THE 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: NASA's Asteroid Redirect Mission (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, 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 the boulder and return to Earth with samples. NASA originally proposed a robotic mission concept to capture an entire small asteroid (4-10 m in size) that would leverage several key ongoing activities in human exploration, space technology, and planetary defense. Subsequently, an alternate approach to collect a boulder from a large asteroid was also proposed. NASA evaluated both mission approaches, to determine their feasibility, identify the important differences between them, and evaluate the key risks and figures of merit for each concept. On March 25, 2015, NASA announced the selection of the boulder capture option for the robotic segment of ARM. The ARRM is planned to launch at the end of 2020 and the ARCM is scheduled for late 2025.

Mission Objectives: The Asteroid Redirect Mission is designed to address the need for flight experience in cis-lunar space and provide opportunities of for testing the systems, technologies, and capabilities that will be required for future human deep space operations. 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 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 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 Community Input to ARM: 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. The FAST included eighteen participants that were selected from exactly 100 applications received from highly qualified individuals representing academia, industry, NASA, non-profit research institutes, and other organizations, and explored several aspects of potential science benefits and knowledge gain from ARM. 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 EV_5) for engineering design purposes. 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. In order to increase knowledge gain potential from the mission, opportunities for partnerships and accompanying payloads were also investigated.

FAST Report and Inputs: The FAST report and associated public comments will be used to support mission requirements formulation and serve as an initial inquiry to the science and engineering communities relating to the characteristics of the ARRM reference target asteroid. This report also provides a suggested list of potential investigations sorted and grouped on their likely benefit to ARM and relevance to NASA science and exploration goals. These potential investigations could be conducted to reduce mission risks and increase knowledge return in the areas of science, planetary defense, asteroid resources and in-situ resource utilization (ISRU), and capability and technology demonstrations. Participation in the FAST by non-civil service personnel was limited to providing non-consensus, non-voting input. The report represents the FAST's final product for the ARM. The FAST report was divided into several sections with the first section providing details about the purpose of the FAST, an overview of ARM, a summary of the study request, and information about the FAST selection process and membership. The second section includes responses to a set of high-priority questions that were derived from the ARRM engineering team's risk analysis and were needed to help design and develop the ARRM mission, spacecraft, and capture system. The questions were grouped into seven topics and the major findings for each question listed. In addition, this report includes an initial list of potential investigations that could be performed by ARM (ARRM and ARCM) resulting from brainstorming activities by the FAST. Many of the identified investigations require additional sensors, subsystems, or operations, which are beyond the scope of the current program. These inputs are not intended to be inclusive of all possibilities, but were meant to aid formulation and development of the ARRM, and reflect the FAST members' experience and expertise in small body missions and knowledge related to science, planetary defense, asteroidal resources and in-situ resource utilization (ISRU), and relevant capabilities and technologies. The last two sections of the report includes a list of additional findings by the FAST in combination with public input and a summary of relevant public inputs and comments received by the FAST. All public inputs directly relevant to ARM, including any additional comments received in response to the posting of this draft version, will be summarized in the final version of the report and will be posted in their entirety on the FAST website: http://www.nasa.gov/feature/arm-fast.

Support of Future ARM Activities: As of December 2015, the FAST has been formally disbanded. However, plans have been made to stand up an ARM Investigation Team (IT), which will be formed in mid-2016 with a call for membership expected in April of 2016. The multidisciplinary IT will assist with the definition and support of mission investigations, support ARM program-level and project-level functions, provide technical expertise, and support NASA Headquarters interactions with the technical communities through mission formulation, mission design and vehicle development, and mission implementation.