

ESA Propulsion Laboratory (EPL)

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Abstract: Any spacecraft needs chemical and/or electric propulsion systems to operate in space. The development of such systems requires a major effort in testing activities. The ESA Propulsion Laboratory (EPL) provides test services to the ESA Propulsion and Aerothermodynamics Division, which is responsible at European Space Agency for R&D activities and support to projects in the areas of chemical propulsion, electric and advanced propulsion and aerothermodynamics. The EPL also provides technical advice and support to external organisations for subjects related to propulsion testing and test facilities. A laboratory dedicated to electric propulsion exists at ESTEC since early 1980s. In the last years, the activities of the laboratory, under project request, have been expanded to chemical propulsion (cold gas and other non-toxic propellants). In 2004, EPL obtained dual ISO 17025 accreditation and ISO 9001 certification. In 2007 the EPL changed its physical location and several tests were performed in order to validate the correct functioning of the facilities. During 2009 to 2011 the normal operations were re-established and several tests for ESA projects and basic research in the field of chemical and electric propulsion were carried out. This paper will describe the present EPL structure, capabilities and activities.

Nomenclature

<i>EPL</i>	=	ESA Propulsion Lab
<i>EP</i>	=	Electric Propulsion
<i>ESA</i>	=	European Space Agency
<i>FEEP</i>	=	Field Emission Electric Propulsion

I. Introduction

Electric Propulsion systems are baselined in several ESA missions that will be launched before 2015 (Alphabus, Small GEO, Bepi Colombo, Aeolus, Lisa-pathfinder, etc.). Furthermore, future missions such as LISA, post-GOCE, EDRS, etc. will require also EP systems to achieve stringent propulsion requirements. Chemical propulsion systems such as cold gas thrusters are also baselined in many ESA missions (Small GEO, GAIA, Cryosat, etc.) The development of all these Electric and Chemical thrusters requires a great effort in the testing area. The ESA propulsion lab (EPL) provides support to ESA projects, develops new propulsion systems and contributes actively in the operational phases of some missions (Smart-1, Artemis, etc.). The main effort of EPL is directed towards the performance, endurance and assessment testing of propulsion systems for ESA missions. Furthermore, the EPL fosters collaboration with international industry and Academy in the field of space propulsion research, development and testing. This paper will present the structure, the facilities, the capabilities and the activities of EPL at ESA.

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II. Main Purpose and history of EPL

The EPL supplies services to ESA projects requiring a first independent and fast assessment. Furthermore, the EPL enables a fast access to qualification tests that are long and expensive in nature.

Some ESA projects using the EPL capabilities are:

- GOCE (cold gas and ion engines),
- Lisa-pathfinder (FEED, mini-ion engines and cold gas microthrusters)
- Cryosat (cold gas thrusters)
- GALILEO (cold gas thrusters)
- Microscope (FEED and cold gas thrusters)
- Small GEO (cold gas thrusters)
- Bepi-Colombo (components of EP systems, operation procedures)

The EPL dedicates 80 % of its resources to respond to customers needs and 20% to internal research, hands-on and training. The activities carried out at the EPL are charged to ESA programmes and research and development programmes.

The ESA Mechanical department where EPL is located has passed an accreditation and certification process carried out by the Dutch Accreditation Council (RvA). Dual ISO 17025 accreditation and ISO 9001 certification processes were obtained in 2004 by the EPL and are validated every year in annual audits. Therefore, the procedures and outputs of the EPL are exposed to the quality requirements of the accreditation body.

The laboratory offers the following capabilities:

- design, preparation, and execution of performance characterisation and endurance tests of electric thrusters
- performance tests of components for electric propulsion: cathode/neutralisers, propellant feeding and power supply and conditioning units
- performance tests of components for chemical propulsion
- design, manufacturing and validation of test diagnostic equipment (thrust stand, data acquisition systems, diagnostic probes)
- certification of thrust, mass flow and electrical power measurements based on ISO 170125

The ESA propulsion Laboratory in the past has hosted qualification tests such as the Radio Frequency ion engine (RIT-10) lifetime test that last 22000 hours. A facility of this type occupied for a long time is an investment that could not be done at that time by a single entity. ESA provided this opportunity to the Artemis project. The EPL has also been involved during the development and acceptance of the propulsion system for Smart-1.

Research and development on FEEDs was also done at the Electric Propulsion Lab and this work was the reference for all the companies involved in this field. Nowadays, the work performed in FEED has helped the ESA projects (LISA pathfinder, LISA, GAIA, GOCE, etc.) to identify the critical areas of this technology and the way to proceed to solve the technology issues in an independent manner.

During the last two years the ESA propulsion laboratory has extended its activities also to chemical propulsion systems such as testing of cold gas thrusters, development of in-situ propellant systems, development of components for chemical propulsion systems, etc. The work performed for example in FEEDs and cold gas microthrusters will help projects such as Gaia, Cryosat and Lisa-pathfinder to develop and check their propulsion systems.

The ESA Propulsion lab also host tests devoted to the development of new engines such as mini-ions and mini-Hall Effect thrusters that will be baselined in future space missions. Pioneering work in spacecraft thruster interaction has also been performed at the EPL in the last year creating the basic knowledge for ESA in this domain.

III. EPL Organisation

The laboratory is managed by the EPL manager assisted by the EPL infrastructure and quality manager. In every test, a test team is formed. A senior test manager is in charge of the team composed by senior and junior engineers. This organisation helps not only to perform the test but also to train junior engineers who can learn directly in the field under the supervision of the senior members of the team. A risk analysis is always performed before starting any test activity.

The operation, maintenance and procurement are under the monitoring of the Head of the Propulsion and Aerothermodynamics division.

The EPL personnel have implemented all the required procedures during the test plans, procedures and reporting preparation.

A specific annual steering board has been nominated comprising the EPL management and the main projects representatives. This board assesses the work performed within one year and design the strategy of EPL in investments and activities for the next year.

The EPL areas that required investment are mainly:

- Vacuum facilities
- Diagnostic packages
- Data Acquisition systems

EPL Facilities and Activities

The European Space Agency has invested in the ESA Propulsion Laboratory to allow the Agency to assess the special characteristics of the electric propulsion thrusters in the last decades. Lately, this lab has expanded its field of application to cold gas and other chemical activities such as testing of propulsion components (valves, pressure transducers, etc.).

The testing of propulsion systems requires facilities capable to simulate vacuum conditions and designed for this scope. In some cases such as electric propulsion thrusters the vacuum conditions required are very demanding (up to 10×10^{-9} mbar).

ESA projects are currently making a good use of the EPL, exploring its capabilities in terms of testing facilities and propulsion expertise coming from the Propulsion and Aerothermodynamics Division personnel.

EPL does not compete with European industries. Furthermore, EPL is a reference for all the propulsion companies in Europe and provide them with support in case it is required. A clear example of this point is the involvement of the EPL in the preparation of the network of electric propulsion facilities put in place in the last years. This network will allow customers to change testing facilities in case a logistic or technical problem arises, minimising the schedule and cost impact in the project. To achieve this, a coordinated effort among the industry bodies and ESA is being carried out. The EPL is a reference for all the industrial participants in the field of standardization and procedures definition and contributes actively to propose alternative solutions to the problems found in this field.

EPL collaborate also with European Universities and industries in the development of new engines such as mini-ions and mini-Hall effect thrusters. Furthermore a collaboration with non ESA member states has been carried out in some specific occasions with the Australian National University (testing of a Helicon Antenna Thruster) and NASA (colloids microthruster testing).

Features of testing facilities at EPL:

- Certification ISO9001 (Quality Management)
- Accreditation ISO17025 (General Requirements for the competence of testing and calibration laboratories)
- Cleanroom ISO class 8 capability (eq. to class 100,000)
- Seismic block for noise isolation

- 7x test facilities dedicated to space propulsion testing:
 - Vacuum chamber re-creating space environment with pressure down to 10^{-12} atm
 - Beam target reducing the on-ground testing disturbances
 - High-speed High-resolution data acquisition systems
- Calibrated commercial measurement instruments:
 - Various electronic equipment from 1microV/1nA to 35 000V/20A
 - 3x Mass spectrometers for residual gas analysis
- Customized measurement instruments with clear chain of calibration
 - 6x balances for thrust from MicroNewton to Newton
 - 2x Beam diagnostics for beam divergence and energy distribution

EPL performs direct or indirect measurements of thrust, mass flow, electrical and plasma parameters.

Specific diagnostic systems available at EPL include two Mettler-Toledo high-precision (0.1 milligram) electronic load-cells customized for miliNewton thrust measurement of cold gas thrusters, a NPL double-pendulum compensated stand for microNewton thrust measurements^{1,2}, two Alta specially-designed thrust balances for miliNewton thrust measurement of EP thrusters, two Hiden Analytical Mass Spectrometers, a Leybold Transpector Gas Analysis System, and various systems based on fixed or movable electrostatic probes for plume analysis.

The design and manufacturing of very specific diagnostics is normally realised in collaboration with external entities, nevertheless the EPL has independent capabilities to carry out this kind of activities¹. Fig 1 shows microthrust Balance developed by NPL for microthrust thrust level (1- 100 microNewtons).

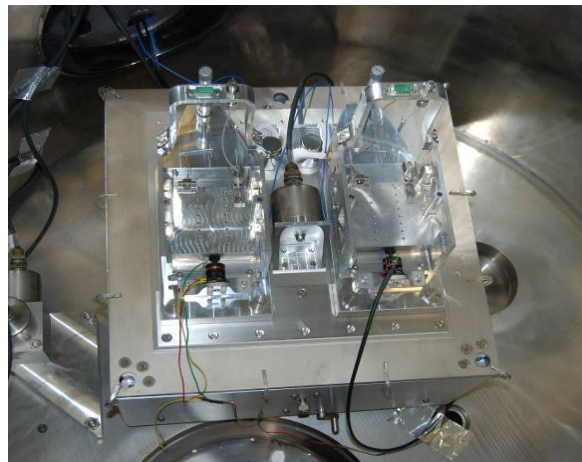


Fig 1 Micro-Newton Thrust Balance

New exploratory investigations such as spacecraft thruster interaction tests are being pursued at the EPL. Ground-based vacuum facilities possess a low-density background neutral gas due to physical pumping limitations and to the leak rate of the facility. The facility background gas present in the vacuum chamber can have undesirable effects on the measurement of electric propulsion thruster performance and plume characteristics. High-energy exhaust particles interact with the neutral background particles through charge-exchange collisions (CEX). In the plume, the effects of CEX products are more evident in the perimeter, where they lead to an increase in the measured current density. Thruster operation and performance are dependent on the backpressure of the facility. Several investigations are underway to model thruster performance and the interactions between ion thruster plumes and spacecraft numerically. For simulations of laboratory experiments, one of the most important auxiliary inputs required by these codes is background pressure of a laboratory vacuum chamber. In the frame of a project funded by the European Space Agency (ESA) dedicated to the “Assessment of Interactions between Spacecraft and Electric

Propulsion Systems” (AISEPS), a miniaturized radio-frequency ion thruster μ N-RIT (RIT-4), developed by Giessen University, was tested in the Corona vacuum facility at the ESA Propulsion Laboratory (EPL), ESA-ESTEC². Figure 2 shows the mini-ion engine developed by Giessen University working at the EPL during a specific test on spacecraft thruster interaction.



Fig. 2. Miniaturized RIT-4 ion engine from Gießen University

The EPL at ESTEC has a seismic block where several vacuum facilities are placed that has improved the high frequency noise isolation to allow direct thrust measurements with specific microthrust balances. For the low frequency noise isolation, active systems have been designed and tested in 2011. These isolation facilities are helping EPL in the microthrust measurements for microthrusters such as FEED, cold gas, and mini-ion engines. Fig. 3 gives a panoramic view of EPL



Fig 3. view of EPL

Conclusions

ESA Propulsion Lab (EPL) actively supports ESA projects and basic research and development of new propulsion systems at ESA. EPL has a dual ISO 17025 accreditation and ISO 9001 certification since 2004.

The EPL has seven vacuum facilities. Each facility is equipped with a vacuum tank including the pumping system and sensors, test racks including high- and low- voltage power supplies and Data Management Systems, computers for data acquisition and test control, and ancillary equipment for the test execution. The main room is rated cleanroom class 8 (equivalent to class 100,000) and four vacuum facilities are located on a 180 tonnes concrete bloc for seismic noise isolation. The EPL is also including an assembly room with laminar flow benches and optical microscope for visual inspection, a control room for remote testing and observation of the main room, a basement

for pumps and compressors, and a storage room. The EPL design and manufacture its own diagnostic tools together with industry (balances, plasma diagnostics, etc.)

The EPL collaborates with International entities (industry and Academia) in the development of new propulsion systems.

The EPL is a reference for all the industrial participants in the field of standardization and procedures definition and contributes actively to propose alternative solutions to the problems found in this field.

References

¹ *Development and Status of the ESA Micro-Newton Thrust Balance, 32nd IEPC, September 2011, Wiesbaden, Germany*

² *Experimental investigations on the influence of the facility background pressure on the plume of the RIT-4, 32nd IEPC, September 2011, Wiesbaden, Germany*