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GRASS: a Gravimeter for the Investigation of Small Solar System Bodies

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Abstract

An innovative and compact sensor is being developed that can measure absolute surface accelerations in the order of nano-g. The instrument shall be compatible with any exploration mission to small bodies (asteroids/moons) that carry landers or rovers. One target is the Didymos binary asteroid system to be investigated by the HERA mission, which will land the Juventas CubeSat carrying the gravimeter on board on the surface of Didymoon.

1. Introduction

Gravity is one of the principal properties of a planetary object one of the first to be measured in any exploration mission. Direct measurements of surface gravity vector provide valuable information on the interior and on density anomalies in the near subsurface, on tidal and on rotational forces. In addition, knowledge of gravitational accelerations induced by small bodies with irregular shapes is crucial for any landing/rover mission as well as for proximity operations. Despite its scientific merit, up to now, an instrument that is fully dedicated to gravity measurements has never been operational in previous planetary missions except for the Moon.

2. GRASS on Juventas/HERA

Juventas [1,2] is a 6U CubeSat that will provide bonus science to the HERA mission. The Hera mission [3] is currently under study at ESA in the framework of the AIDA project associated to the NASA DART impactor mission to the binary asteroid Didymos. It foresees landing of the Juventas CubeSat on the surface of the secondary of the Didymos system, called Didymoon. This will be the first time a rendezvous mission with the binary asteroid Didymos and touchdown on the smallest asteroid ever visited. Juventas will have a dedicated mission phase for the surface geophysical investigation [4]. GRASS is part of the Juventas payload and will give insight into the gravitational field inside the Brillouin sphere by providing local gravity measurements on the surface of Didymoon and thereby support the analysis of the interior structure of the moonlet. The GRASS science objectives can be found in Table 1.

Table 1: Science objective overview of GRASS on Juventas (the objective number refers to Juventas science objectives [1,2]).

	Objective #1	Objective #4
Science objective	Measure Didymoon mass and surface accelerations	Determine Didymoon dynamical state
Investi-gation	Monitoring of local gravity field and its variation on the surface of Didymoon	Determination of rotation kinematics (mean rotation, axis of rotation, librations, nutations)
Measure-ment	Measurement of the local surface acceleration vector as a function of time	

In parallel to Juventas, there are additionally similar missions and mission studies that consider the gravimeter as payload on small platforms and

CubeSats on the Martian moon Phobos (MMX mission) and AI3 for the ESA Fast Class mission opportunities [5].

3. Instrument description

The proposed compact gravimeter will be a novel system designed for low gravity environments. Its form factor and small power consumption will allow accommodating the instrument inside a small lander and/or a CubeSat. The concept is based on the instrument described by [6]. The instrument's TRL is currently raised from 3 to 4.

3.1 Measurement principle

The gravimeter measurement principle is based on the displacement and deflection of a flat spring due to the gravitational field. A capacitive transducer translates this deflection and the modulation of the measured g-vector by rotation allows the rejection of the zero-g bias. In addition, no leveling is required, which is one of the main challenges for absolute gravimetry.

3.2 Design and budgets

The instrument consists of two axes oriented orthogonally to each other, allowing the reconstruction of the full gravity vector. Figure 1 shows a conceptual drawing of a single axis with the motor for rotation, and the flat spring between the electrodes (in green) in the cylindrical sensor head.

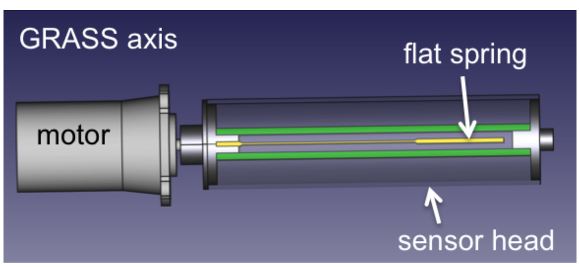

Figure 1: CAD drawing of a single axis of GRASS.

The front-end electronics is located inside the sensor head, but an external board is required for data storage, communication with the onboard computer and further signal processing. The dimensions of the sensor head can be scaled to different gravity environments, with a longer flat spring required in lower gravity. The flat spring length is in the order of 60 to 100 mm, the width is 15 mm and the thickness between 0.1 and 0.3 mm. The power consumption is in the order of 150 mW.

3.3 Operations

The operation of the instrument requires the slow rotation of the cylindrical sensor head with several consecutive measurements in order to achieve the required performance. When located on a moving platform (rover), inhomogeneities in the shallow subsurface can be tracked along the rover trajectory. When stationary located, several measurements during an orbit/rotational period of the small body will allow determination of the dynamic state of the object.

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