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PRIME: a REXUS project to demonstrate a miniature free falling unit for plasma measurements

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Abstract

PRIME (Plasma Measurement with Micro Experiment) is a student experiment, to be launched on REXUS26 sounding rocket in 2019 as part of the REXUS/BEXUS programme. The project aims to develop a miniature recoverable Free Falling Unit for plasma parameter measurements in the lower ionosphere. Two identical Free Falling Units are ejectable from the Rocket Mounted Unit. The geometry of the Free Falling Units is designed to be compatible with future 'DART' rockets, from the company T-Minus Engineering. A Free Falling Unit consists of an Experiment and a Recovery Unit, which share a common battery and an umbilical. The Recovery Unit consists of a parachute with its deployment mechanism and a localization system. The Experiment Unit includes the deployable, cylindrical Langmuir probes with a data acquisition system. The measurements will be validated against model and independent observations of the ionospheric parameters.

1. Introduction

Communication and navigation systems are dependent on signal propagation in the ionosphere, which is affected by space weather. Observations of plasma parameters under various conditions are important for improving models of this region. This gives a motivation to study the ionosphere [1]. Information about the properties of plasma in the ionosphere is limited by the amount and frequency of the measurements that can be performed. The measurements can be either in-situ or remote ones, with in-situ measurements usually giving better accuracy and resolution. In-situ measurements require the use of sounding rockets, and hence cannot be performed regularly.

Currently, the 'Improved Orion' is one of the standard sounding rocket launch vehicles used for atmospheric and ionospheric measurements, bringing tens of kg payload up to about 100 km altitude. It is the launch vehicle used in the REXUS/BEXUS programme, The REXUS/BEXUS programme is realised under a bilateral Agency Agreement between the German Aerospace Center (DLR) and the Swedish National Space Board (SNSB). The Swedish share of the payload has been made available to students from other European countries through the collaboration with the European Space Agency (ESA). Experts from DLR, SSC, ZARM and ESA provide technical support to the student teams throughout the project. EuroLaunch, the cooperation between the Esrange Space Center of SSC and the Mobile Rocket Base (MORABA) of DLR, is responsible for the campaign management and operations of the launch vehicles. T-Minus Engineering [2] a company based in the Netherlands is developing a smaller 'DART' launch vehicle, providing an affordable alternative for bringing small payload (about 1 kg) to altitudes of over 100 km, which would enable more frequent measurements of the upper atmosphere. The volume available for payload of the DART is constrained by its inner diameter of 30 mm.

The purpose of the Plasma Measurement with Micro Experiment (PRIME) is to validate a miniature free falling payload complying with the dimensions of the DART rocket, in a flight on board REXUS26 sounding rocket. Two Free Falling Units (FFUs) with Langmuir probe based measurement system, see figure 1, will be ejected from the rocket module. The FFUs will continue in the ballistic flight, reaching an apogee of about 85 km, and record the currents collected by the probes. These measurements will enable us to obtain altitude profiles of electron

temperature and density and compare the results with incoherent scatter radar data (EISCAT), ionosondes, and compared to models.

This abstract presents the status of the PRIME experiment development in the experiment part after the Preliminary Design Review.

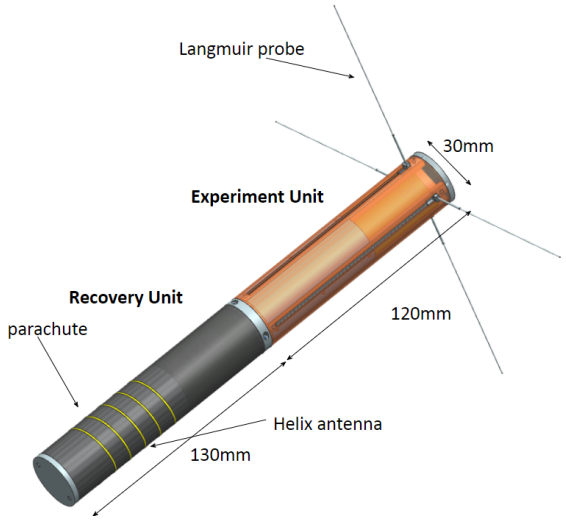

Figure 1: Free Falling Unit

2. Experiment

2.1 Langmuir Probes

The PRIME experiment uses four cylindrical Langmuir probes. Measuring current collected by the probes for known bias voltages is used to reconstruct the electron density and the electron temperature by analyzing the current-voltage curve. The analysis is dependent on assumptions about the plasma, such as the magnetic field strength, frequency of collisions and photoelectric currents. The probes deploy from the FFU in a symmetric configuration in the plane perpendicular to the FFU axis. An angular rate sensor, magnetometer and sun sensors provide data for reconstruction of the orientation of the probes with respect to the magnetic field of the Earth and the sun direction [3]. As the launch of the REXUS rocket is usually during the day, photoelectron emission will contribute to the current balance of the probes. The value of the photelectric current depends on material of the probe and the illumination conditions. The values of the maximum photoelectric current density in full illumination by the solar UV radiation for stainless steel (2.4 nA/cm2) and gold (2.9 nA/cm2) are lower than for aluminium (4.8 nA/cm2), making them suitable for the probe surface [4]. The expected value of the electron density in the altitude range of 60 km to 90 km is between 104 m-3 to 1011 m-3 [5]. The expected temperature will be in the range of 170K to 300K [6]. The Debye length resulting out of these parameters is maximum 2 mm [7]. Given the experiment dimensions, the Langmuir Probe will operate in the "thick sheath collisionless regime" [3]. Thus, the radius of the probe shall be much smaller than the Debye length and the length of the probe to much larger than the radius of the probe.

2.2 Similar Experiments

Our arrangement is similar to the design of the Multi-Needle Langmuir Probe [8]. The Multi-Needle Langmuir probe was flown up to an altitude of 300 km above ground level. It had a length of 41 mm and radius of 1 mm. The analysis started from the "thick sheath collisionless regime". Although the geometry and dimensions of the probe relating to the plasma is similar for the PRIME and Multi-Needle Langmuir probe experiment, we may not necessarily use the same analysis due to the differing conditions in which the probe will be flown, in particular with respect to higher collisionality and solar UV irradiation. The KTH SPIDER experiment used four spherical Langmuir Probes with a radius of 12.5 mm to measure plasma parameters in the E region of the ionosphere [9]. The interpretation of the data was intended based on "thin sheath collisionless regime", although it may not be fully applicable to it. For the PRIME experiment, we intend to investigate the refinements of the basic Langmuir probe theory that can improve the results of the analysis.

References

[1] Mark A. Clilverd et al. Remote sensing space weather events: Antarctic- Arctic Radiation-belt (Dynamic) Deposition-VLF Atmospheric Research Konsortium network. In: Space Weather 7(4). 2009

[2] T-Minus Engineering. http://www.t-minus.nl/, accesed on 10.3.2018

[3] Cherrington, B.E. Plasma Chem Plasma Process 2: 113. 1982

[4] Feuerbacher, B., Fitton, B. Experimental investigation of photoemission from satellite surface materials. In: J. Appl. Phys. 43 (9), 1563– 157. 1972

[5] Barabash, V., Osepian, A., Dalin, P., and Kirkwood, S. Electron density profiles in the quiet lower ionosphere based on the resultsof modeling and experimental data. In: Ann. Geophys., 30, pp. 1345-1360. 2012

[6] W.Kohnlein. A model of the electron and ion temperatures in the ionosphere. In: Planetary and Space Science. 34(7), 609-630. 1986

[7] G. D. Severn. A note on the plasma sheath and the Bohm criterion. In: American J. Phys. 75 (92). 2007

[8] K S Jacobsen, A Pedersen, J I Moen and T A Bekkeng. A new Langmuir probe concept for rapid sampling of space plasma electron density. In: Measurement Science and Technology 21, 8. 2010

[9] Asplund, Joakim. Design and Implementation of a Sounding-Rocket Electric-Field Instrument: Signal Conditioning and Power Supplies. reference for picture of circuitry. EES Examensarbete / Master Thesis ; TRITA EE 2016:049. p. 82. 2016 [10] Katharina Schüttauf et al. RXUserManualv7-1507Nov17. pp 3. 2017