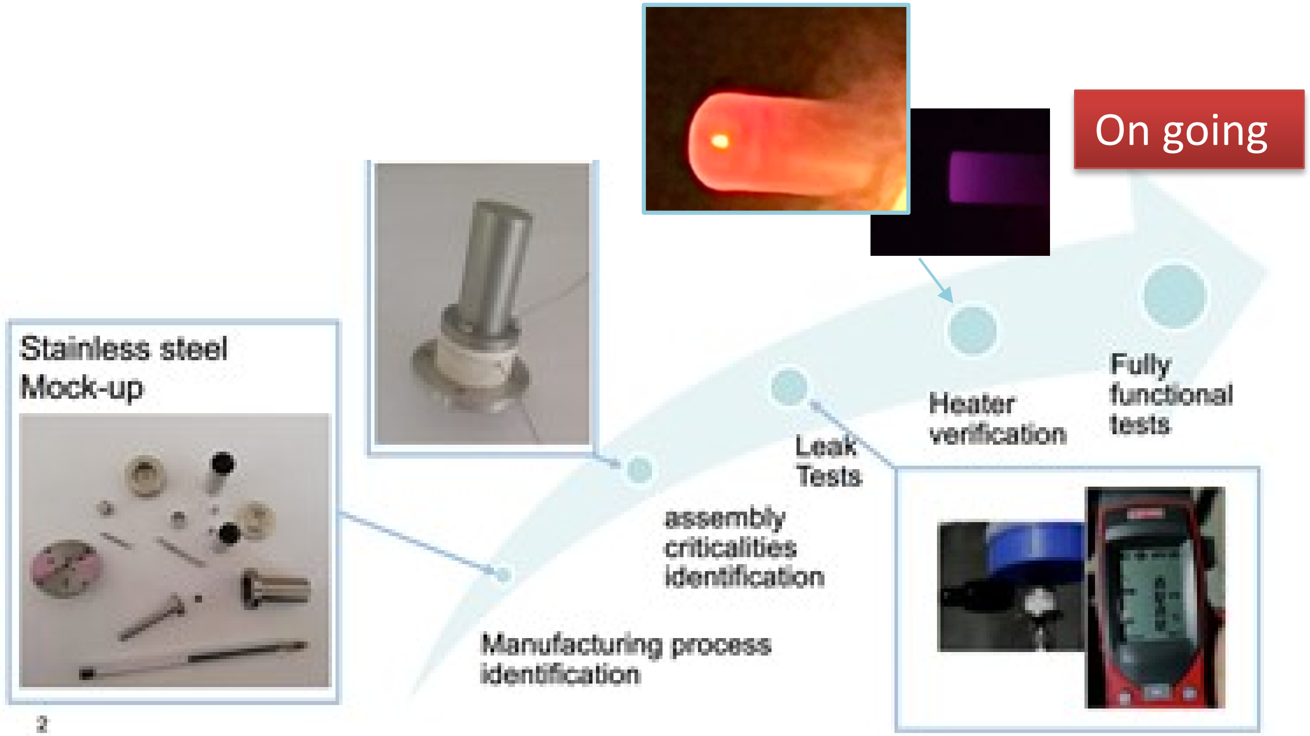
Cathode Heat Wave Lab during characterization testing at MSVC in triode mode

Heat Wave Lab cathode

180 W operation mode	Mean	Std
Anode current (A)	1.009	0.001977
Full_range_CAMERA_ITR90_116_(mbar)	2.96E-06	1.20E-08
Flow rate Xe anode (mg/s)	0.7612	0.000981
Flow rate Xe cathode (mg/s)	0.084	3.19E-16
Thrust (mN)	10.1	0.05
Acquisition Interval time	02:05:33	

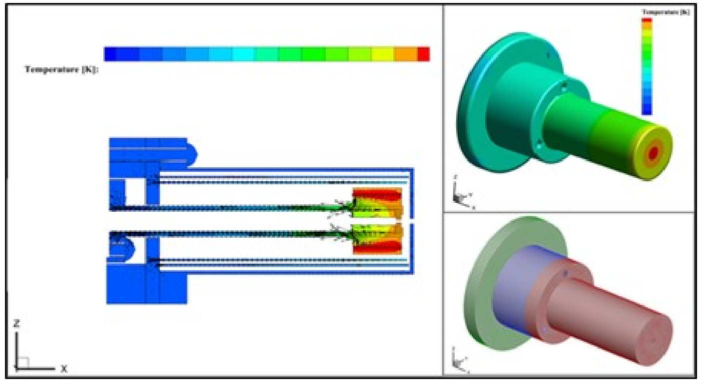
Laboratory hardware Cathodes

- Hardware designed and manufactured in order to verify design procedure and develop manufacturing processes for hollow cathodes.
- CR-CAT has been manufactured, the heater verification has been accomplished and the fully functional tests are on going.



Catodo CR-CAT

CIRCAT	
Discharge Current	1 A
Discharge Voltage	14.2 V
Mass Flow Rate	0.097 mg/s
Propellant	Xenon



CR-CAT – Thermal analyses

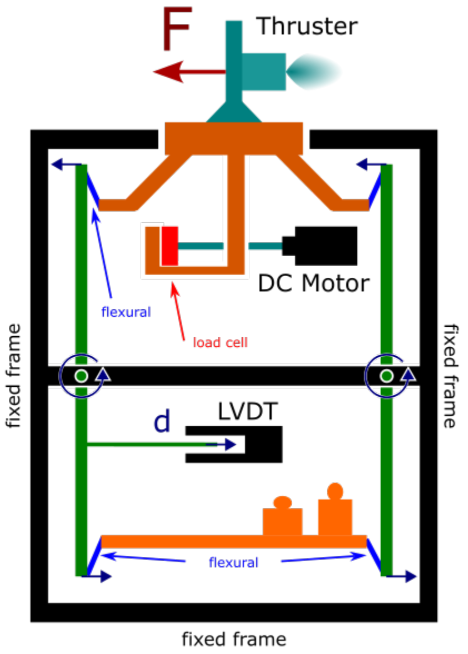
Thrust Measurement and Calibration

In order to perform **small thrust measurement**, a *double pendulum system* has been developed.

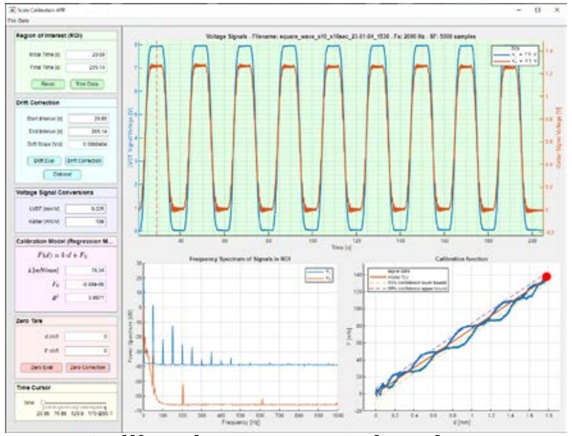
A calibration procedure has been developed in 2022 to obtain force/displacement conversion:

- by means of a stepper motor, it is possible to simulate a big *displacement* of the thrust stand. This create a big *virtual force* acting on the double pendulum;
- by means of a load cell, the force is measured;
- correlating both displacement and force data, a calibration curve is obtained by means of statistical methods (MATLAB).

The results confirms that the requirements are obtained.



Double pendulum schematic



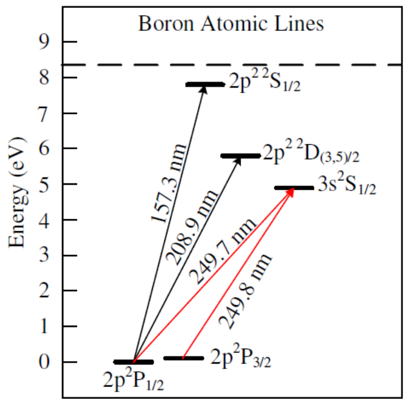
Calibration curve estimation

Thrust stand features
Maximum thruster weight <7 kg
Measurable thrust range 0-100 mN
Accuracy 1 mN
Repeatability 0.5 mN
Resolution <0.15 mN

Actual Scale System

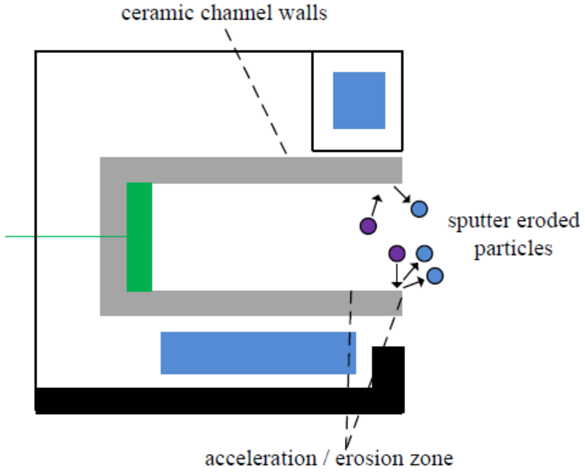
Cavity Ring-Down Spectroscopy – CIRA status of development

The **CRDS** technique will be adopted **to measure HET erosion rates of acceleration channel**. It is based on the absorption measurement of sputtered boron atoms into the plasma plume, in the wavelength region of 250 nm.
The measurement of Boron ground states is linked to the sputter erosion rate of boron nitride channel.

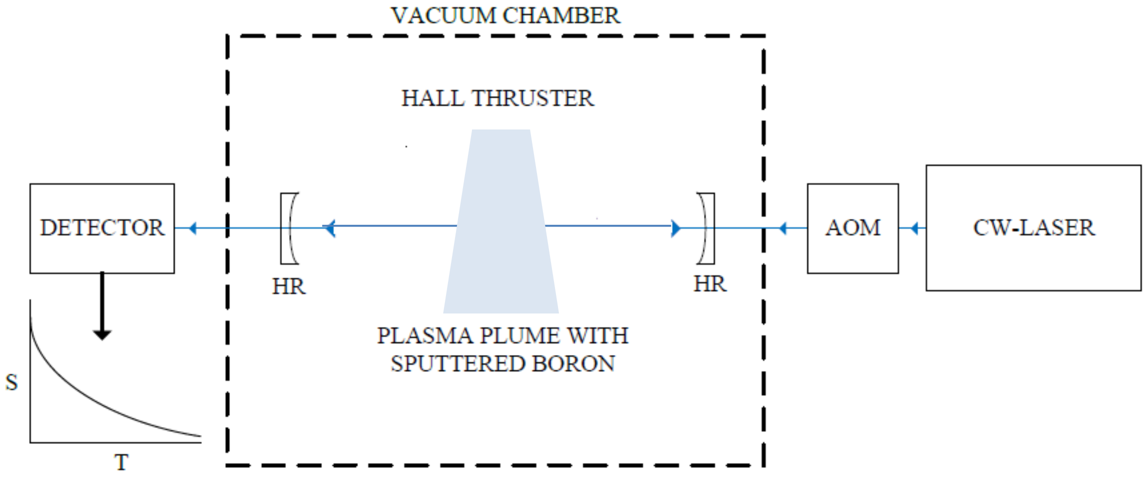


- The light emitted from a **continuous-wave laser**, matching the boron atomic line, is trapped into an optical cavity formed by **high-reflectivity mirrors.**
- The light couples the cavity and makes many passes between the mirrors, crossing many times the plasma volume containing the sputtered boron.
- A **photo-detector** placed behind the cavity measures the temporal decay of optical intensity within the cavity due to boron absorption.
- The difference in the temporal decay rate with and without the laser coupled with the cavity yields the boron concentration in the plasma plume.

A set up of a **small scale system** has been prepared and will tested preliminarily in CIRCE lab in Caserta.
Cira has designed and manufactured the cavity.



Schematic of a sputtering erosion of an HET by ion bombardment on the acceleration channel



Simplified diagram of the CRDS set-up to measure boron in the plume of an HET thruster.
AOM: acousto-optic modulator to shut off the laser, HR: high-reflectivity cavity mirror

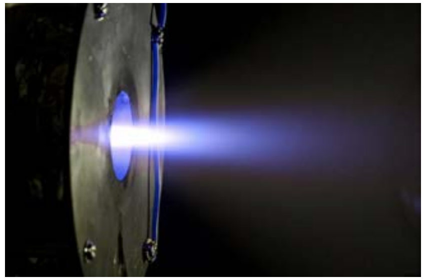
Challenges:
- Implementation of the set-up.
- Complexity and high cost of equipment.
- Delivery of the laser beam into the vacuum chamber.
- Ability to maintain the cavity alignment.
- Ability to avoid reflectivity degradation of the mirrors.
- Processing of measurements.

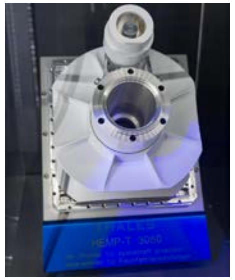
Strengths:
- High sensitivity.
- Quantitative measurements.
- Non-intrusive detection.

Innovative technologies project: early advancements

- The project in its first stage is focused on very low power thrusters (2-6 mN)
- Patent and literature review has highlighted the most interesting technologies.
- Development of **Preliminary Design Tools** for HTP, HEMPT, GIT in the low-power class.
- Trade-off analyses of different HPT's configurations

**

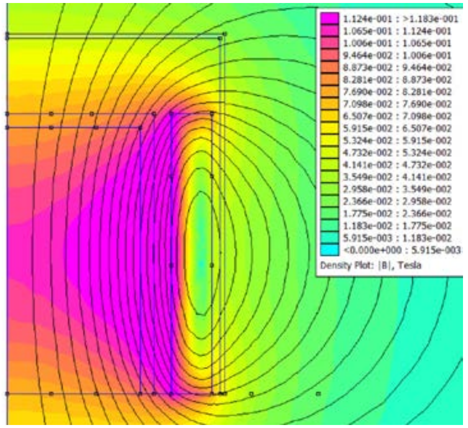




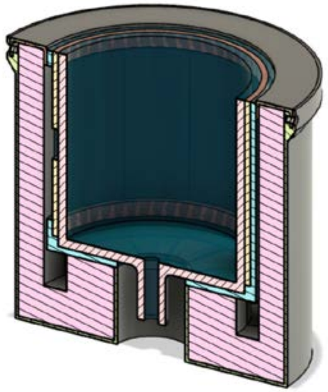
Preliminary Design Tools

↓

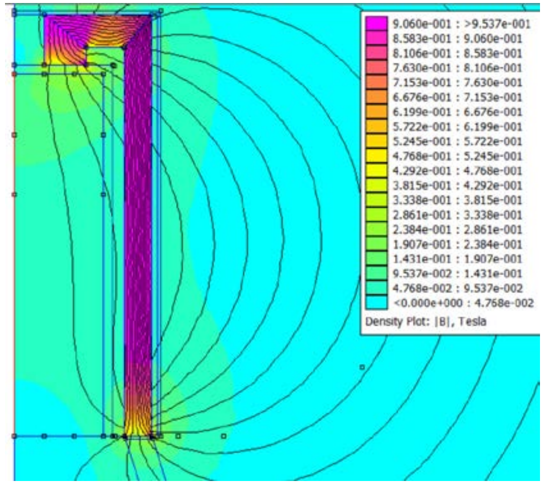
Genetics Algorithms - Particle Swarm Optimization to improve scaling methodologies



Coils Config.



HPT Preliminary Design



Permanent Magnets Config.

**"Dual-Stage Gridded Ion Thruster (DS4G)". ESA Advanced Concepts Team — Advanced Propulstion.
HIPATIA (HelIcon PlasmA Thruster for In-Space Applications) Project è un progetto ESA insieme alla SENER Aerospacial e la UC3M ma non trovo un nome specifico del solo propulsore.
"HEMPT 3050 Propulseur ionique". Thales Group.

New Test Facilities

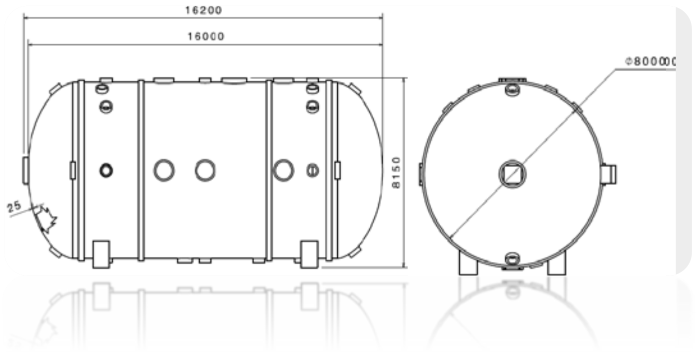
Large Scale Vacuum Chamber (LSVC) is a 8-meters-diameter vacuum facility that will be located at **CIRA** in Capua in a new dedicated building

Some unique facility capabilities include:

- A **large chamber volume** (8 m diam by 16 m long)
- Capable of **2,500,000 l/s** (air) **pumping speed** and equipped with the most advanced diagnostic systems.
- **Auxiliary chamber**, connected to the main chamber, in order to ease the eventual operations on the engines without influencing the vacuum conditions
- **Performance** characterization, **plasma diagnostics** and **lifetime** tests of **HET** with a power higher than **25 kW**
- **R&D activities** on **high power HET**, based on alternative propellants, or other technologies like **MPD, VASIMR**

Large Scale Vacuum Chamber (LSVC)	
Dimensions	(ab.) 8 m diam. x 16 m length
Vacuum	Up to 5e^{-7} Pa (ultimate pressure)
	Lower than 2.5e^{-3} Pa (working)
Applications	Tests on complete high power EPT, solar simulation, thermal simulation, plasma interaction effects on spacecraft, integration of space systems. Equipped with state-of-the-art diagnostics
Reference test article	HET (50 kW class) fed up by Xenon (100 mg/s)

Sketch of LSVC



Original plan

Why time has passed?

CIRA is evaluating whether an infrastructure of this class could be **a real need** for the National/European electric propulsion community - a possible scaling of size and performance is envisaged.

Conclusions and Outlook

- According to the strategic plan, CIRA realized MSVC (Medium Scale Vacuum Chamber) in order to cover the R&D activities for the present class of EP thrusters (up to 5 kW power)
- MSVC will operate **R&D activities and integrate the other Italian space simulators**, conceived as commercially oriented. The installation at CIRA premises has been completed in September 2019 and the final acceptance test phase has been accomplished in December 2019. The start-up phase has been concluded and the simulator is fullt operative
- CIRA has also improved researchers **know-how on Electric Propulsion** by developing advanced methodologies of design, analysis and testing of laboratory thrusters
- Low-power class Hall Effect Thruster including a hollow cathode, CRHET-250, has been designed, manufactured and tested. Test campaign will continue in 2023 to fully characterize the thruster.

Outlook

- Some projects, funded by ProRA (Ministry of University and Research), have been launched in order to support research in the new commercial electric propulsion era covering different areas of electric propulsion and **improving the testing capability** of the National and European sector

Italian Aerospace Research Centre

CIRA (Italian Aerospace Research Centre)

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Acknowledgments

CIRA team: V. Salvatore, M. Fragiacomo, D. Cardillo, E. Marenna, V. De Simone
ATT personnel: F. Rinalducci, D. Cardoni and M. Sugoni, for their precious cooperation in MSVC realization
Grado Zero srl team for their support to intrusive diagnostic design and manufacturing