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Probing the internal structure of asteroids with seismic instruments on-board cubesat platforms

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Abstract

We present recent scientific and technical studies performed at ISAE in order to understand the interest and feasibility of deploying a seismometer at the surface of an asteroid using a cubesat platform. First, the scientific justification of performing such measurements is studied by simulating the seismic signals expected at an asteroid's surface, particularly those resulting from micro-meteoroid impacts. Then, the signal characteristics are extracted to produce requirements on the scientific payload. Some crucial technical aspects are also explored including first order thermal computations and experiments to understand the dynamics of the platform deployment and the subsequent movements under seismic waves in a reduced-gravity environment.

1. Introduction

Despite the successes of recent space missions [e.g., 1,2], there is still no clear understanding of the asteroid internal structure(s). Depending on their size, evolution and physical properties, many different asteroid internal structure models have been suggested from completely cohesive bodies, through to rubble pile objects. Here we discuss both the potential for using seismic instrumentation to probe asteroid internal structures and we also introduce some of the challenges involved in such in mission.

2. Seismological signals

Seismic signals from natural sources such as meteoroid impacts and thermal cracking [3] may occur at the surface of an asteroid.

Assuming low amplitude seismic waves, cohesive material and seismic properties similar to lunar regolith, we present normal mode simulations in a spherical geometry for a micro-meteoroid impact. These simulations allow us to infer the expected characteristics of such seismic signals and to specify the performance requirements of a seismic payload that will use these impacts as sources.

2.1 Seismic simulations

We simulate an impact at 6 km/s of a 10-gram micro-meteoroid into asteroids of various sizes. Despite strong seismic wave attenuation due to the expected scattering in the regolith layer, direct waves still present accelerations exceeding the local gravity for sub-kilometric asteroids. Frequencies in the 10-100 Hz range dominate the signals. Various seismic reflections inside the asteroid are expected, suggesting signal durations on the order of minutes.

2.2 Specification of seismic sensors

Seismic sensors for such experiments should be either short period rugged passive seismic exploration sensors, or MEMS high frequency sensors. In order to be able to measure the expected low amplitude signals from such micro-meteoroid impacts, their noise level and sensitivity should be of the order of magnitude of the Apollo seismometers. A low power consumption of the over-all system would also be necessary for integration into a cubesat platform.

3. Key technical issues

There are many technical challenges involved in performing seismology on an asteroid. Here we present studies of two specific technical issues related, respectively, to the thermal sustainability of the platform, and to the platform deployment and subsequent movements under seismic waves in a reduced-gravity environment.

3.1 Thermal study

A preliminary thermal study assuming that the seismometers will be on-board a 1U cubesat platform with a typical 1U cubesat payload is presented. The results suggest that to survive on the surface of an asteroid, the platform requires significant insulation. Additionally, thermal conduction between components should be increased in order to smooth the strong thermal gradient between the top and bottom surfaces of the platform.

3.2 Platform rebounds in reduced gravity

In order to understand the dynamics of the deployment of a cubesat onto the surface of an asteroid, and to understand the duration of any subsequent bouncing motion that might hamper the seismic measurements, an experiment is currently under development at ISAE to study low-velocity collisions into granular surfaces in reduced gravity conditions. The key challenge to designing such an experiment is finding a way to simulate reduced gravity conditions on Earth so that the prevailing forces in micro-gravity collisions can be reflected in the experimental results. We accomplish this by allowing a free-falling projectile to impact a granular surface with a constant downward acceleration that is slightly less than that of gravity (a system of pulleys and counterweights is used). The effective surface acceleration felt by the granular material is, therefore, very small. During the experiment, high-speed cameras will image the collision and wireless accelerometers, placed on the surface container and in the projectile, will provide further data.

4 Conclusions

We investigate the feasibility of deploying a seismometer at the surface of an asteroid using a cubesat platform. Through our analyses of natural seismic sources, we find that seismic signals are likely to be produced by the impact of small (~10 gram) micro-meteoroids. Based on the amplitude and frequency content of such signals, we suggest that either short period rugged passive seismic exploration sensors, or MEMS high frequency sensors should be included in a cubesat platform for asteroid seismology.

Finally we present studies related to two specific technical issues. In the study of the thermal sustainability of the platform, we find that the platform requires significant insulation and an effort should also be made to reduce the temperature gradients between the cubesat faces. The second study reports on an experiment under development to study low-velocity collisions into granular surfaces in reduced gravity conditions. This experiment will provide information important for the platform deployment and subsequent movements under seismic waves in a reduced-gravity environment.

In conclusion, despite the challenges involved, studying the internal structure of asteroids using seismic instrumentation onboard a cubesat platform is a promising prospect.

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