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ASTEROID RETRIEVAL MISSION CONCEPT – TRAILBLAZING OUR FUTURE IN SPACE AND HELPING TO PROTECT US FROM EARTH IMPACTORS

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ABSTRACT

The Asteroid Retrieval Mission (ARM) is a robotic mission concept with the goal of returning a small (~7 m diameter) near-Earth asteroid (NEA), or part of a large NEA, to cis-lunar space using a robotic 40 kW-class solar electric propulsion (SEP) vehicle and currently available technologies. The feasibility of the mission was investigated by a team of engineers and scientists during two workshops at Caltech's Keck Institute for Space Studies (KISS) held in late 2011 and early 2012. The mission concept is continuing to be analyzed by the National Aeronautics and Space Administration (NASA) as a possible future mission opportunity. The mass of the asteroidal material returned from this mission is anticipated to be between 50 and 1,000 metric tons, depending on the orbit of the target NEA and the thrust-to-weight and control authority of the SEP vehicle. Even larger masses could be returned in the future as technological capability and operational experience improve. The use of high-power solar electric propulsion is the key enabling technology for this mission concept, and is beneficial or enabling for a variety of space missions and architectures where high-efficiency, low-thrust transfers are applicable. The ARM mission concept appears to be feasible, but it is important to identify and assess key

mission challenges and potential showstoppers in anticipation of future mission development activities.

There are many important benefits that would result from the successful completion of this mission. They include providing a near-Earth source of in-situ resource utilization (ISRU) materials for human and robotic space exploration, developing technologies and techniques to enable a future space-based economy based on the processing of asteroidal materials, and providing invaluable operational experience critical to future planetary defense efforts. This mission would offer an attractive near-term destination for human missions that can be leveraged to develop systems and operational experience for human and robotic activities in the vicinity of a NEA. It would allow repeated crew visits to a NEA for extended periods of time before embarking on longer duration missions to more distant NEAs. The returned asteroidal material also provides numerous opportunities for commercial, scientific, academic, and international cooperation.

The critical resource for human space exploration is water, which can used for propellants, radiation shielding, thermal control, human consumption, non-potable applications (plant growth, cleaning, etc.), and other uses. Carbonaceous NEAs can consist of up to 40% extractable volatiles by mass (~20% water), along with other valuable materials (metals, minerals, carbon compounds, etc.). A 1,000-ton asteroid could provide as much as 200 metric tons of water. C-type asteroids also possess low compressive strength that simplifies cutting, crushing, and processing, which could be a key target characteristic for practical resource extraction and recovery. The paradigm shift enabled by the ARM concept would be to allow in-situ resources to be used at the human mission departure location (i.e., cis-lunar space) versus at the deep-space mission destination. This approach eliminates, or drastically reduces, the risk associated with utilizing ISRU for human deep-space missions. Also, the testing and validation of extraction and processing equipment and methods would enable large-scale commercial ISRU operations to become a reality, either in cis-lunar space or for future deep-space resource recovery.

Most of the ARM operations and technologies could also be applicable to planetary defense efforts. These include the operational approaches and systems associated with the NEA rendezvous, station-keeping, and approach mission phases utilizing a low-thrust, high-power SEP spacecraft, along with interacting with, capturing, maneuvering, and processing the massive amounts of material associated with this mission. Finally, the processed materials themselves (e.g., water-derived, high-specific impulse chemical propellants) could be used for planetary defense.

This paper will provide an overview of the ARM concept along with identified operational approaches and options, discuss the key technologies and capabilities that would be developed in support of the mission, and identify how the mission will benefit humanity and aid in the knowledge and operational experience to enable future planetary defense efforts.