RITA Development and Fabrication for the Artemis Satellite
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ABSTRACT
The Radiofrequency Ion Thruster RIT 10 has been developed and spacequalified in Germany as an experiment for the European Retrievable Carrier EURECA. This experiment has already been delivered to the EURECA main contractor and has been integrated and tested on the spacecraft. The launch is currently scheduled for 29 June 1992.

Currently RITA is planned to be used for the Ion Propulsion Package on the experimental communication satellite ARTEMIS which is under development in Europe under ESA/ESTEC responsibility. The Ion Propulsion Package will be used to perform N/S-stationkeeping as a responsible subsystem during 10 years of satellite operation.

For this purpose the thrust level of RITA has been increased from 10 to 15 mN. A complete redesign of the Power Supply and Control Unit will simplify the control of the thruster and neutralizer and decrease the number of parts in this electronic unit. The RF-generator has been redesigned by use of the newest technology, which results in an increase of efficiency. In the flow control unit the latch valves have been replaced by normally closed valves to reduce the number of valve types. The thruster design as for EURECA will be used with some design simplifications.

The development of RITA for ARTEMIS has finished the Breadboard Phase at the end of 1990. We are now developing the Engineering Qualification Models (EQM's), which will be qualified in the second half of 1992. RITA-Flight Model fabrication will start in mid 1992 and will take about 1.5 years. The launch of ARTEMIS is planned for 1995.

RITA Function Principle
The RIT (Radiofrequency Ion Thruster) generates thrust by accelerating Xenon ions out of a plasma induced by RF-energy. In order to prevent electric charging of the equipment and the spacecraft, a neutralizer feeds electrons into the beam of ions after acceleration.

Fig. 1 shows the RIT 10 thruster and neutralizer main components and the power supplies necessary for its operation.

The working mode of the RIT 10 thruster with Xenon is:

1. The mass flow of the propellant Xenon to the thruster and to the neutralizer will be controlled by the components of the of the Flow Control Unit (FCU).
2. The Xenon flows through the feed line interface (gas feeder) via the insulator and the extraction anode, which also functions as a gas distributor, into the discharge vessel of the thruster. The discharge vessel made from quartz is surrounded by an induction coil which is connected to an RF-generator which generates a high frequency (~1 MHz) electrical eddy field in the discharge vessel. Free electrons within the Xenon gas collect energy from the induced electric field and ionize the neutral propellant atoms by inelastic collisions.
3. During normal operation of the discharge sufficient free electrons from the ionizing process are available to keep the discharge stable operating without a secondary electron source.
4. To initiate the main discharge the neutralizer is activated first. Electrons from the discharge at the neutralizer tip are drawn into the discharge chamber by an electrostatic field generated by voltages applied to the accel electrode and to the anode.
5. When the discharge is ignited thrust will be generated by acceleration of ions in the electrostatic field applied to an extraction system comprising an extraction anode, an isolating plasma holder, an acceleration electrode and a deceleration electrode.
6. To neutralize the emitted ion beam, a plasma bridge neutralizer is used to inject electrons into the beam. The neutralizer first produces electrons by thermionic emission from a heated internal cathode. Then these electrons emitted into the neutralizer, which is filled with low-pressure Xenon, support a plasma in the neutralizer tip generated by a low voltage arc discharge between cathode and keeper. Out of this plasma electrons are extracted into the ion beam to maintain a zero-charge equilibrium in the thrust beam.

RITA ON EURECA
The European Retrievable Carrier EURECA is designed to perform a number of missions in the lower orbit range. Its first mission is primarily dedicated to scientific experiments in the microgravity field. In addition some technological experiments will be flown and RITA will be one of them.

EURECA is a platform approximately 2.5 m long and 4 m wide, which, fully equipped, will almost fill the cross section of the Shuttle's cargo bay. Its mass, including propellant for altitude and orbit control, will approach 4000 kg, approximately 1200 kg of which will be available for payloads.

EURECA-I will be launched and retrieved by the Space Shuttle. After the Shuttle has reached its orbit, EURECA-I will be removed from the Shuttle cargo bay and released as a free flyer.

An orbital transfer maneuver will transfer the spacecraft from the nominal Shuttle orbit altitude of 300 km to 500 km. EURECA-I will then conduct its mission operation of 6 months duration.

Retrieval and return to earth of EURECA will be made as soon as possible after completion of its payload operation.

Objectives of the RITA Experiment on EURECA I
The primary objective of the RITA-10 test flight on EURECA-I is to demonstrate the use of RITA-10 as a mature technology and thus open the way for its operational use.
To achieve this objective, the specific aims of the test flight are:

- to operate the RITA system in the real space environment and to compare space and ground test performance data;
- to obtain operational experience of the RITA system, on-board a spacecraft.

Specific aspects are:

- to verify survival of the launch environment, to experience switch-on, operation and shut-down procedures under automatic control;
- to verify operation under full and reduced thrust, (10 mN to 5 mN);
- to evaluate ground-station work load;
- to evaluate RITA interactions with the spacecraft; plume impingement, plume contamination, electrostatic charge control, electromagnetic interference;
- to demonstrate RITA life endurance and reliability;
- to examine the RITA hardware after recovery of the EURECA-I spacecraft on ground;
- to examine the EURECA-I spacecraft for plume interaction effects;
- to improve the RITA-10 design and operational procedures based on lessons learned from the test flight, in readiness for full operational use for north-south stationkeeping of telecommunication spacecraft.

RITA Design for EURECA

The RITA is one of the 15 experiments which are planned to be flown on the EURECA I Spacecraft. RITA will be mounted on a standardized Equipment Support Panel (800 x 800 mm) which are fixed by 4 screws to the EURECA structure.

RITA for EURECA consists of the following components:

- Power Supply Unit (PSU) which is electrically connected to the EURECA mainbus
- Digital Automatic Control Unit (DACU) which is electrically connected to the EURECA Data Handling System
- RF-Generator, which generates the RF-energy for propellant ionization
- Propulsion Unit (PU) which contains the RIT 10 thruster and the neutralizer
- Flow Control Unit (FCU) controlling the gas flow to the thruster and to the neutralizer
- Tank Unit containing 4 kg of Xenon
- Cabling Unit for internal electrical connections of the several units

The Xenon is stored in a commercially available diving bottle which is fabricated under controlled conditions. The bottle is mounted on the ESP via 2 brackets which are connected by 2 tie rods. A hand operated valve closes the bottle during all ground activities. It is opened short before launch.

The Xenon is fed from the bottle to the flow control unit and flows from there directly to thruster and neutralizer.

RITA Characteristic Data for EURECA

- Thrust Level
  The thrust level can be varied between 5 m N and 10 m N
- Power Input
  The power input from EURECA mainbus is
  - 440 W for 10 mN
  - 270 W for 5 mN
  with linear interpolation for values in between.
- Acceleration voltage 1500 V
- Exhaust velocity 47 km/s
- Experiment mass 40 kg

FIG. 2 shows the RITA FM Hardware.

The current mission planning considers the operation of RITA for 2367 hours at thrust levels between 5 and 10 mN, depending on the power available from EURECA.
Electric Propulsion for Artemis

Artemis is a technological communication satellite which is currently in planning and design by ESA/ESTEC and its main contractor Alenia. Within new communication payloads also electric propulsion for North-South stationkeeping shall be tested on this satellite.

In Europe two ion propulsion technologies are under development.

- The UK 10, an electron bombarding ion propulsion system with a maximum thrust level of 25 mN. A separate paper on this conference will report on this system in /1/.
- The RITA, an RF-ion propulsion system with a maximum thrust level of 15 mN.

Both technologies are planned to be tested on Artemis. A detailed description of the Ion Propulsion Package is given in a separate paper in this conference in /2/.

Requirements on Ion Thruster Assemblies

The following requirements are applicable to the RITA ion propulsion assembly on Artemis:

- Thrust level: 15 mN ± 5%
- Thrust vector accuracy: ± 1.0°
- Lifetime: 7 years storage on ground
- Operative cycles: 3650 with 3 hours operation time each
- Impulse per thruster: 600,000 Ns
- Specific Impulse: 3000 s
- Input voltage: 42.5 ± 0.5 VDC
- Max. power consumption: 580 W

RITA Design for Artemis

For the application of RITA on Artemis the design as used for EURECA will be improved by an overall simplification of the design and by a mass reduction. The RITA design for Artemis shall later on be able to be used on any commercial satellite. This goal will be achieved by simplification of requirements on accuracies and on operational procedures.

Fig. 3 shows a blockdiagram of the two RITA’s as installed on Artemis.

Fig. 4 shows the basic assembly of a RITA

RITA 10 Thruster and Neutralizer

The design of thruster and neutralizer will be used in general as designed for EURECA. The thruster grid alignment system has been improved according to higher vibration levels for the ARIANE launch. Better thermal control capabilities have been implemented to cope with the increased thrust level.

Fig. 5 shows the cross-section of the thruster and Fig. 6 the cross-section of the AEG-neutralizer.

The design of the PROEL neutralizer is described in a separate paper of this conference in /3/.
Flow Control Unit (FCU)

The FCU shall supply the thruster and the neutralizer with an appropriate amount of Xenon gas flow as a propellant. Fig 7 shows the block diagram of this unit.

RF-Generator

The RF-generator transforms a variable primary voltage of 10 to 60 V into a high frequency alternating voltage and a maximum power output of 150 W. Fig. 8 shows the interface block diagram.

The output power of the RF-generator will be controlled by the primary voltage delivered by the Power Supply and Control Unit (PSCU). By variation of the RF-generator output power the ion density in the discharge chamber and therefore the ion beam current and the thrust level is controlled.

The RF-field is generated in a frequency range between 850 and 1000 kHz. The output lines of the generator are connected via a series resonant network to the discharge vessel at the RIT 10 thruster. The RF-energy is conducted by inductive coupling via a coil, which is mounted on the outer diameter of the cylindrical case of the discharge vessel of the RIT 10.

The frequency of the RF-field will be automatically adapted to the resonant frequency of the load. All conditions in the discharge vessel like

- No plasma (before ignition)
- Plasma without extraction (stand by condition)
- Plasma with extraction (thrust condition)
- Arcings

must be considered.

Fig. 9 shows the dimensions of the RF-generator in flight hardware design. The efficiency of this unit is >85% at the nominal output power of 120 W.

Power Supply and Control Unit (PSCU)

The RIT-10 PSCU has been designed by FIAR/Milano and Padova taking four major goals into consideration:

- maximum simplicity, reliability, testability and modularity
- minimum mass
- maximum efficiency
- maximum flexibility to allow on flight changes of thrust operating parameters

A detailed description of the PSCU is given in a separate paper of this conference in [9].

RITA Data for Artemis

TABLE I shows the operational data of RITA for thrust levels between 5 and 15 mN. All data are for fixed thrust levels.

<table>
<thead>
<tr>
<th>Thrust Level</th>
<th>5 mN</th>
<th>10 mN</th>
<th>15 mN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current (mA)</td>
<td>120</td>
<td>150</td>
<td>180</td>
</tr>
<tr>
<td>Voltage (V)</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Mass flow rate (mg/s)</td>
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<td>1.23 mg/s</td>
<td>1.23 mg/s</td>
</tr>
<tr>
<td>Density (g/cm³)</td>
<td>228</td>
<td>228</td>
<td>228</td>
</tr>
<tr>
<td>Propellant rate</td>
<td>204</td>
<td>204</td>
<td>204</td>
</tr>
</tbody>
</table>

Fig. 9: Dimensions of the RF-Generator
The mass breakdown of RITA is as follows:

- Power Conditioning and Control Unit (PSCU) 8.0 kg
- RF-Generator 1.3 kg
- RIT 10 thruster 1.6 kg
- Flow Control Unit 2.0 kg
- RITA internal harness 1.5 kg
- Piping and Supports 0.5 kg
- Total RITA mass (1 thruster) 14.9 kg

Neutralizer Lifetime Test at ESTEC

Two neutralizers are currently running at ESTEC in parallel in a dedicated vacuum test facility: One AEG neutralizer as designed for EURECA and one neutralizer from PROEL with a special design for Artemis. They are both operated in a cyclic mode, 2 hours ON and 0.5 hour OFF.

The neutralizer No. 1 (AEG) has now reached more than 9000 hours of operation and No. 2 (PROEL) more than 5000 hours. Both are operating without problems.

Function Test of RITA

At the end of the Breadboard Phase a function test of the complete RITA has been performed to demonstrate the compatibility of the RITA-units, to investigate operational parameters and to measure the actual thrust vector behaviour with respect to the thruster mounting plane.

The test setup of this function test is shown in Fig. 10. The tests have been performed in the vacuum test facility of the University of Giessen. Thruster, RF-generator and Flow Control Unit (FCU) are mounted inside the chamber hatch. The ion beam is directed to a watercooled beam target at the down end of the big chamber. For beam diagnostics a turnable beam collector is installed in the chamber which allows the measurement of the ion distribution in the beam within 30 seconds by turning the collector by 180 degrees.

Fig. 10: Testsetup for RITA Function Test

Fig. 11 shows typical operating parameters for a test run of the RIT 10 thruster during one hour at 15 mN thrust level. The ion beam current - representing the thrust level - is very stable. It is interrupted by 2 arcs where the high voltages have been switched off for a few seconds and then switched on again. The accel drain current is in the range of 5 mA, which is very acceptable. The temperature of the end electrode rises from environment temperature to about 110 °C within one hour and is then stable.

Fig. 12: Beam Profile of RIT 10 Thruster

Fig. 13: Stability of Thrust Vector of RIT 10
Model Philosophy and Time Schedule for Artemis

The development- and fabrication time schedule of RITA will be aligned with the time schedule of Artemis, which is planned to be launched in 1995.

Fig. 14 shows the model philosophy of RITA and its units. In general the development philosophy follows the Prototype approach:
- Breadboard Models have been fabricated for units/components which are new or which have been changed remarkably.
- Engineering models are fabricated for lifetime testing of thruster and neutralizer.
- A prequalification on unit level will be performed on EQM’s
- One PFM is built for the final qualification of the units
- FM’s will be built if further models are necessary.

The breadboard phase has been started in April 1989. This phase has been finished at the end of 1990 with a function performance test of the complete RITA subsystem in the vacuum test facility at the University of Gießen.

Since March 1991 we are working on the EM/EQM Phase where EM’s for a thruster/neutralizer lifetime test and EQM’s for the qualification of the units will be built.

Qualification of the EQM’s and fabrication of PFM’s/FM’s will start middle of 1992. PFM’s/FM’s will be delivered to the Artemis main contractor at the end of 1993.

Fig. 14: Model Philosophy of RITA for Artemis

Literature

/1/ IEPC 91-056
The UK-10 Ion Thruster Test Programme at AEA Technology, Culham Laboratory
S.D. Watson, Culham Laboratory, Abingdon, U.K.

/2/ IEPC 91-055
Ion Propulsion Package for N/S Stationkeeping of the Artemis Satellite
H. Bassner, H.-P. Berg, K. Fetzer, G. Müller, MBB Munich

Conclusion

With a testflight of RITA as an experiment on EURECA in 1992 and the development for the application on Artemis RITA has a very good chance to become a useful and reliable subsystem for North/South-stationkeeping for commercial geostationary satellites.

During detailed function testing of RITA the beam diagnostic tests have shown that the thrust vector stability is very good and a closed loop for thrust vector adjustment during thruster operation is not necessary.

Lifetime tests currently performed on neutralizers deliver promising results with >9000 operating hours.

A test of the radiated emission of thruster and neutralizer during operation will be performed in October/November this year and will hopefully show that a disturbance of the satellite must not be expected.

A lifetime test of a thruster, starting at begin of 1992, is expected to demonstrate that the operation time with Xenon is comparable or better than the already achieved operation time of 8500 hours with Mercury.

/3/ IEPC 91-024
Design Consolidation and Space (Pre) Qualification of a Plasma Bridge Neutralizer for the RITA Ion Thruster
M. Bianconi, G.F. Cirri, G. Matticari, A. Severi
PROEL Technology, Florence, Italy

/4/ IEPC 91-027
Power Supply and Control Unit for Radiofrequency Ion Thruster RIT 10
P. Cesa, S. Gandini, P. Leoni, G. Passoni
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