APOPHIS PATHFINDER: A SMALLSAT MISSION TO CHARACTERIZE THE POTENTIALLY HAZARDOUS ASTEROID (99942) APOPHIS. J.F. Bell III[1], L. Papsidero[2], J.W. Ware[2], J.W. Rice Jr.[1], T. Linn[2], T.S.J. Gabriel[1], D. Thomas[1], S. Smas[1], and the MILO Space Science Institute, [1]Arizona State University, School of Earth & Space Exploration, Box 876004, Tempe AZ 85202 USA (Jim.Bell@asu.edu; +1-480-965-1044); [2]Lockheed Martin, 12257 S Wadsworth Blvd, Littleton, CO 80127.

Introduction: The MILO Space Science Institute [1] (http://miloinstitute.org), a non-profit deep space mission collaboration between Arizona State University and Lockheed Martin, is planning a mission called Apophis Pathfinder. The mission would perform the first-ever close flyby of the ~370-meter diameter, near Earth asteroid (99942) Apophis, a Potentially Hazardous Asteroid (PHA) that occasionally comes extremely close to the Earth. For example, on April 13, 2029 where it will pass Earth's center of mass at a distance of approximately 31,000 km – roughly five Earth radii above the surface and well within Earth's geosynchronous satellite ring.

The target launch date is 2024-2026, reaching the asteroid within about a year, and before its 2029 close Earth approach. Apophis is an S-type (stony asteroid), similar to the LL Chondrite meteorite class according to its visible to near-infrared (VNIR) spectrum [2]. Radar data indicate that it is elongated with possibly two lobes [3].

The extremely close pass in 2029 of such a relatively large asteroid represents a once-in-a-millennium opportunity to study not only a PHA in general, but possibly also the internal structure of such a body as well, if tidal effects from the Earth impart observable surface changes [*e.g.,* 4,5]. As such, Apophis Pathfinder's advance flyby would complement one or more larger robotic missions that might be flown by the world's major space agencies to study Apophis around the time of its close encounter in 2029.

The MILO Apophis Pathfinder mission's pre-2029 flyby precursor investigation of the asteroid would use a pair of smallsats to provide initial science reconnaissance data and to inform and influence planetary defense strategies and rendezvous planning for other missions to Apophis in 2029 and to other PHAs in the future. The Apophis Pathfinder mission would assess physical and regolith properties, both to address Decadal Survey-level science and for threat assessment and mitigation of hazardous objects. The ability to determine the mass of such a small object (traditional spacecraft Doppler tracking methods for mass determination won't work for objects smaller than a few km diameter) would rely on a novel optical and radio tracking multi-spacecraft approach [*e.g.,* 5] that Apophis Pathfinder would demonstrate for the first time. Additional observations would be obtained using data from small and high-heritage payload elements like VNIR and thermal imagers, near-IR point or imaging spectrometers, and a deep space radio communications system. Such flyby data would provide new scientific information about asteroids like (99942) Apophis, which is potentially similar to more than 80% of the other known PHAs based on its VNIR spectrum. Mission data would not only enhance advance planning for future missions to (99942) Apophis, in 2029 or future close approaches to Earth, but would also provide new data needed to formulate future Planetary Defense strategies for similar classes of PHAs.

Apophis Pathfinder would be conducted by a consortium of U.S. and international universities and space agencies that join the MILO Institute's membership-based model for deep space exploration [1]. The MILO Institute's philosophy is that missions like Apophis Pathfinder would not only produce compelling Decadal Survey-relevant science results, but also provide payload flight opportunities, spacecraft teaming opportunities, data processing and analytics training and development opportunities, and Principal Investigator training for the broad scale of MILO members, expanding the involvement of deep space exploration to a wider range of U.S. and international institutions.

References: [1] "The MILO Institute: A new model for deep space exploration," Space News, Dec. 21, 2018 and http://miloinstitute.org; [2] Binzel, R.P. *et al., Icarus,* 200, 480, 2009; [3] Brozović *et al., Icarus,* 300, 115, 2018; [4] Binzel, R.P., *6th IAA Planetary Defense Conf.,* Abstract IAA-PDC-19-03-01, 2019; [4] Bell, J.F. III *et al., 6th IAA Planetary Defense Conf.,* Abstract IAA-PDC-19-03-09, 2019; [5] Christensen, L., R.S. Park, & J.F. Bell III, *J. Spacecraft Rockets,* in press, 2021.