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Asteroid Redirect Mission Overview and Potential Science Opportunities

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Abstract

The National Aeronautics and Space Administration (NASA) is developing the first-ever robotic mission to visit a large near-Earth asteroid, collect a multi-ton boulder from its surface, and redirect it into a stable orbit around the Moon. Once returned to cislunar space in the mid-2020s, astronauts will explore it and return to Earth with samples. This Asteroid Redirect Mission (ARM) is part of NASA's plan to advance the technologies, capabilities, and spaceflight experience needed for a human mission to the Martian system in the 2030s. Subsequent human and robotic missions to the asteroidal material would also be facilitated by its return to cislunar space. An overview of robotic and crewed segments of ARM will be provided along with a discussion of the potential science opportunities associated with the mission.

1. Introduction

NASA is developing the ARM, which includes the goal of robotically returning a multi-ton boulder (typically 2-4 meters in size) from a large near-Earth asteroid (NEA), 100 meters or greater in size, to cislunar space using an advanced 50 kW-class Solar Electric Propulsion (SEP) spacecraft designated the Asteroid Redirect Vehicle (ARV) [1]. An overview of the ARM robotic segment is shown in Figure 1.

After the ARV returns to a lunar distant retrograde orbit (LDRO) in the mid-2020s, initial astronaut exploration and sampling of the returned material will take place as part of ARM as depicted in Figure 2. Subsequent human and robotic missions to the asteroidal material would also be facilitated by its return to cislunar space and would benefit scientific and partnership interests, expanding our knowledge of small celestial bodies and enabling the demonstration of mining asteroid resources for commercial and exploration needs.

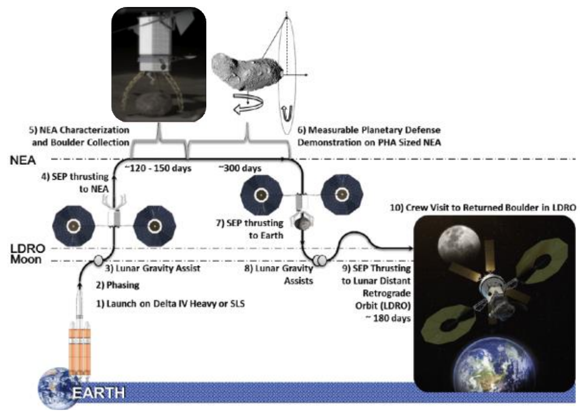

Figure 1: Robotic Segment Overview.

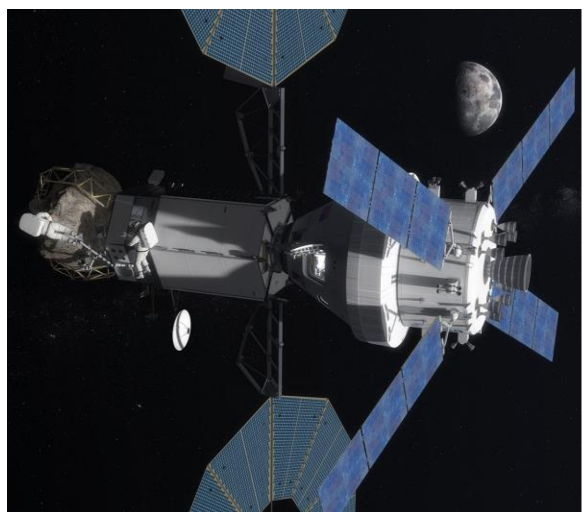

Figure 2: Crewed Segment Illustration.

The capabilities, systems, and operational experience developed and implemented by ARM and subsequent missions to the returned asteroidal material will advance NASA's goal of sending humans to deep-space destinations and eventually to the surface of Mars. The robotic segment would also permit the demonstration of planetary defense techniques on a hazardous-sized NEA.

2. Robotic Segment

The ARV will launch in the early-2020s and arrive at the NEA approximately two years later. After arriving, the ARV will spend approximately two months characterizing the surface and selecting three candidate boulders. During this time, the spacecraft will perform a series of seven-day reconnaissance passes over the surface at decreasing range, down to a final altitude of less than one kilometer. Over the following two months, the team will practice the operations right up to the low-gravity landing at the preferred boulder site as depicted in Figure 3. Once all systems have been confirmed to be functioning nominally, the operations team will command the ARV to autonomously land, capture the boulder, and ascend to a safe distance.

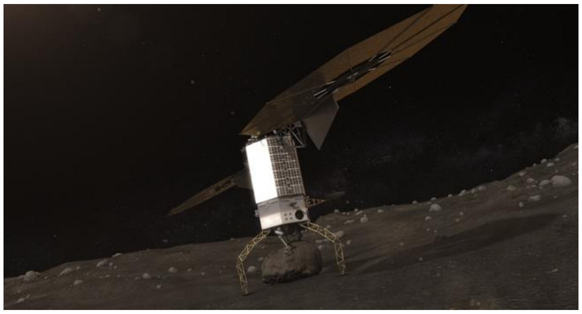

Figure 3: Boulder Capture Illustration.

After the boulder has been collected and secured, the ARV will be commanded to perform an Enhanced Gravity Tractor (EGT) planetary defense demonstration. During the EGT phase, the ARV will operate in a halo orbit around the target asteroid for up to two months, using the mass of the vehicle and boulder to slowly alter the asteroid's orbit [2]. Subsequently, the ARV and boulder would transit to the LDRO. The robotic segment asteroid will be selected a year before launch. To be a valid candidate, an asteroid must have an orbit that allows for a return in the mid-2020s, and have a confirmed or inferred presence of boulders on its surface. The team is currently assuming 2008 EV_5 as the reference target and is also evaluating Itokawa, Bennu, and 1999 JU_3.

3. Crewed Segment

In the mid-2020s, NASA's Orion spacecraft will launch on the agency's Space Launch System (SLS), carrying astronauts to rendezvous with the ARV and the returned boulder. The current concept for the crewed segment of ARM is a two-astronaut, 24-25 day mission. This crewed mission will further test many capabilities needed to advance human spaceflight for deep-space missions to Mars and elsewhere, including new sensor technologies and a docking system that will connect Orion to the ARV. Astronauts will conduct spacewalks outside Orion to study and collect samples of the asteroid boulder wearing new spacesuits designed for deep-space missions. Collecting these samples will help determine how best to secure and safely return samples during future human missions. Additionally, since asteroids are remnants from the formation of the solar system, the returned samples could provide valuable data for scientific research or commercial entities interested in asteroid mining as a future source of space-based resources.

4. Potential Science Opportunities

ARM provides numerous commercial, academic, and international partnership opportunities for payloads on the ARV (e.g., sensors or ride-along missions) and its launch vehicle during the robotic segment, or as secondary payloads on the SLS and possibly as part of the EVA operations during the crewed segment. These payloads may address scientific investigations, commercial interests such as asteroid resource prospecting, demonstration of planetary defense capabilities, or Strategic Knowledge Gaps (SKGs) for future human exploration. Science, planetary defense or commercial opportunities could also include precursor missions to potential target asteroids or the moons of Mars or independent small body missions.

Acknowledgements.

The images provided are credited to NASA/Analytical Mechanics Associates (AMA), Inc.

References

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[2] Mazanek, D., Reeves, D, Hopkins, J., Wade, D., Tantardini, M., and Shen, H., "Enhanced Gravity Tractor Technique for Planetary Defense," 4th IAA Planetary Defense Conference – PDC 2015, Frascati, Roma, Italy, April 2015.