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Apophis Seismology: The 'Smart Marbles' Concept

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ABSTRACT

In recent decades, our understanding of asteroids has been transformed from points of light to geological worlds owing to modern spacecraft exploration and state-of-the-art radar and telescopic investigations. Yet their internal geophysical structures remain largely unknown. Understanding the strength and internal integrity of asteroids is not just a matter of scientific curiosity; it is a practical imperative for advancing knowledge for planetary defense against the eventuality of an asteroid impact. Nature is providing us in 2029 with a once-per-thousand year experimental opportunity to learn the structure of asteroid interiors when the asteroid Apophis approaches to within about 30,000 km of Earth's surface (passing inside Earth's geosynchronous satellite ring). This rare event provides a chance to test current hypothesis on the effects of tidal forces on asteroids as well as the opportunity for internal geophysical study to inform asteroid mitigation strategies. However, more work is needed to prepare for this event by determining the best observing strategies and developing new instrumentation to fully take advantage of this unique opportunity.

Now is the time to be strategizing how we, as a spacefaring society, can best leverage this natural experiment. A concept study performed by MIT 12.43/16.83 Space Systems Engineering (2017) found that a robust science mission to study Apophis' close approach could be accomplished with currently available, high heritage proven flight hardware and launch capacity. However, one significant limitation of the mission proposed is that it does not include an instrument for directly detecting and measuring tidally induced seismic shaking (it is only capable of observing induced changes if they occur).

Traditional planetary landing packages have historically carried a steep price tag and high level of risk with a less than 30% success rate for launched seismometers (Lognonne, 2005, and references therein). The development of a simple, low-cost, low-risk instrument package for seismic measurements on small, air-less planetary bodies would not only advance the capabilities of an Apophis mission but would also have potential applications for missions to the Moon, the moons of Mars, or other asteroids.

The primary methodology we have been investigating is using a network of uncoupled sensors distributed across the surface of the body. By deploying 10's-100's of 'Smart Marbles' we would be able to obtain improved coverage and greater redundancy (thus less risk) than traditional landing packages. Each 'marble' would consist of simple, off-the shelf components (keeping cost low) including a set of accelerometers, short-range communication, onboard power, and micro-processor. The 'Smart Marbles' package will provide scientific capabilities that are not possible with non-contact remote sensing instruments while offering broader coverage and lower risk than previously flown landing packages.

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