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Science and Planetary Defense Priorities for Spacecraft Encounter Mission Concepts at (99942) Apophis During its 2029 Close Encounter with Earth

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ABSTRACT

On April 13, 2029, the approximately 350 m diameter near-Earth asteroid (99942) Apophis will pass through the Earth-Moon system at a closest approach to our planet of less than six Earth radii. This extremely close Earth flyby represents a perhaps once-in-a-millenium opportunity for unique studies of a Potentially Hazardous Asteroid (PHA). In particular, Apophis's extremely close pass by the Earth provides the potential opportunity to study tidal distortion, surface down-slope movement, and/or spin rate change effects that could provide unique insights into its interior structure and other physical properties. The encounter also provides an unprecedented opportunity to consider a variety of robotic space mission concepts for studying a highly-representative member of the approximately 2,000 PHAs, over a variety of mission sizes and timescales. For example, a "simple" single-spacecraft flyby mission at low relative velocity (a few km/sec or less) could enable the geology,

composition, and mineralogy of Apophis to be determined via remote sensing imaging and spectroscopy. A second in-tandem spacecraft could also potentially enable the determination of mass and thus bulk density from such a flyby. A more ambitious rendezvous (orbital or co-orbital) mission could achieve all of the above plus novel interior structure/strength data on PHAs via gravity mapping as well as real-time monitoring of tidally-induced dynamic changes before, during, and after the closest approach to Earth. Finally, an even more ambitious rendezvous mission with *in situ* elements (*e.g.,* surface impactor, lander, rover, radio transponder) could enable all of the above plus much more detailed and direct assessment of the asteroid's orbital evolution, composition, mineralogy, and internal structure via surface and subsurface sampling, sounding, and/or radio tracking. The Apophis encounter also offers NASA a unique, near-term opportunity to combine PHA science investigations with planetary defense experiments. For example, a highly complementary set of mitigation experiments to assess could be combined with science objectives in various mission concepts, and could include gravity tractoring, modifying differential thermal emission, explosive placement and observation, and impact deflection.

The 2029 Apophis encounter will also inevitably cause unprecedented public attention. Proactive science and planetary defense mission analysis could enable NASA to control that narrative and demonstrate visionary, relevant leadership. Detailed assessments of the expected science, planetary defense, and public education returns from this wide range of possible mission architectures must be performed soon, however (and optimally be included among the highest priorities of the next National Academy of Sciences Planetary Decadal Survey), in order to allow enough time for the detailed development, launch, and operation of one or more missions that can exploit this truly historic opportunity.

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