Electric Propulsion Testing: European Space Agency Propulsion Laboratory Experience

D. Di Cara, A. Bulit, J. Gonzalez del Amo

Abstract

The ESA Propulsion Laboratory (EPL) is located at ESTEC, the European Space Research and Technology Centre of the European Space Agency. ESTEC, sited in Noordwijk, The Netherlands, is the largest ESA establishment, a test centre and hub for European space activities. It has responsibility for the technical preparation and management of ESA space projects and provides technical support to ESA's satellite, space exploration and human space activities.

EPL provides test services to the ESA Propulsion and Aerothermodynamics Division of ESTEC, which is responsible for R&D activities and support to ESA projects in the areas of chemical propulsion, electric and advanced propulsion and aerothermodynamics.

This paper will describe the EPL organization, facilities and activities.

Keywords

spacecraft propulsion; electric propulsion testing; cold gas testing.

Introduction

Spacecraft propulsion systems, electric and chemical, are extensively used to provide the necessary forces and torques for orbit transfer, orbit maintenance and attitude control of satellites.

Europe is currently developing the next generation types of electric and chemical propulsion systems for future application. Evaluating the performance on ground of such systems is a complex activity that requires a great effort. Nevertheless, full performance characterization, qualification and acceptance of such propulsion systems are an essential part of the overall spacecraft verification plan to ensure that the final product achieves all the design, performance and quality requirements.

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EPL is specialized in testing of electric propulsion systems below 2 kW. Nowadays, there are hundreds of spacecraft using electric propulsion systems operating at this power level for station keeping. The Telecommunication market is the major customer for electric propulsion systems based on Gridded-Ion and Hall-Effect Thruster technology. However interplanetary missions such as Deep Space 1, Hayabusa and Smart-1 have paved the road for the common use of electric propulsion systems also for Science and Exploration missions. Moreover, a new set of missions requiring very low and accurate thrust will benefit from miniaturized electric propulsion systems (FEEP and mini-ion thrusters) and cold gas thrusters capable to provide ultra-precision controllability.

In answer to future projects needs, the activities of EPL, have been recently focused on measurement of thrust in the low mN level and recently expanded to cold gas thrusters testing.

In 2003 EPL has obtained the ISO 17025 accreditation and the ISO 9001 certification.

This paper will describe the EPL organization, facilities and activities.

EPL Organization

The laboratory is managed by the EPL manager assisted by the EPL infrastructure and quality manager.

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

For each test, a Test Manager and a number of Test Engineers are appointed.

EPL Tasks & Activities

EPL provides test services to ESA projects requiring independent performance assessments of propulsion systems, including possible failure investigations.

EPL also provides support to European R&D activities on propulsion with performance evaluation of new technologies and patent exploitation.

Additionally, the laboratory supports European Aerospace Industries acting as reference for Standard in Testing methods and tools.

Finally, EPL is acting as focal point for European networking of propulsion test facilities, promoting international scientific/technical cooperation.

ESA projects which have used or are currently using the test services provided by EPL are:

- ARTEMIS (ion engine)
- Cryosat (cold gas thrusters),
- GOCE (cold gas thrusters and ion engine),
- GALILEO (cold gas thrusters),
- GAIA (µN cold gas thrusters),
- Microscope (FEEP),
- LISA-Pathfinder (FEEP, µN cold gas thrusters, mRITs),
- Small-GEO (xenon cold gas thrusters)
- Bepi-Colombo (EP systems components).

EPL also hosts tests devoted to the development of new engines such as mini-Gridded Ion Thrusters and mini-Hall Effect thrusters that are perceived as enabling technologies for future Space Science and Earth Observation missions.

Currently EPL is commissioning a flow bench that shall allow testing of chemical propulsion components (leakage). A pressure panel is also being assembled for the management of different gases used in chemical propulsion.

Tests for In-Situ propellant production are planned for EPL dedicates 80 % of its resources to respond to customers' needs and 20 % to internal research, hands-on and training.

EPL changed physically its location at ESTEC in 2007 (Figure 1). This event was the perfect moment to plan for new investments and re-organize the use of facilities and resources to provide the services required by the internal customers already identified and possible new ones.

Figure 1 – View of the EPL

New vibration suppression mechanisms were set up allowing to perform direct measurements of µN thrust levels and thrust noise.

A new facility is currently being assembled to assess the interactions between Electric propulsion thrusters and the spacecraft.

EPL Facilities and Capabilities

Testing of propulsion systems requires facilities capable to simulate vacuum conditions and equipped with tools capable to exploit the propulsion system performance.

Features of testing facilities at EPL:

- Certification ISO 9001 (Quality Management)
- Accreditation ISO 17025 (General Requirements for the competence of testing and calibration laboratories) for measurement of:
    - Force: 1 µN – 500 mN
    - Mass flow: 1 µg/s – 300 mg/s
    - Power: 1 mW – 2 kW
- Cleanroom ISO class 8 (class 100,000)
- Seismic block for noise isolation
- 7 x test facilities with:
    - Ultimate pressure down to 10^{-9} mbar and pumping speed up to 60,000 L/s in xenon;
    - Beam diffusers reducing the on-ground testing disturbances (backsputtering)
    - High-speed/ High-resolution data acquisition systems.
- One flow bench for chemical propulsion component testing.
- Calibrated commercial measurement instruments:
    - Various electronic equipment from 1microV/1nA to 35 000V/20A
    - 3 x mass spectrometers for residual gas analysis
- Customized measurement instruments with clear chain of calibration:
    - 5 x balances for thrust measurement from 1 µN to 500 mN
    - 3 x beam diagnostics systems equipped with Langmuir Probes, Faradays Cups and Retarding Potential Analyzers;
    - Thermocamera, thermocouples, pyrometer.

The EPL is also including an assembly room with laminar flow benches, ultrasonic bath and optical microscope for visual inspection, a basement for pumps and compressors, and a storage room.

The laboratory offers the following capabilities:

- Planning and execution of performance characterization and endurance tests of electric thrusters and cold gas thrusters.
- Functional and performance tests of components for electric propulsion system and cold gas systems: cathode/neutralizers, propellant feeding systems, and power supply and conditioning units.

- Design, manufacturing and validation of diagnostic equipment (thrust balances, data acquisition systems, diagnostic probes)
- Certification of thrust, mass flow and electrical power measurements based on ISO 17025.

The design and manufacturing of very specific diagnostics is normally realized in collaboration with external laboratories; nevertheless, EPL has independent capability to carry out this kind of development. Figure 2 shows a Low Thrust Balance developed by Alta (Italy) for thrust measurement in the range 2 to 50 mN and a Micro-Newton Thrust balance developed in collaboration with NPL (National Physics Laboratory, UK) for measurement of µN-levels thrust and thrust noise.

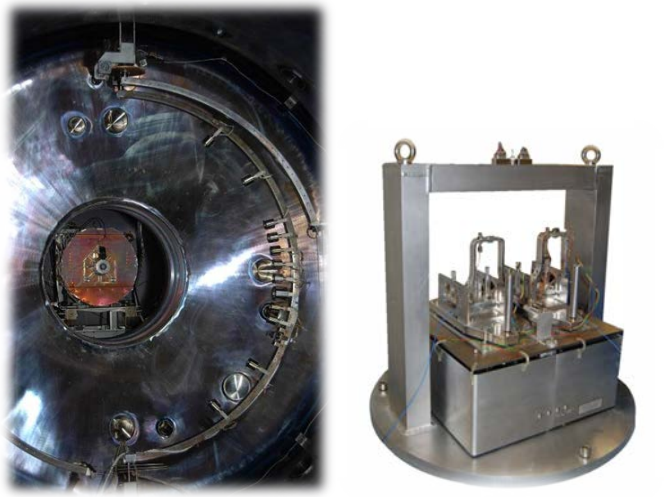

Figure 2 - Low Thrust Balance and diagnostic probes (left) and Micro-Newton thrust balance (right) for milli-Newton and Micro-Newton thrust measurement respectively.

Conclusions

EPL provides an independent performance assessment of propulsion technologies: the domain of competence of the EPL includes direct or indirect measurements of thrust, mass flow, and electrical parameters related to propulsion system operation (ISO 17025 and ISO 9001 accreditations maintained since 2003). EPL provides test services at component and system level for electric, cold-gas and other non toxic propulsion systems. Measurements' capabilities are non-limited to thrust, flow and electrical power. The EPL can design and manufacture customized probes for non-standard measurement.

EPL is often consulted for advices in all aspects related to spacecraft propulsion testing.

EPL testing capability is currently focused on low/medium-power electric propulsion technologies (FEEP, Gridded Ion Engines, Hall-Effect Thrusters, Resistojets and EP components) and cold-gas systems and is currently extending its capability towards chemical propulsion

activities.

EPL is supporting the development of micro-thrust propulsion for future ESA Science and Earth Observations missions, mid and high-power electric propulsion for future ESA Science and Exploration and thruster-spacecraft interactions analysis for future Telecommunication and Science missions.

REFERENCES

1. R. Blott, D. Robinson, S. Gabriel «Verification-Electric Propulsion's Achelles Heel», IEPC, Paper 062, 32nd International Electric Propulsion Conference, Wiesbaden, Germany, September 2011.
2. O. Sutherland, et al, «Standardization and validation of a test harness for microNewton thrust measurement using the Mettler Toledo AX504», 5th International Spacecraft Propulsion Conference, Crete, May 2008.
3. J. Pérez Luna et al. «Development Status of the ESA Micro-Newton Thrust Balance», IEPC, Paper 011, 32nd International Electric Propulsion Conference, Wiesbaden, Germany, September 2011.
4. M. Wartelski et al. «The Assessment of Interactions between Spacecraft and Electric Propulsion Systems Project», IEPC, Paper 014, 32nd International Electric Propulsion Conference, Wiesbaden, Germany, September 2011.
5. Bulit et al. «Experimental Investigations on the Influence of the Facility Background Pressure on the Plume of the RIT-4 Ion Engine», IEPC, Paper 014, 32nd International Electric Propulsion Conference, Wiesbaden, Germany, September 2011.

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