

Space Studies of the Earth-Moon System, Planets, and Small Bodies of the Solar System (B)  
Past, Present and Future of Small Body Science and Exploration (B0.4)  
Consider for oral presentation.

## THE ASTEROID REDIRECT MISSION (ARM)

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**Introduction:** To achieve its long-term goal of sending humans to Mars, the National Aeronautics and Space Administration (NASA) plans to proceed in a series of incrementally more complex human spaceflight missions. Today, human flight experience extends only to Low-Earth Orbit (LEO), and should problems arise during a mission, the crew can return to Earth in a matter of minutes to hours. The next logical step for human spaceflight is to gain flight experience in the vicinity of the Moon. These cis-lunar missions provide a “proving ground” for the testing of systems and operations while still accommodating an emergency return path to the Earth that would last only several days. Cis-lunar mission experience will be essential for more ambitious human missions beyond the Earth-Moon system, which will require weeks, months, or even years of transit time. In addition, NASA has been given a Grand Challenge to find all asteroid threats to human populations and know what to do about them. Obtaining knowledge of asteroid physical properties combined with performing technology demonstrations for planetary defense provide much needed information to address the issue of future asteroid impacts on Earth. Hence the combined objectives of human exploration and planetary defense give a rationale for the Asteroid Re-direct Mission (ARM).

**Mission Description:** NASA’s ARM consists of two mission segments: 1) the Asteroid Redirect Robotic Mission (ARRM), the first robotic mission to visit a large (greater than 100 m diameter) near-Earth asteroid (NEA), collect a multi-ton boulder from its surface along with

regolith samples, demonstrate a planetary defense technique, and return the asteroidal material to a stable orbit around the Moon; and 2) the Asteroid Redirect Crewed Mission (ARCM), in which astronauts will take the Orion capsule to rendezvous and dock with the robotic vehicle, conduct multiple extravehicular activities to explore the boulder, and return to Earth with samples. NASA's proposed ARM concept would leverage several key ongoing activities in human exploration, space technology, and planetary defense. The ARRM is planned to launch at the end of 2021 and the ARCM is scheduled for late 2026.

**Mission Objectives:** The Asteroid Redirect Mission is designed to address the need for flight experience in cis-lunar space and provide opportunities for testing the systems, technologies, and capabilities that will be required for future human operations in deep space. A principle objective of the ARM is the development of a high-power Solar Electric Propulsion (SEP) vehicle, and the demonstration that it can operate for many years in interplanetary space, which is critical for deep-space exploration missions. A second prime objective of ARM is to conduct a human spaceflight mission involving in-space inter-action with a natural object, in order to provide the systems and operational experience that will be required for eventual human exploration of the Mars system, including the moons Phobos and Deimos. The ARCM provides a focus for the early flights of the Orion program. Astronauts will participate in the scientific in-space investigation of nearly pristine asteroid material, at most only minimally altered by the capture process. The ARCM will provide the opportunity for human explorers to work in space with asteroid material, testing the activities that would be performed and tools that would be needed for later exploration of primitive body surfaces in deep space. The operational experience would be gained close to our home planet, making it a significantly more affordable approach to obtaining this experience.

**Target Asteroid Candidates:** NASA has identified the NEA (341843) 2008 EV5 as the reference target for the ARRM, but is also carrying three other NEAs as potential options [(25143) Itokawa, (162173) Ryugu, and (101955) Bennu]. NASA is continuing to search for additional candidate asteroid targets for ARM. The final target selection for the ARRM will be made approximately a year before launch, but there is a strong recommendation from the scientific and resource utilization communities that the ARM target be volatile and organic rich. Three of the proposed candidates are carbonaceous NEAs. Specifically, the ARRM reference target, 2008 EV5 is a carbonaceous (C-type) asteroid that has been remotely characterized (via visual, infrared, and radar wavelengths), is believed to be hydrated, and provides significant return mass (boulders on the surface greater than 20 metric tons). It also has an advantage in that the orbital dynamics of the NEA fall within the current baseline mission timeline of five years between the return of the robotic vehicle to cis-lunar space and the launch of the ARCM. Therefore, NEA 2008 EV5 provides a valid target that can be used to help with formulation and development efforts.

**Input to ARM and Future Activities:** In the fall of 2015, NASA chartered the Formulation Assessment and Support Team (FAST) to provide timely inputs for mission requirement formulation in support of the ARRM Requirements Closure Technical Interchange Meeting (TIM) in mid-December of 2015, to assist in developing an initial list of potential mission investigations, and to provide input on potential hosted payloads and partnerships. Expertise from the science, engineering, and technology communities was represented in exploring lines of inquiry related to key characteristics of the ARRM reference target asteroid (2008 EV5) for engineering design purposes. As of December 2015, the FAST has been formally retired and the FAST final report was publically released in February of 2016. However, plans have been made to stand up an ARM Investigation Team (IT), which is expected be formed in 2016. The multidisciplinary IT will assist with the definition and support of mission investigations, support ARM program-level and project-level functions, and support NASA Head-quarters interactions

with the science and technology communities through mission formulation, mission design and vehicle development, and mission implementation.