Introduction

NASA’s Asteroid Redirect Mission (ARM) is a capability demonstration mission that will develop, test, and demonstrate several capabilities required for enabling Human Exploration of the Solar System. These capabilities are focused on in-space power and propulsion, transportation and mission operations, and extravehicular activities (Fig. 1). Completion of the ARM human space flight demonstration objectives are an important early step for NASA to develop longer duration crew activities in deep space. Specifically these involve:

- Conducting advanced autonomous proximity operations and rendezvous in deep space
- Transporting multi-ton objects utilizing advanced solar electric propulsion
- Performing integrated crew/robotic vehicle operations in deep-space staging orbits
- Conducting asteroid EVAs for sample selection, collection, handling, and containment
- Developing Earth return trajectories and emergency return strategies

The Asteroid Redirect Robotic Mission (ARRM) has the objective of deflecting an asteroid and returning a large boulder to cis-lunar space; the third segment is the Asteroid Redirect Crewed Mission (ARCM) in which astronauts explore the boulder and bring samples of it back to Earth.

There are five main objectives for the ARM as a whole. These are listed below and have relevance to the Space Technology and Operations Mission Directorate, NASA Headquarters, Washington, DC 20546.

1. Conducting advanced autonomous proximity operations and rendezvous in deep space
2. Transporting multi-ton objects utilizing advanced solar electric propulsion
3. Performing integrated crew/robotic vehicle operations in deep-space staging orbits
4. Conducting asteroid EVAs for sample selection, collection, handling, and containment
5. Developing Earth return trajectories and emergency return strategies

The ARM is divided into three segments (Fig. 2). The first segment is the identification and characterization of potential target asteroids, utilizing NASA’s Near-Earth Object (NEO) observations program; the second segment embodies the Asteroid Redirect Robotic Mission (ARRM), which has the objective of deflecting an asteroid and returning a large boulder to cis-lunar space; the third segment is the Asteroid Redirect Crewed Mission (ARCM) in which astronauts explore the boulder and bring samples of it back to Earth.

The Asteroid Redirect Robotic Mission (ARRM) passed its Key Decision Point B review in July of 2016. The option to retrieve a 1 – 4 meter multi-ton boulder from the surface of a potentially hazardous sized near-Earth asteroid has been approved on August 15, 2016 to proceed to Phase B.

There is a strong desire to select an organically and volatile-rich asteroid target, which has benefits from both a science and in situ resource utilization perspective. The main objective for this portion of the ARM is to place the boulder in cis-lunar space where it will be available for the crewed mission in the 2026 timeframe. There is a secondary objective of collecting regolith samples from the vicinity of the boulder using the geologic context sample pads of the robotic vehicle, which will also be available for retrieval during the crew EVAs. The currently proposed launch date for the ARM is December 2021.

The ARM has four mission phases at the asteroid (Fig. 3). There is an approach phase for general characterization and identification of potential hazards (e.g., satellites, plumes, etc.). A detailed characterization phase for asteroid shape modeling, target identification, and sample site selection; a boulder collection phase for the actual retrieval of the boulder; and a planetary defense demonstration using the extra mass of the boulder with the robotic spacecraft to conduct an enhanced gravity tractor deflection of the near-Earth asteroid.

The ARM offers: 1) an opportunity to study a NEA in situ, 2) an opportunity to develop advanced robotic capabilities to support future human exploration in the Solar System, 3) an opportunity for astronauts to explore asteroids and bring samples back to Earth, 4) an opportunity to study the potential in situ resource utilization properties of the selected target asteroids, 5) an opportunity to study a NEA in situ and to perform a planetary defense demonstration on an asteroid of a hazardous size, 6) the ability to select a type of object to be brought back to Earth that is of interest for science and resource utilization, and 7) potential asteroid remediation to a similar mission for exploring and bringing back samples from the moons of Mars.

The Asteroid Redirect Crewed Mission (ARCM)

Two astronauts will launch aboard the Orion capsule via the Space Launch System to begin the Asteroid Redirect Crewed Mission (ARCM) once the retrieved boulder is located in cis-lunar space. The crew will utilize a lunar gravity assist trajectory during their outbound flight and rendezvous with the robotic vehicle and boulder. Once the Orion and robotic vehicle are securely docked, the crew will conduct 2 four-hour extra-vehicular activities (EVAs) to investigate the boulder, collect samples, and deploy instruments (Figs. 5 & 7). Current plans for the length of ARCM operations are to last approximately 5 days with one day for rendezvous, one day each for the 2 EVAs, one day between EVAs, and one day for contingency operations. After the samples are securely stowed the crew will return to Earth using another lunar gravity assist and splash down off the coast of San Diego, CA (Figs. 8 & 10).

Note: Asteroid operations timeline varies depending on target asteroid. Times shown are for 2008 EV$_5$.

The Ten Second Review

- The Asteroid Redirect Mission (ARM) is a major NASA initiative that will develop, test, and demonstrate several key capabilities needed for future human exploration of the Solar System.
- The ARM is comprised of the Asteroid Redirect Robotic Mission (ARRM) scheduled for launch late 2021 and the Asteroid Redirect Crewed Mission (ARCM) scheduled for launch late 2026.
- The ARRM will use a multi-purpose high-power Solar Electric Propulsion (SEP) vehicle and demonstrate in-space transportation and landing capabilities using a high-thrust (160 kN) Electric Thruster (EAT), landing on its surface, capturing a multi-ton boulder, and bringing it back into a stable lunar orbit.
- The crew of the ARCM will rendezvous with the robotic vehicle in lunar orbit via Orion, conduct extra-vehicular activities (EVAs), investigate and collect samples from the boulder and regolith context pads, and then return to Earth.
- ARM offers: 1) an opportunity to study a NEA in situ and to perform a planetary defense demonstration on an asteroid of a hazardous size, 2) the ability to select a type of object to be brought back to Earth that is of interest for science and resource utilization, and 3) potential asteroid remediation to a similar mission for exploring and bringing back samples from the moons of Mars.

http://www.nasa.gov/asteroidinitiative