NASA's ASTEROID REDIRECT MISSION (ARM). P. A. Abell[1], D. D. Mazanek[2], D. M. Reeves[2], P. W. Chodas[3], M. M. Gates[4], L. N. Johnson[5], and R. L. Ticker[4], [1]Astromaterials Research and Exploration Science Division, NASA Johnson Space Center (paul.a.abell@nasa.gov), [2]Systems Analysis and Concepts Directorate, NASA Langley Research Center, [3]Center for Near-Earth Object Studies, Jet Propulsion Laboratory, [4]Human Exploration and Operations Mission Directorate, NASA Headquarters, [5]Planetary Defense Coordination Office, NASA Headquarters.

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.

Mission Description and Objectives: NASA's Asteroid Redirect Mission (ARM) consists of two mission segments: 1) the Asteroid Redirect Robotic Mission (ARRM), a 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, and return the asteroidal material to a stable orbit around the Moon; and 2) the Asteroid Redirect Crewed Mission (ARCM), in which astronauts will explore and investigate the boulder and return to Earth with samples. The ARRM is currently planned to launch at the end of 2021 and the ARCM is scheduled for late 2026.

The Asteroid Redirect Mission is designed to address the need for flight experience via conducting integrated crewed and robotic vehicle mission operations in cis-lunar space and provide opportunities of for testing the systems, technologies, and capabilities that will be required for future human deep space missions. 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 interaction with a natural object, in order to provide the systems and operational experience that will be required for eventual human exploration of Mars, including the Martian moons Phobos and Deimos. The ARCM provides a focus for the early flights of the Orion program, which will take place before the infrastructure for more ambitious flights will be available. 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 extravehicular activities that would be performed and the tools that would be needed for later exploration of primitive body surfaces in deep space. These operations would be conducted in proximity to our home planet, making it a significantly more affordable approach for obtaining the necessary experience for future human exploration of deep space.

The overall mission objectives of ARM are listed as follows:

1. Conduct a human exploration mission involving in-space interaction with an asteroid boulder in the mid-2020s, providing systems and operational experience required for human exploration of Mars.
2. Demonstrate an advanced solar electric propulsion system, enabling future deep-space human and robotic exploration with applicability to the nation's public and private sector space needs.
3. Enhance detection, tracking and characterization of Near-Earth Asteroids, enabling an overall strategy to defend our home planet.
4. Demonstrate basic planetary defense techniques that will inform impact threat mitigation strategies to defend our home planet.
5. Pursue a target of opportunity that benefits scientific and partnership interests, expanding our knowledge of small celestial bodies and enabling the mining of asteroid resources for commercial and exploration needs.

Target Asteroid Candidates: NASA has identified the NEA (341843) 2008 EV_5 as the reference target for the ARRM, but is also carrying three other NEAs as potential options [(25143) Itokawa, (162173) Ryugu, and (101955) Bennu]. 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 reference target, 2008 EV_5 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 EV_5 provides a valid target that can be used to help with formulation and development efforts.

Recent ARM Activities and Milestones: In the fall of 2015, NASA established the Formulation Assessment and Support Team (FAST), which was chartered by NASA 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. Potential investigations focused on reducing mission risks and increasing knowledge return in the areas of science, planetary defense, asteroid resources and in-situ resource utilization (ISRU), and capability and technology demonstrations. More specific areas of interest included target origin, spatial distribution and size of boulders, surface geotechnical properties, boulder physical properties, and considerations for boulder handling, crew safety, and containment.

As of December 2015, the FAST has been formally disbanded. However, after ARM passed Key Decision Point-B in August 2016, NASA decided to formally stand up an ARM Investigation Team (IT), which will commence work in the mid-2017 timeframe. A call for membership to the IT, as well as a call for hosted payloads, were extended to the community on September 6, 2016 via a Broad Agency Announcement. The IT will work in collaboration with ARM management and technical personnel from NASA and the Jet Propulsion Laboratory (JPL) to provide expert knowledge and input in the planning of all aspects of the ARRM, which includes spacecraft interfaces, requirements, outbound cruise and asteroid rendezvous, asteroid characterization, boulder selection and capture, planetary defense demonstration, and transfer to cis-lunar space, as well as design considerations as they relate to the ARCM. The IT will also work with the ARCM project team to develop plans to explore the asteroidal material returned to cislunar space, investigate the boulder after capture during the ARRM, and assist in extra-vehicular activity (EVA) site selection, sample acquisition, and sample curation.

Other activities that occurred in late 2016 were the NASA community update on ARM hosted by the White House Office of Science and Technology Policy (OSTP) and NASA headquarters On September 14, 2016; the release of the request for proposal (RFP) by JPL seeking design, development and build of the robotic spacecraft that will capture a multi-ton asteroid boulder from deep space during the first segment of ARM on September 20, 2016; and a report from the Small Bodies Assessment Group (SBAG) discussing the connecting between ARM mission objectives with respect to small body science and exploration goals on September 26, 2016.

Conclusion: NASA continues to meet milestones on its deep space exploration programs including Orion, Space Launch System, as well as the ARM. While NASA continues to use the International Space Station to prepare for deep space exploration, these new capabilities will enable our next steps on the journey to Mars. ARM is a key piece of our deep space endeavors, providing important exploration capabilities for future robotic and human missions.