COMPACT IN-SITU INSTRUMENTS FOR THE GEOPHYSICAL EXPLORATION OF SMALL BODIES.

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Introduction: Over the last century seismic and geodetic methods have revolutionized our understanding of the internal structure of the Earth, of the Moon, and of Mars. The same techniques can be applied to measure an asteroid's physical properties and internal structure. This information is critical for understanding the evolutionary history of asteroids, and for planetary defense (to understand the damage that may cause upon impact, and to evaluate mitigation strategies).

Rotational dynamics can help us to understand the physical properties and mass distribution (relative moments of inertia) of an individual body, as well as the physical processes that govern the rotation. For example, the amplitude of forced librations of a binary system, and the decay of excited rotation sates such as the free librations, inform us directly about the internal structure [1]. The interactions between a lander and the asteroid surface (during landing and rebounds, for example) can be used to constrain the surface mechanical properties [2-4]. Natural seismic sources, such as micro-meteoroid impacts, thermal cracking and tidal quakes, are expected to occur on asteroids [5-8]. Such sources, or artificial sources such as the Hayabusa SCI-2 impactor [9], excite seismic waves and can allow the asteroid's internal structure to be imaged with a seismometer [8].

In the framework of two European Commission Horizon 2020 projects (PIONEERS and NEO-MAPP), we are developing two complementary in-situ geophysical instruments, designed specifically to fit inside a small asteroid lander and function in the challenging environment of the asteroid surface.

Compact 6 Degrees of Freedom instrument: The PIONEERS 6 DoF (Degrees of Freedom) instrument combines MEMS accelerometers and fiber optic gyroscopes and makes precise measurements of the small body's rotational dynamics, including forced librations of binary systems. This instrument can also precisely measure the landing dynamics in order to probe the mechanical surface properties and can also be used for active seismic experiments. In addition, this 6 DoF instrument can function as an IMU for a lander deployed on the surface and improve its navigation during its trajectory from the orbiter to the asteroid surface.

Compact seismometer: The low mass, low power seismometer, being developed as part of the NEO-MAPP project, consists of three sensors (geophones) that will each measure the ground motion along one axis. This instrument can measure both natural and artificial seismic sources. The seismic sensors are commercial sensors with no active electronics that have been specifically designed for borehole extreme environments. The robustness of the sensors has been demonstrated during initial environment testing (vacuum, vibration) using the facilities at ISAE-SUPAERO. The instrument analogue and digital electronics are developed at ISAE-SUPAERO.

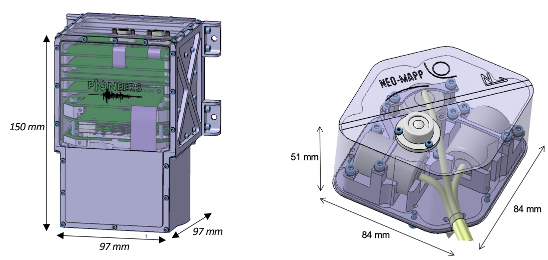

Figure 1. Left: 6 DoF instrument. Right. Seismometer.

In this presentation we will discuss the science case for these two instruments, including an analysis of the signals we expect to measure. Then we will present the design, development status and expected performance of each instrument.

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