Arcjet Test Mission (ARTEMIS) on EURECA*

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Abstract

An experiment for demonstrating the flight readiness of a 0.7 to 1 kW thermal arcjet thruster system is proposed for use on the European Retrievable Carrier EURECA. The thruster will employ preferably hydrazine as a propellant, although ammonia might be used as an alternative. It will operate on thrust and power levels complying with the μg-environment and payload power restrictions of the EURECA carrier. The thrust strategy for the thruster will be chosen to assist the onboard control systems and to ease the spacecraft retrieval phase by controlling the semi major axis or the circularity of the orbit during the mission as planned for the RITA ion thruster experiment. A total of up to 800 thruster ignitions is planned during the six months EURECA mission, the pulse duration depending on the mission requirements. The experiment will consist of two redundant arcjet thrusters (only one operating at a time), the power conditioning unit with a rechargeable battery system and the propellant storage and feed system. The experiment will be operated and controlled by its own controller in accordance with the mission requirements for thruster firing and power availability. Depending on power availability from the EURECA carrier the batteries will be charged constantly with about 100 W to allow the operation of other experiments during the thrust pulses. The unit will be monitored by its performance parameters and a CCD camera to establish the size and the constituency of the plasma plume. The thruster influence on the spacecraft telecommunication links will be checked by monitoring radio transmissions during thruster operation. Passive experiments will be used to evaluate the plasma plume impact on spacecraft materials. The experiment can be flown as a stand alone experiment as well as together with the arcjet experiment DIVA studied by BPD and Centrospacio, Italy, with which it could share some components. The experiment will be developed in a cooperation of the Institut für Raumfahrtsysteme in Stuttgart and the MBB-ERNO Raumfahrttechnik GmbH in Bremen, who are currently developing the engineering model of a 1 - 2 kW hydrazine thermal arcjet thruster. The timeframe of the experiment suggests a three to three and a half year developing and qualification period.

Motivation for the experiment

The interest in electrical propulsion systems has increased during the last years with the availability of sufficient electrical power on spacecrafts. Several recent studies have shown the ability of electric thrusters to enhance certain satellite missions. One type of electric thruster is the thermal arcjet engine, where the propellant is heated while passing through an electric arc that accelerates the propellant by inducing energy through ohmic heating in a high temperature plasma. The application of a thermal arcjet developed by Rocket Research and NASA on the TELSTAR 4 satellite scheduled for launch in 1993 demonstrates the advanced arcjet design status already achieved in the U.S.A. [1]. The main advantage of the arcjet on this mission is the increase in specific impulse of the attitude control system, thus reducing the propellant mass onboard the spacecraft and the launch costs due to the use of a smaller launch vehicle. Another advantage could be a longer satellite lifetime with a given satellite configuration and propellant mass. Comparable systems are considered for use on the Intelsat VIII satellites and studies are underway to evaluate arcjet systems when applied to orbit transfer vehicles or to use an arcjet thruster instead of a chemical apogee impulse thruster. Arcjets could find another application

when mounted on earth observation platforms or the Columbus Free Flyer to compensate the drag losses. Bennett et. al. [1] showed a significant 50% increase in payload mass for an earth observation platform, while Heinrich [2] calculated a 30% mass reduction for the Columbus Free Flyer - due to less propellant necessary - if arcjets would be utilized.

All these examples show the necessity to develop flight qualified arcjet systems. To date only one system [3], the Rocket Research - NASA development, has reached this status. In Europe arcjet studies are conducted at two facilities, the Institut für Raumfahrtsysteme at the University of Stuttgart in Germany and BPD Difesa E Spazio in Colleferro in cooperation with the University of Pisa, Italy. Both institutions have gained considerable knowledge in arcjet design and operation [4,5] and are now working independently on the development of 1-kW class arcjet engines. Thus, this technology should soon be available on a competitive basis, and it becomes necessary to demonstrate the flight readiness of the two systems to potential users that might be reluctant to use a new, unproven technology on a commercial satellite mission. The European Retrievable Carrier EURECA offers the possibility to demonstrate the effectiveness of an arcjet engine in the 1-kW class range. In the same context the DIVA study [6] proposes also a flight demonstration of the arcjet developed by BPD in cooperation with the University of Pisa.

The ARTEMIS Experiment

This work describes an experiment for the 1-kW thruster currently under development and testing at the University of Stuttgart in cooperation with MBB-ERNO Raumfahrttechnik GmbH under a contract from DARA (Deutsche Agentur für Raumfahrtangelegenheiten, German Space Agency) [7], including additional diagnostic packages such as monitoring the thruster performance and observing the thruster plume with a CCD-camera. A navigation payload based on the GPS system could be used to enhance the arcjet thrust level determination by measuring the platform orbit with a higher accuracy. Several system components such as the propellant feed system from this experiment and the DIVA study might be used by both experiments if the experiments will be flown on the same mission. However, the ARTEMIS experiment can also be flown as a stand alone experiment. A possible, although quite tight timeline for the development of the experiment is shown in Fig. 1. This timeframe was set up with the present schedule of EURECA flight three in mind.

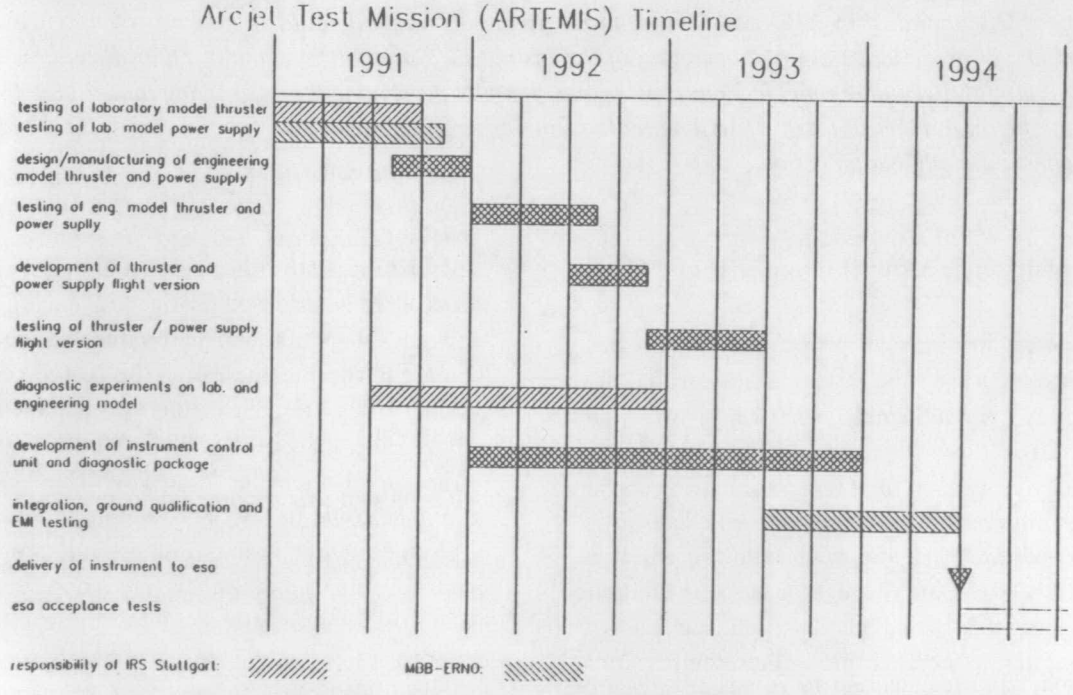

Fig. 1: ARTEMIS Experiment Timeline

arcjet thruster with gas generator [3]	2,0 kg
power conditioning unit [3]	5,0 kg
battery pack +	31,0 kg
tank structure and prop. feed system *	15,0 kg
propellant hydrazine N_2H_4 +	55,0 kg
experiment control unit *	5,0 kg
experiment diagnostic package *	10,0 kg
CCD camera with electronic and data storage system *	15,0 kg
total mass at take off, approx.:	135,0 - 140,0 kg

+ = calculated

* = estimated, based on [8]

Table 1: Preliminary Mass Estimate for ARTEMIS Experiment, EURECA experiment panel mass not included

batteries are charged constantly with	100 W for 5.2 hours:
total stored energy per cycle:	1 870 kJ
battery efficiency: 90%	1 680 kJ
arcjet operation time: 25 min	
power available for experiment:	1 120 W
power supply efficiency: 90% available for thruster:	1 000 W
heat that has to be dissipated:	
from the thruster (glowing thruster nozzle)	150 W
through active cooling (electronic components)	150 W

	battery charging (constantly)
100 W	
experiment control unit	
dormant	5 W
operating, (valves etc.)	25 W
CCD-camera and camera control	
dormant	5 W
operating	15 W
total power	
dormant	110 W
operating	140 W
without battery charging (thruster would operate on 900 W and 90% PCU efficiency)	
operating	1040 W

Table 2: Power Balance for ARTEMIS

The ARTEMIS Experiment would include the following components:

- Two redundant thermal arcjet engines with hydrazine gas generators,
- propellant storage and feed system,
- power conditioning unit with rechargeable battery energy storage,
- experiment control unit,
- experiment diagnostic package.

Table 1 and 2 give a preliminary mass estimate and power balance for the experiment.

High emphasis will be placed on the redundancy of the whole system, because the arcjet technology has not been used on a satellite mission until now. All systems will be planned such that a failure in a subsystem does not jeopardize the whole experiment; it should be possible to "remove" failed components by surpassing them. The control unit will allow an override function of most control features, where the override does not endanger the EURECA system but would allow a more flexible response to performance complications.

Subsystems
Arcjet Engine

The arcjet engines used for this experiment would be an enhanced version of the ARTUS (arcjet thruster, University of Stuttgart) 1 kW thermal arcjet engine currently under development at the Institut für Raumfahrtsysteme (IRS) in cooperation with MBB ERNO under a contract from DARA [7]. Fig. 2 shows a cut away view of the ARTUS-thruster. The thruster is an improved laboratory version of the NLA1-IRS engine [9] developed at the IRS. The NLA1-IRS engine was operated with ammonia (NH_3) as propellant. In contrast to these preliminary tests, the ARTUS engine will operate with hydrazine as a propellant. Thus, the engines have to be equipped with a hydrazine gas generator developed by MBB-ERNO. If the thruster would be operated with ammonia (see propellant system) a gas generator would not be necessary.

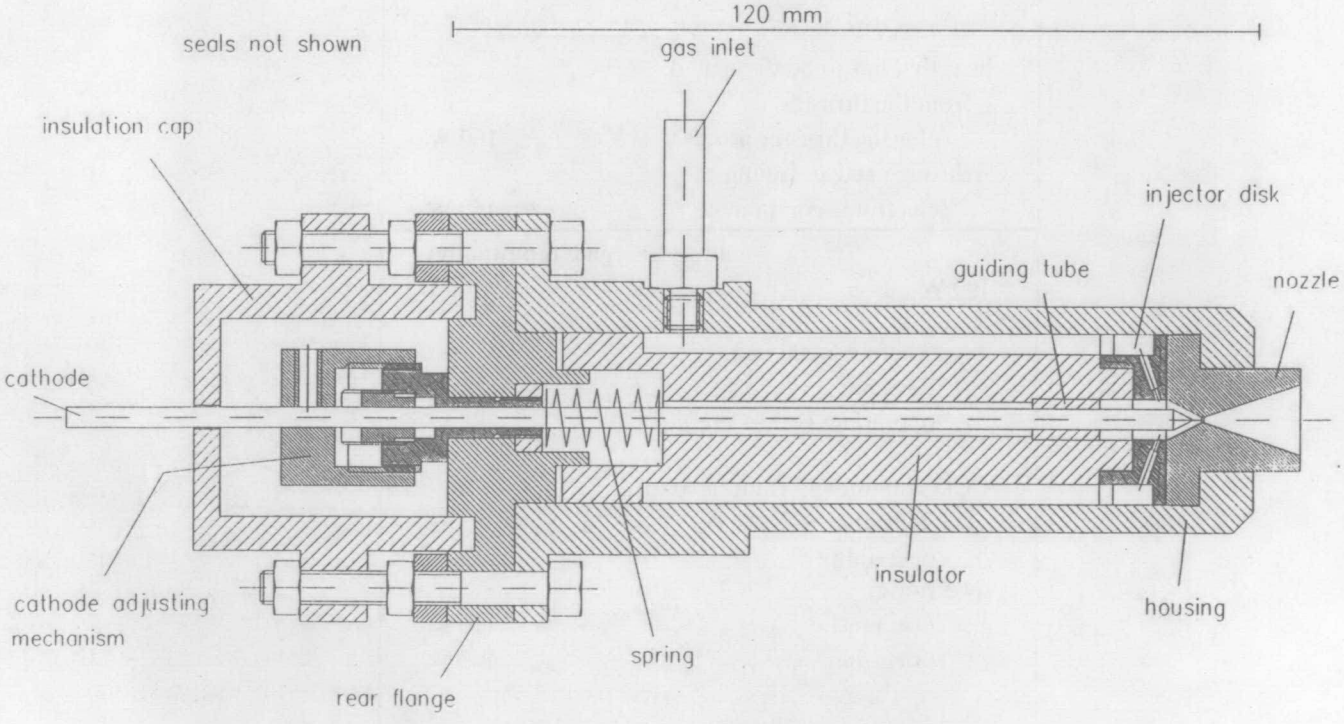

Fig. 2: Cut away view of ARTUS 1-kW thruster, laboratory version