APOPHIS T-9 YEARS AND COUNTING: SETTING THE STAGE FOR THE SCIENCE OF PLANETARY DEFENSE. R. P. Binzel[1], [1]Department of Earth, Atmospheric and Planetary Science, Massachusetts Institute of Technology, Cambridge, MA 02139 USA; rpb@mit.edu.

Introduction: The 350-meter asteroid (99942) Apophis, an object 5-times larger and 100-times more massive than the Tunguska impactor, will safely miss the Earth on Friday April 13, 2029. However, its close flyby distance at an altitude of 31,000 km (closer than geosynchronous satellites; about one-tenth the lunar distance) provides a once-per-thousand-year natural experiment as a learning opportunity for the science and planetary defense. Our current challenge is to perform detailed studies of what physical effects, if any, may be induced on Apophis by Earth's tidal forces. By corollary, mission studies are needed to explore how measurements of any physical effects of this "natural experiment" may be used to deduce the internal and structural properties of potentially hazardous asteroids. The 2029 encounter opportunity makes Apophis the "poster child for planetary defense" transitioning the field to a new era from space situational *awareness* to space situational *understanding*.

Community Support for Holding Apophis T-9 Workshop: This workshop is an outcome of multiple community recommendations. NASA's Small Bodies Assessment Group (SBAG) issued a finding in January 2019 encouraging *NASA and the small bodies community to determine the science and planetary defense goals for the 2029 Earth flyby of (99942) Apophis, and to evaluate the opportunities, both in space and on the ground, that the flyby affords.* Similarly, a resolution passed by the 2019 International Academy of Astronautics Planetary Defense Conference acknowledged that *the occurrence of such a large asteroid flyby is a once-per-thousand year natural event that will provide a unique opportunity for advancing small body knowledge for both science and planetary defense.* Thus emerging is broad recognition of the Apophis 2029 event as the Planetary Defense Opportunity of the Decade, if not the millennium. Workshop attendees will be encouraged to participate in developing a White Paper for the upcoming Planetary Decadal Survey so that the Apophis opportunity is recognized as a key science opportunity of high priority.

Motivation for the Science of Planetary Defense: Interiors of asteroids remain *terra incognita,* just as the interior of Mars has remained unknown for millenia up to the time of the current *InSight Mars* mission. Thus, the fundamental question: "What is the internal structure of a potentially hazardous asteroid?" is of interest both for science and for planetary defense. Here we argue that the objectives for science and planetary defense are all one in the same. *As an axiom, we propose: Knowledge is the first line of planetary defense.* ("Know thy enemy.") From the observed outcome of the 2029 encounter it may be possible to determine whether Apophis is a solid monolithic body or loosely held conglomerate "rubble pile." For the latter, the scale of internal fracturing could range from Apophis being a "gravel pile" to being a bi- or multi-lobate structure of just a few large blocks. These vastly different physical constructions have a correspondingly huge range of intrinsic strengths; dramatically illustrating challenges to any future eventuality of actual planetary defense mitigation planning. Having specific knowledge of the detailed internal structure for one potentially hazardous asteroid could prove invaluable to the security of future civilization.

Objectives for the Apophis T-9 Workshop: As we move toward implementing plans for the Apophis opportunity, we seek to quantify:

- What Earth-based measurements are uniquely enabled, and to what reasonable precision, by virtue of Apophis' minimal close approach distance?
- What measurement techniques can be employed, Earth-based or *in situ*, to detect and measure physical changes to Apophis that may be induced by tidal stresses created by the Earth encounter? What level of measurement precision is reasonably achievable?
- What measurement techniques can be employed, Earth-based or *in situ*, to detect and measure physical changes – including seismic vibrations – from which the interior properties and structure of Apophis may be deduced? What level of measurement precision is reasonably achievable?
- What extent of physical changes, if any, do models predict to result from the close approach, including the amplitude and frequency of possible seismic vibrations?
- Does the precision of measurements, expected to be reasonably achievable, fall within the range of model predictions?
- If measurements are achieved, within the expected level of precision, but no physical effects are detected, what scientific knowledge outcomes are delivered by a "null result"?
- Do the science outcomes of a "null result" have sufficient merit such that the Earth-based or *in situ* measurements are worthwhile to execute?