Finding and characterizing candidate targets for the Asteroid Redirect Mission (ARM)

P. Chodas[1]

[1]Jet Propulsion Laboratory, California Institute of Technology

NASA's proposed Asteroid Redirect Mission (ARM) leverages key on-going activities in Human Exploration and Space Technology to advance NASA's goals in these areas. One primary objective of ARM would be to develop and demonstrate a high-power Solar Electric Propulsion (SEP) vehicle which would have the capability of moving significant amounts of mass around the solar system. SEP would be a key technology for robust future missions to deep space destinations, possibly including human missions to asteroids or to Mars. ARM would use the SEP vehicle to redirect up to hundreds of tons of material from a near-Earth asteroid into a stable lunar orbit, where a crew flying in an Orion vehicle would rendezvous and dock with it. The crew would perform an extra-vehicular activity (EVA), sample the material, and bring it back to the Earth; follow-on visits would also be possible. Two ARM mission concepts are being studied: one is to go to a small 4–10-meter-diameter asteroid, capture the entire asteroid and guide it into lunar orbit; the other is to go to a large 100–500 meter asteroid, remove a 1–10 meter boulder, and bring the boulder back into lunar orbit. A planetary defense demonstration could be included under either concept. Although some candidate targets are already known for both mission concepts, an observation campaign has been organized to identify more mission candidates. This campaign naturally leverages off of NASA's NEO Observations Program. Enhancements to asteroid search capabilities which will come online soon should increase the discovery rates for ARM candidates and hazardous asteroids alike.

For the small-asteroid ARM concept, candidate targets must be smaller than about 12 meters, must follow Earth-like orbits and must naturally approach the Earth closely in the early 2020s, providing the opportunity for a low-velocity capture into the Earth/Moon system. About a dozen candidates are known with absolute magnitudes in the right range and with orbits suitable for missions launching no earlier than June 2019; the maximum asteroid return masses for these range from 45 to 800 tons according to the orbit. Unfortunately, many of the currently known candidates have not had their sizes, masses and spin rates adequately constrained in order to provide confidence that they are within the capability of the ARM vehicle to return. Still, three candidates have been characterized well enough, two by the Spitzer Space Telescope, 2009 BD and 2011 MD, and one by radar, 2013 EC_{20}. 2009 BD was not actually detected by Spitzer, indicating it was smaller than expected, about 4 meters; similarly, 2013 EC_{20} turned out to be smaller than desired, less than 3 meters. A fourth candidate, 2008 HU_4, should be characterized with radar in 2016 when it passes near the Earth. In general, physical characterization of these very small asteroids is best performed immediately after discovery, while they are still very near the Earth. Radar is important for characterizing size and rotation state, while long-arc high-precision astrometry can help characterize mass through estimation of the area-to-mass ratio. Rapid-response characterization for an ARM candidate was successfully demonstrated last year for 2013 EC_{20}, mentioned earlier. More candidates for the small-asteroid concept are expected: new potential candidates should be detected at the rate of 3 to 5 per year, based on extrapolations from past discovery rates.

For the large-asteroid ARM concept, there is an additional characterization challenge: the surface of the asteroid must be observed with enough resolution that the presence of ∼3-meter boulders can be either directly seen or inferred from high-SNR radar. The maximum size and mass of the returnable boulders depends on the asteroid orbit in much the same way as for the other concept. Asteroid Itokawa is a strong candidate because it has already been well characterized by the Japanese Hayabusa spacecraft. The future targets of the OSIRIS-REx and Hayabusa 2 missions, Bennu and 1999 JU_3, should also become strong candidates in 2018. Also considered a valid candidate is 2008 EV_5: radar detected decameter-scale boulders on its surface, from which the presence of returnable ∼3-meter boulders can be inferred. The characterization rate for large-asteroid concept candidates using high-SNR radar is about 1 per year. NASA plans to choose between the two ARM concepts, capture an entire small asteroid versus pick up a boulder from a large one, within about a year.