ASTERIA: A robotic precursor mission to near-Earth Asteroid 2002 TD60. T. Safko[1], D. Kelly[2], S. Guzewich[3], S. Bell[4], A. S. Rivkin[5], K. W. Kirby[5], R. E. Gold[5], A. F. Cheng[5], T. M. Aldridge[6], C. M. Colon[7], A. D. Colson[8], D. V. Lantukh[9], P. Pashai[10], D. Quinn[11] E. H. Yun[10], and the ASTERIA team[12]. [1]Villanova U., [2]U. of Michigan, [3]Johns Hopkins University, [4]Amherst College, [5]JHU/APL, [6]Northern Illinois U., [7]Rutgers U., [8]Florida Inst. Tech., [9]Georgia Inst. Tech., [10]U. Maryland, [11]U. North Carolina, [12]Various.

Introduction: Asteroids have long captured the attention of the astronomical, astrophysical, and geological community as points of interest. Many asteroids are thought to be undifferentiated mixtures, preserving material from the dawn of the Solar System. This allows for a glimpse into inner planet formation. Asteroids which evolve into near-Earth orbits, termed near-Earth Objects (NEOs), are of particular interest to the scientific community. Recently, NEOs have become targets of interest not only for science and hazard reasons, but also for their exploration implications. These objects have been included in NASA's "flexible path" as an intermediate goal to sending astronauts to Mars. Before a crewed mission to a NEO can be designed, a series of robotic precursor missions are planned in order to characterize NEOs, identify hazards and potential resources to human missions, and locate targets of interest.

We conducted a student-led mission study to look at possible first steps. The Asteroid Exploration, Reconnaissance, and In-Situ Analysis (ASTERIA) mission concept is intended as a precursor mission to a NEO. This mission will provide the reconnaissance necessary for a future human mission, while obtaining complimentary scientific data needed to characterize the object. The goals of this mission are hence twofold: to determine relevant physical and chemical characteristics of NEOs which will assist in planning future human missions, and to make scientific observations allowing for a more thorough understanding of Solar System formation.

Mission Design: Twenty-four interns within the Space Department of the Johns Hopkins University Applied Physics Laboratory (APL) participated in a concept study of a robotic mission to the NEAR-Earth asteroid 2002 TD60, with staff support from APL and the NASA Johnson Space and Goddard Space Flight centers. This target was selected based on two main criteria. First, launch was required before the end of 2014 with less than one year cruise until rendezvous so data could be returned during 2016 and fed forward into planning the next precursor. The mission was also to approximately fit under a Discovery mission class budget of $500 million. The cost cap drove the fuel and Δv requirements. With these factors in mind the asteroid 2002 TD60 was selected. We did not require the ASTERIA target itself to be a possible target for human exploration in the 2025 timeframe.

Target Information: The asteroid 2002 TD60 is an S-type Amor asteroid [1], with a semi-major axis of 1.21 AU. The asteroid exhibits non-principal axis rotation (tumbling) with periods of ~2.85 and ~6.78 hours [2]. Surface acceleration models imply a non-zero tensile strength, suggesting that the asteroid is a monolith [2]. A magnitude of 19.24 suggested a diameter of ~400 m given a typical 18% albedo for S-types, and radar observations with the Arecibo array found dimensions of 620×400×220 m [2]. Lightcurve models based on these dimensions match the observed lightcurve [3].

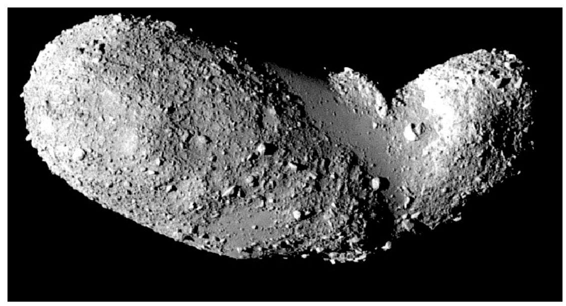

Figure 1: Image of the asteroid Itokawa from the Hayabusa mission.

Spacecraft Engineering: The ASTERIA spacecraft is designed to serve as a successor to NEAR Shoemaker while utilizing more modern heritage components. It is 3-axis stabilized by a combination of thrusters and reaction wheels. Power for the craft would rely on four fixed solar panels along with two lithium-ion batteries. The main engine selected can provide 145 lbf of thrust for large trajectory correction maneuvers. Primary communications with Earth would rely on one high gain antenna, with short-range and emergency communications using two low gain antennas and one fanbeam antenna. A 1 GB solid-state recorder was selected to meet the data requirements set by the science team and the constraints of periodic communications with Earth.

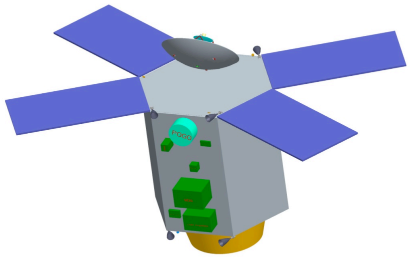

Figure 2: *ASTERIA* spacecraft design

Mission Payload and Concept of Operations: The primary payload on this mission includes a wide angle camera (WAC), LIDAR, a gamma-ray/neutron spectrometer (GRNS), and a radiation experiment. Secondary payload options include a lander, an IR spectrometer, an X-ray spectrometer, and a dust counter. The primary payload would be composed entirely of high-heritage instruments with the WAC and GRNS using slightly modified versions of MESSENGER's MDIS and GRNS, the LIDAR based on NEAR Shoemaker's, and the radiation experiment based on LRO (CRaTER) [4-6].

The mission would launch in November 2014 with an arrival and commencement of science operations in August 2015. Science operations are broken down into five main phases: the approach, out-gate, in-gate, home, and surface interaction.

The surface of the asteroid would be completely mapped with the WAC and LIDAR instrument in both the Out-Gate phase and the Home phase with WAC resolutions of 1 m/pixel and 10 cm/pixel respectively. GRNS would be used during the Home phase and the Surface Interaction phase in order to detail the chemical composition of the surface and search for hydrated materials.

Phase	Starting Distance	Science Measurements
Approach	100 km	WAC, LIDAR, CRaTER, Radio Science
Out-Gate	10 km	WAC, LIDAR, CRaTER, Radio Science
In-Gate	5 km	WAC, LIDAR, CRaTER, Radio Science
Home	1 km	WAC, LIDAR, CRaTER, GRNS, Radio Science
Surface Interaction	< 100m	WAC, LIDAR, CRaTER, GRNS, Lander

Table 1: Concept of operations summary table

High Phase Angle Imaging: During the last two weeks of the Home phase, a series of maneuvers will be preformed causing the spacecraft to pass within eclipse for no more than ten minutes. During this time, a series of images will be taken with the WAC of the limb of the asteroid in order to search for dust levitated above the surface of 2002 TD60.

Surface Interaction: A major objective of the mission from both a science and human precursor perspective would be to interact with the surface of the asteroid. Interacting with the surface will provide a more comprehensive understanding of the environment future astronauts will work in. Scientific data obtained in this phase will detail regolith characteristics, the dust environment, and elemental surface composition.

The Surface Interaction phase would last two months and would involve three main stages. Each stage would require approximately two weeks of planning and calibrations at the Home position 1 km away from the object. The first stage would involve a close pass of the asteroid (within 100 m) in order to image the surface with the WAC at a resolution of 1 cm/pixel. The second stage of this phase would require an additional two weeks of planning and calibration prior to the maneuver. This stage would release the lander (if present) and image the asteroid as the lander contacted the surface. The final stage of this phase would involve the firing of the main thruster at the surface of the asteroid at a distance on the order of a few meters. The motion of the spacecraft and rotation of the asteroid would be in opposite directions, preventing any lofted dust from impacting the spacecraft. Then the spacecraft would rotate slightly in order to image any dust that is liberated from the surface by the thruster.

References:

[1] Lazzarin M., et al. (2005) MNRAS 359, 1575-1582 [2] Pravec P., et al. (2005) Icarus 173, 108-131. [3] Scheirich P. (2005) IAU Symposium 229 [4] Gold R., et al. (2001) Planetary and Space Science 49, 1467-1479. [5] Chin G., et al. (2007) Space Science Review 129, 391-419. [6] Cole T., et al. (1997) Space Science Review 82, 217-253.