# Electric Propulsion Activities at European Aeronautic Defense and Space Company Astrium Space Transportation

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## Abstract

This paper presents the activities of Astrium Space Transportation in the field of electric propulsion. Astrium ST is an electric propulsion provider for propulsion systems, components and test services. The Radio Frequency Ion Thruster family "RIT" is described and a presentation of the pressure regulation device XRFS is given. Additionally, electric propulsion system aspects are included in this paper.

Astrium has a broad knowledge in test conduction for life & endurance tests, environmental tests and sophisticated tests like dual firing or solar radiation for electric propulsion. The description of Astrium ST's test activities and services is complemented with the history of EURECA and ARTEMIS. Both missions mark milestones for electric propulsion in Western Europe. Both missions were equipped with Astrium ST's RIT-10 thruster assemblies RITA 10.

## Keywords

electric propulsion system; radio-frequency ion thruster; thruster family; RITA 10 flight heritage; test services; electric propulsion components

## Introduction

More than 40 years heritage in chemical and electric propulsion, one of the pioneers of electric propulsion in Western Europe, outstanding experience in planning and conducting tests for electric propulsion: all this is Astrium ST.

Today, electric propulsion activities at Astrium ST are composed of three columns, electric thrusters & components, electric propulsion systems and test design & test services.

Main focus of the electric propulsion activities at Astrium ST are Radio-Frequency Ion Thrusters (RITs). Initial research on the RIT-Technology was conducted by Giessen University in the 1960s. The predecessor of Astrium, Messerschmitt-Boelkow-Blohm (MBB), joint this development and took the industrial leadership in 1970. [1, 2].

The RITs are based on a simple and robust technology. The principle of the ionization and acceleration process is displayed in Figure 1. Radio-Frequency Ion Thrusters produce thrust in a two step process:

- First, the propellant is ionized in the electro-magnetic field of an rf-coil;
- Secondly, the ions are accelerated in the electrostatic filed of a grid system, which is referred to as ion optics system.

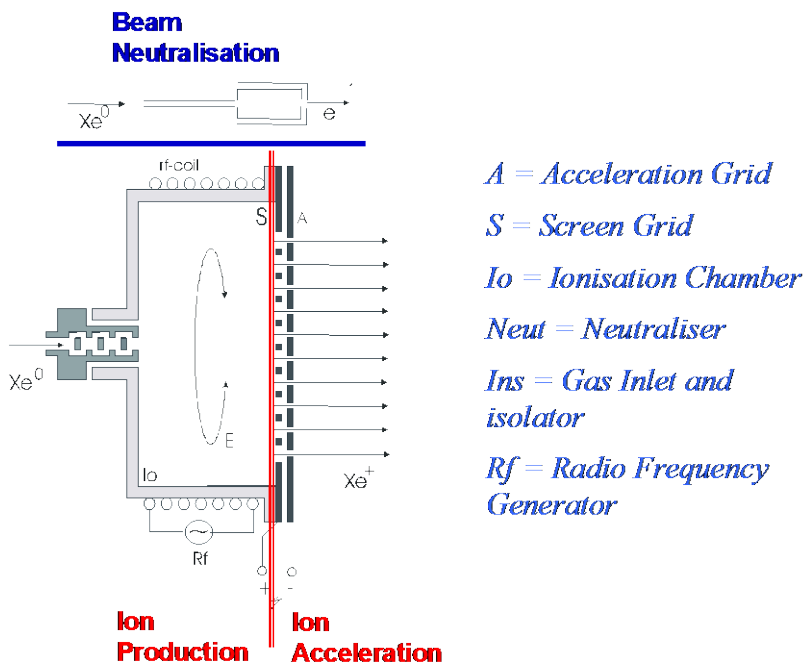


**Figure 1 - Ionization Process Radio-Frequency-Ion-Thrusters**

One advantage of the RIT technology is the scalability of the thrusters for applications with very low thrust needs in the µN-range up to thrusters in the 100 mN-range. Another key feature is the excellent thrust control and thrust stability of the RIT engines. Independent from the thruster size RIT engines are from unbeaten simplicity and robustness in design. This is the bases for highest reliability.

## 2. Electric thrusters and components

## 2.1 Thrusters

Nowadays, Astrium ST has a portfolio of Radio-frequency-Ion Thrusters (RIT) for different applications ranging from miniaturized ion engines for high precision orbital maneuvers for example for formation flying to high power engines for applications onboard telecommunication platforms and interplanetary probes. The RIT family of Astrium is presented in Figure 2.

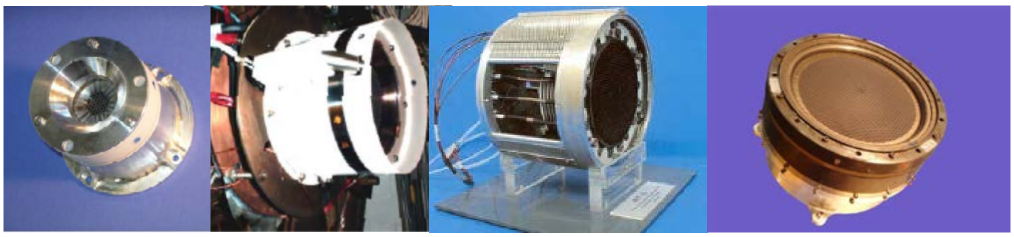


**Figure 2 - RIT family (RIT-15 elegant breadboard courtesy of Gießen University)**

The RIT-µX thruster is a miniaturized thruster for high precision maneuvers requiring ultra fine thrust control. The nominal thrust range varies from 50 µN to 500 µN with a specific impulse between 300 s and 3000 s. The power consumption is below 50 W. By changing the thruster's grid system RIT-µX is adaptable to any thrust range between 5 to 3000 µN. Presently, Astrium ST is testing RIT-µX optimized for the thrust range 10-100 µN under a contract granted by the European Space Agency ESA.

The development of the RIT-µX thruster is embedded in the RIT family. The development of the breadboard bases on the development, test and (finally) operation in space of the RIT-10 thruster assembly.

The RIT-10 has a nominal thrust of 15 mN, which could be extended on request to 5-25 mN. The specific impulse of the RIT-10 is above 3300 s and the nominal power consumption is 470 W. Typical application of the RIT-10 is North-South-Station Keeping (NSSK) of small spacecrafts. The RIT-10 thruster assembly (RITA) has been successfully flown on EURECA and ARTEMIS [3].

The flight of RITA-10 on EURECA is considered as one milestone in European space propulsion. The European Retrievable Carrier Mission (EURECA) was launched by the Space Shuttle Atlantis in 1992. One year later, EURECA was returned to Earth by Space Shuttle Endeavour. This gave the unique opportunity of thruster inspection after operation in space. Thruster operation during the EURECA mission was as expected and the performance data was in good agreement with the ground test results and predictions. Furthermore, the mission proved electromagnetic compatibility between satellite, payload and electronics, no interference was measured. During the EURECA mission the thruster accumulated 240 hours of operation in space.

**Figure 3 - EURECA satellite attached to grappler of space shuttle**

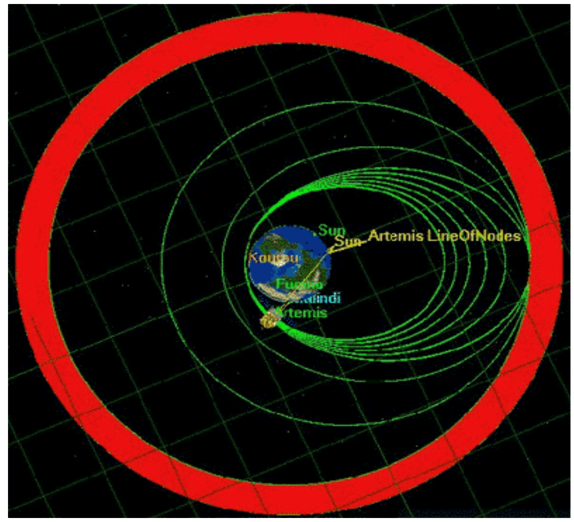


**Figure 4 - ARTEMIS orbit rising to target orbit**

The second milestone in electric propulsion is the successful orbit rising performed by RITA-10 for the ARTEMIS satellite. Intentionally, RITA-10 was installed on the ARTEMIS satellite for North-South-Station Keeping (NSSK). During launch of the satellite, which took place 2001, an anomaly of the launcher occurred. This led to an orbit to low for satellite operation. With a thrust of only 15 mN the RIT-10 thruster performed the orbit rising of the satellite to its target orbit. This required 7.500 hours of operation, of which 6427 hours were performed by one singe thruster. The propellant used for this maneuver was only 14.2 kg Xenon. Doing so, the RIT performed the first west European orbit rising using EP. [3]

Nominal thrust of the RIT-15 is 50 mN, which could be extended to 10…70 mN. The specific impulse is greater than 3300 s and the nominal power consumption is 1500 W. Typical application for this thruster is NSSK of medium size spacecrafts. An elegant breadboard of RIT-15 has been developed and extensively tested by Gießen University. Astrium's generic scalable thruster design allows a rapid implementation of an Engineering Model (EM) and Flight Model upon customer request.

RIT-22 is a thruster intended for NSSK on large spacecrafts and advanced orbit toping maneuvers. It is also an ideal device for primary propulsion of interplanetary probes. The nominal thrust of this thruster is 150 mN at an input power of 4400 W. The specific impulse is greater than

4000 s. When more power is available, RIT-22 is operable with a thrust up to 250 mN. The RIT-22 EM has been operated for more than 4,000 hours with a thrust of 175mN and specific impulse of 4650 s.

## 2.2 Components

In addition to the different thrusters described in the section above a Xenon Regulator and Feed System (XRFS) is available at Astrium. A sketch is presented in Figure 5.

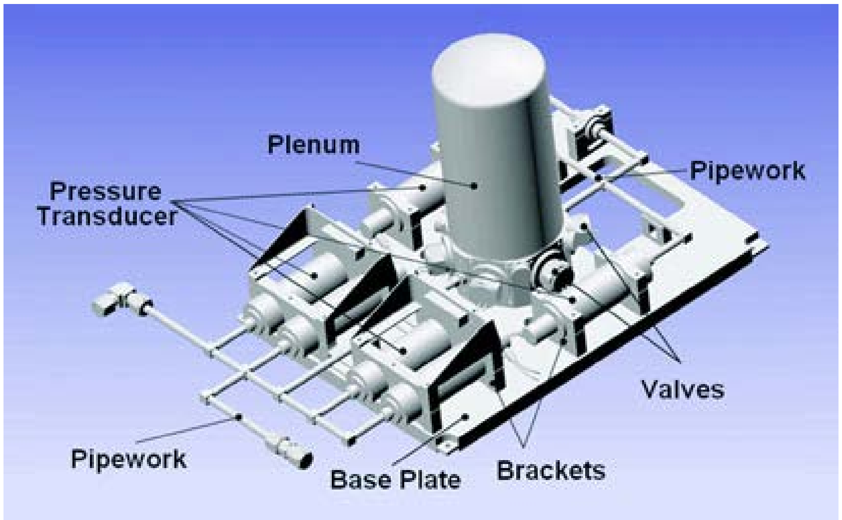


**Figure 5: XRFS Regulator**

Key features of the XRFS regulator are an upstream operating pressure capability of 130 bar with improvements planned for 190 bar. The downstream pressure is adjustable by use of control electronics. The flow rate of the XRFS is optimized for use with the SPT100 and PPS1350 thrusters. As the required flow rate for gridded ion thrusters of the 5 kW class is similar, XRFS fits also perfectly for these engines. XRFS is a fully redundant system with three inhibits against leakage. The pressure transducers, seal material and heaters of the XRFS are ITAR controlled. The Xenon throughput mass in total is 300 kg with a mass flow rate between 0 mg/s and 20 mg/s.

# 3. Electric propulsion systems

The Radio-Frequency Thruster Assembly (RITA) unit consists of the thruster unit (TU), the flow control unit (FCU) and the power processing unit (PPU) (see Figure 6). The thruster unit includes the ion thruster, the neutralizer and the RF-generator. The power processing unit provides all required electrical voltages for the thruster system. Furthermore, the PPU provides the interfaces to the spacecraft power bus and the data/command buses. The PPU enables autonomous thruster operation including exception handling in case of unexpected events in RFG, Thruster, FCU or the PPU itself.

The flow control unit ensures the flow of the propellant from the spacecraft pressure regulator to the thruster.

The RITA of the EURECA mission is shown in Figure 7. The scope of Astrium ST is not limited to RIT based systems. For instance, Astrium ST contributed to the EUROSTAR reviews on electric propulsion system. EUROSTAR is equipped with a plasma propulsion system (PPS).

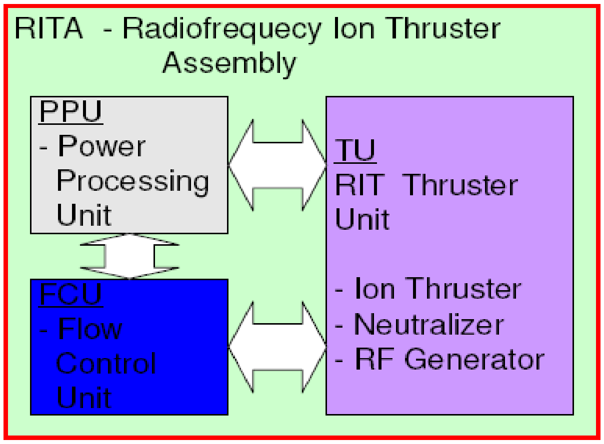


**Figure 6 - RIT-Assembly Components**

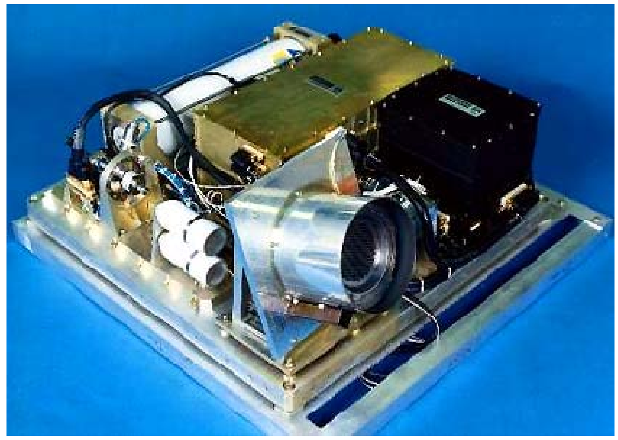

**Figure 7 - RIT-Assembly Aboard EURECA**

Astrium ST's typical system architecture for the North-South-Station Keeping (NSSK) application is presented in Figure 8. This architecture is fully redundant for thrusters and electronics. It contains one Xenon storage tank (XST) and one Xenon regulator and feed system (XRFS). On each pointing mechanism, Thruster Orientation Mechanism (TOM), one nominal and one redundant thruster is mounted. One pointing mechanism is oriented to the North and one to the South direction.

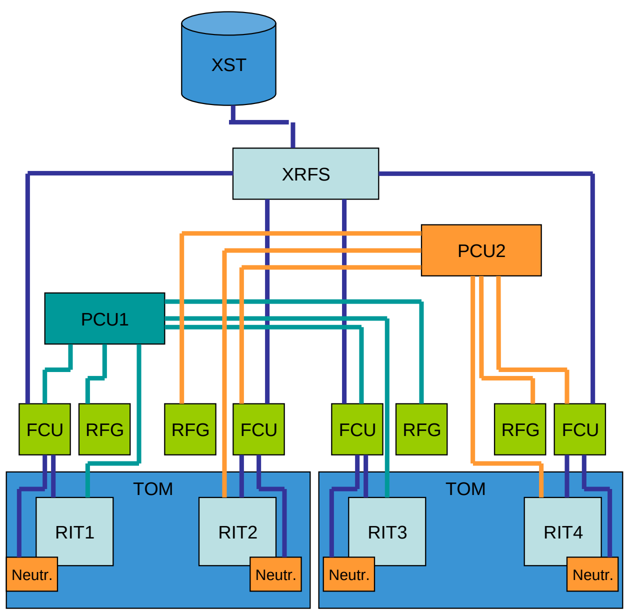


**Figure 8 - Astrium's System Architecture for NSSK**

There are two electronic units (PCUs), of which one controls the nominal thrusters and one the redundant thrusters. Each thruster has its dedicated flow control unit (FCU), neutralizer and radio-frequency-generator (RFG). This layout is also applicable for plasma propulsion thrusters ("SPT", also "HET")

## 4. Test Design and Test Services

Astrium designs electric propulsion tests and provides test services. The activities cover the full spectrum from standard environmental tests over life and endurance tests to advanced tests like simultaneous firing of thrusters.

Astrium has conducted hundreds of vibration tests of chemical thrusters and components in its own environmental test laboratories as well as in external facilities. All environmental tests for qualification of the RIT-10 for the EURECA and ARTEMIS mission were performed by Astrium in-house. Astrium has experience in environmental tests for small, medium and the new high power electric propulsion class. The environmental tests can be supported by Astrium ST's own analysis department.

On ground experience with life and endurance tests in external test facilities, for example University Giessen, ESA ESTEC facilities and Aerospazio, Italy, for more than 45,000 hours in total are basis for Astrium ST's excellent test logistic [4].

Astrium ST has designed and implemented a test setup for simultaneous firing of two RIT-22 thrusters to investigate possible beam interactions. As outcome of this test campaign only a very small attractive force between the two beams was found.

## 5. Conclusion

The radio-frequency-ion thruster family available at Astrium provides an adequate answer to the propulsion needs of various types of missions. The RIT technology is based in a simple and robust technology.

Astrium has an outstanding heritage in design, implementation and support in electric propulsion testing. This includes environmental tests, lifetime and endurance tests like the 20,000 hour life test of RIT-10 and advanced tests.

With its long lasting heritage in electric and also chemical propulsion Astrium offers electric propulsion system solutions for various mission types.

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