SMALL RECOVERABLE PAYLOAD FOR DEPLOYABLE SOUNING ROCKET EXPERIMENTS

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ABSTRACT

We present a design of a small payload for deployment from sounding rockets. The payload is intended for measurements in the ionosphere and the acquired data is stored onboard. For a secure recovery of the data and possible re-use of the payload, an inflatable structure is deployed during the payload descent. This reduces the payload speed and protects it from ground impact. On the ground, a localization system is activated, sending the payload position via a satellite link, and providing a radio beacon signal. The proposed small payload will allow high time resolution multipoint measurements in the ionosphere with small separation distances, thus allowing to address a number of unresolved questions in the field.

1. INTRODUCTION

In the last few years, multi-point measurements of plasma characteristics by constellations of satellites, such as the Cluster or Themis missions, have provided a step towards resolving spatial and temporal ambiguities in the magnetosphere. For auroral and ionospheric research, sounding rockets have proved a very efficient means of data collection, and multi-point measurements can here be achieved by ejecting daughter payloads from the main rocket. For a larger number of daughter payloads, radio bandwidth limitations for the data transmission become an issue. By storing data onboard of each daughter and with subsequent recovery of the payloads, the limitations would be lifted, and the collection of large amounts of high resolution data would be possible. This would allow a system that is scalable with the number of subpayloads, with the size and mass of the daughters as the main limitation.

We here present the conceptual design of a miniaturized independent daughter payload intended for ionospheric electric and magnetic field measurements. The first prototype, the LAPLander (Light Airbag Protected Lander), is scheduled for launch from ESRANGE in March 2010 with REXUS 8: an unguided spin-stabilized single stage rocket, reaching a maximum altitude of approximately 100 km. The payload will be ejected from the nose cone before the motor separation, spinning with a frequency of roughly 4 Hz. The experiment is a part of the REXUS-BEXUS programme for university students, implemented by the Swedish Space Corporation (SSC) together with Deutches Zentrum für Luft- und Raumfahrt (DLR) and the European Space Agency (ESA), and financed by the Swedish National Space Board and DLR. The primary objective is to test the functionality of the impact and recovery systems. As no standardized reliable low-weight recovery system exists for a small, fast-spinning payload, the LAPLander utilizes a specially designed airbag-parachute structure, inflated by pressurized CO₂, both in order to decelerate the descent velocity and protection the payload at the moment of impact. To recover the payload, a redundant radio system with a radio-beacon and a satellite transmitter will be utilized, where the GPS position of the payload is transmitted as e-mail and sms text message over the satellite link. During the flight, sensor data will be stored in an on-board memory, which is later to be recovered. The flight profile will be recreated in order to understand the aerodynamic properties of the payload.

2. DESIGN OVERVIEW

The payload is designed to be optimized in terms of size and mass. An overview drawing of the design is shown in Fig. 1 The payload is shaped as a cylindrical disc, with 24 cm in radius and 8 cm in height. It weights approximately 2-3 kg. The design is built around a central electronics box, which provides bearing structure to the payload, and 4 wire boom deployment systems intended for electric field measurements [1], placed in a cross shape around the electronics box. For the LAPLander however, the boom deployment units have been replaced by dummies as the rocket trajectory does not allow for a full test of the wire booms. The airbag-parachute structure will be recovered mainly in the spaces available between each boom unit, and partly below them. The top and bottom will be covered by circular aluminum discs, coated by a thin heat resistant mylar or kapton film, and the sides are protected by two half cylindrical plates, held together by a carbon fiber braided sleeve hinge on one end, and a wire on the other. Before inflation, a wire-cutter releases the
side covers. The payload is constructed exclusively of non-magnetic materials, in order to keep the contaminations on the magnetic field measurements as low as possible.

3. RECOVERY SYSTEM

The inflatable structure consists of 4 toroidal airbags extending radially out from the disc. A parachute fabric is attached across the airbags, covering half of each torus as shown in Fig. 2. The structure thereby provides both an increased deceleration during final part of the fall (i.e. after inflation), and protection at the moment of impact. Drop tests have shown the structure to be stable when falling with the fabric on the bottom part of the airbags. It is unstable when falling in the fabric on the upper part, however it stabilizes quickly in the downside position. Wind tunnel tests have established a drag coefficient of \( \approx 1 \) for the stable configuration, slightly lower than that of an ordinary parachute. The final velocity at 0 km altitude has been calculated for a disc of 2 kg; the airbag-parachute structure should be able to decrease the impact velocity from approximately 24 m/s down to <10 m/s.

The airbags are inflated by pressurized CO\(_2\), stored in custom made pressure tanks containing less than 10g of CO\(_2\). The tank consists of two main parts: a bottom and a cover, both in aluminium. An electrovalve is situated in the cover, thermally insulated by an inner and outer PEEK plate and sealed by o-rings, see Fig. 4. The tanks are filled with frozen CO\(_2\), and the bottom and cover are connected with threading and lock-tight. After a period of time, the dry ice will convert into pressurized liquid CO\(_2\). A circular PCB with the valve control, a pressure sensor and a temperature sensor is attached to the cover.

The valves to be used in the LAPLander are based on a
design by Nanospace AB. The original single use valves [2] used a thin silicone disc with an aperture blocked by a low melting temperature alloy. The alloy is melted by passing a current through a heater element, implemented as a resistive layer on the high pressure side of the valve. A simpler version is developed for the LAPLand experiment, to isolate the tank with liquid CO$_2$. A 12 mm diameter round printed circuit board is designed, with four plated through holes. The holes are closed by soldering them with a fusible alloy with melting temperature of about 62°C (51% In, 32.5% Bi, 16.5% Sn). The heater is implemented as surface mounted resistors (in size 0603), which allows simple adjustment to the voltage requirements of the power system. The heater elements and the connecting cables are lead in on the low pressure side of the valve. Fig. 5 shows the valve. Tests carried out with the valves show that a power of 1.5 W is sufficient to open the valve in normal conditions. The actuation time is under 2 seconds.

4. DIAGNOSTICS AND SYSTEM CONTROL

In order to understand the flight dynamics, the payload is equipped with a set of sensors for flight diagnostics. The variables measured are the following:

- 3-axis acceleration, + 6g range
- three components of angular rate
- temperatures at multiple locations of the payload, and < 3 K accuracy
- ambient air pressure at >20 samples/s

In addition to standard of-the-shelf components, the payload is equipped with two state-of-the-art scientific instruments: Small Magnetometer In Low-mass Experiment (SMILE) [3], and Cornell Attitude GPS Experiment
5. SUMMARY

The paper presents the conceptual design of a recoverable sounding rocket payload intended for use in multi-point measurements of the ionospheric electric and magnetic fields, optimized in size and weight. A first prototype, the LAPLander, is scheduled for launch in March 2010 as a part of the REXUS-BEXUS programme. The experiment objective is to test the functionality of the recovery and localization systems, and to assess the aerodynamical properties of the design.

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