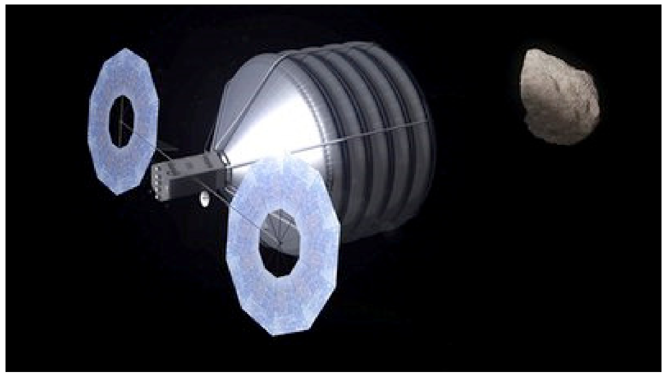

While a proposal under study by NASA to redirect a near Earth object into cislunar space would seem to offer a scientific bounty for researchers, some wonder just how high a priority science would be on such a mission. (credit: NASA)

Science and the ARM

by Jeff Foust
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At first glance, it would seem that planetary scientists, particularly those who study asteroids, would welcome NASA's plans to redirect a small near Earth object (NEO) into lunar orbit for study by astronauts. While scientists have access to tons of meteorites, it's long been a problem to link them to specific asteroids, or even classes of asteroids, leading to calls for asteroid sample return missions. However, Japan's Hayabusa spacecraft, the first asteroid sample return mission, brought back only dust grains, while NASA's upcoming OSIRIS-REx mission is designed to return a minimum of 60 grams of samples of the asteroid Bennu. Astronauts going to a captured NEO, by contrast, could bring back dozens to perhaps 100 kilograms of samples.

"Finding ARM targets from the ground is a challenge, but with a modest investment can be cost-effective," said Larson.

Yet, many scientists and other experts attending the Target NEO 2 workshop in Washington on July 9 expressed less than unconditional support for NASA's Asteroid Redirect Mission (ARM). While agreeing that the ARM concept had considerable benefits for science, exploration, and public interest, many worried about the challenges such a mission faced, concerns that fell into three broad categories. One is simply finding a suitable target for the ARM given the current limited population of known objects. Another is the suite of challenges, technical and programmatic, that such a mission would have to overcome. Finally, some scientists worry about how high a priority science will have on a mission conceived and primarily funded by NASA's exploration program.

Finding a NEO to target

One critical challenge for ARM is to find a suitable asteroid to redirect using a robotic spacecraft. Models of the NEO population suggest that there are millions of objects of the right size, and likely thousands to tens of thousands with both the right size and in suitable orbits for redirection to Earth. However, identifying an object of the right size and in an orbit that can be redirected in the right timeframe is enough of a problem that, today, there are only a handful of known candidate objects for the ARM.

Paul Chodas of JPL's Near Earth Object Program Office noted at the workshop that the total number of known NEOs of any kind just passed 10,000. Of those, about 300 have the right size (approximately four to ten meters in diameter), based on their absolute magnitude. When orbital constraints are factored in, including close approaches to the Earth that would allow for a robotic spacecraft to redirect them into cislunar space some time in the early 2020s, the population shrinks further: only 14 known NEOs meet those size and orbital criteria.

Moreover, that small population is growing slowly. Chodas estimates that current surveys are discovering only about 2.5 candidate NEOs per year, with new systems and enhancements to current ones potentially doubling that rate. "We would expect, roughly, on the order of 15 more ARM candidates to be discovered with the future surveys" over the next three to four years, he said.

A few ground-based telescopes, including the Catalina Sky Survey in Arizona and the Panoramic Survey Telescope & Rapid Response System (Pan-STARRS) in Hawaii, are currently responsible for the bulk of those discoveries. Upgrades to those systems, as well as new surveys like the Asteroid Terrestrialâ€impact Last Alert System (ATLAS), should lead to that expected increase in the discovery rate. "Finding ARM targets from the ground is a challenge, but with a modest investment can be cost-effective," said Steve Larson, principal investigator for the Catalina Sky Survey.

Space-based searches, while promising in theory, appear unlikely to play a major role in identifying ARM candidates. "We need meter-class instruments in space right now if we want to contribute to finding something that we're going to fly people to soon," said Tim Spahr, director of the IAU Minor Planet Center. However, building such a spacecraft would likely take four to five years, said JPL's Amy Mainzer, and thus would not contribute to finding ARM candidates even if work started on it now.

Several spacecraft in orbit now or scheduled for launch in the next few years could offer some help in identifying or characterizing suitable NEOs, she said, ranging from NASA's Spitzer infrared space telescope to the NEO Surveillance Satellite, or NEOSSat, a small Canadian spacecraft launched earlier this year designed to look for NEOs inside the Earth's orbit. NASA is also considering reactivating NEOWISE, a repurposing of the Wide-field Infrared Survey Explorer (WISE) space telescope to look for NEOs. (At a meeting of NASA's Small Bodies Assessment Group (SBAG) the next day in Washington, Lindley Johnson of NASA said the agency was "weeks, if not days" from making the decision to restart NEOWISE.)

These current or near-future missions, though, are unlikely to do much to help find ARM candidates given their limitations. "None of these missions are going to discover lots and lots of five- to ten-meter NEOs, and none of them can really reliably predict the presence of five- to ten-meter boulders on the surface of larger objects," she said.

Those spacecraft, as well as ground-based telescopes, can help with follow-up observations to better understand NEOs, including determining their size, orbit. spin rate, and composition. Chodas discussed how those efforts were used to look at one ARM candidate object, 2013 EC20. That asteroid was discovered on March 7 of this year and quickly followed up by other telescopes, including the Infrared Telescope Facility (IRTF) and Arecibo. The IRTF infrared observations narrowed the size of 2013 EC20 to 2.6–8.4 meters, while the Arecibo radar observations came up with a size of 1.5–3 meters: too small, Chodas said, to be a likely object for the ARM. "It shows, though, that the characterization process works," he said.

"It's very possible that some near Earth objects are literally just sand castles," said Bottke. "When an astronaut goes and touches a five- to ten-meter asteroid, no one knows what's going to happen."

Characterization is also important to make sure that the candidate object is, in fact, an asteroid. Planetary scientist Alan Harris said that some objects could be spent rocket stages or other space debris, while many could be pieces of the Moon ejected by impacts. "We need to evaluate those sources and be sure we collect something that isn't a piece of lunar debris or has Russian writing on its surface," he said.

Scratching the surface of ARM's challenges

Characterizing NEOs is also important to ensure that it's technically feasible to capture and redirect an object. One challenge that any such mission will face is that most small NEOs spin rapidly. Of those small NEOs whose rotation rate is known, the median rate is 3.6 minutes, said Andy Rivkin of APL. Uncertainties in the albedo of asteroids and thus their size can led to uncertainties of a factor of 25–30 in their mass. "Observations will be able to beat that down," he said, "but you need to make those observations, or you need to be able to accommodate that uncertainty with your spacecraft."

It's also uncertain whether the object will be a monolithic object or a "rubble pile" of smaller bodies held together by something like van der Waals forces. "It's very possible that some near Earth objects are literally just sand castles," said Bill Bottke of the Southwest Research Institute. "No one knows how these forces behave in microgravity, so that means when an astronaut goes and touches a five-to ten-meter asteroid, no one knows what's going to happen."

Those uncertainties, and other concerns, are on the minds of engineers working on the design of the spacecraft that would move the NEO into cislunar space (sometimes called the Asteroid Redirect Robotic Mission, or ARRM.) Some elements are better understood than others, such as the maneuvers required by an ARRM spacecraft, powered by a solar electric propulsion system, to rendezvous with a NEO and move it into a "distant retrograde" orbit around the Moon. "The more we look at this, the more reasonable it seems," said Damon Landau of JPL.

Other elements of the mission, including proximity operations by the ARRM spacecraft in the vicinity of the asteroid and the grappling and despinning of the asteroid, offer more challenges, which NASA officials acknowledge. "The technical requirements for this mission are still undefined, and some of them are changing," said John Dankanich of NASA's Marshall Space Flight Center. "This is not the typical science mission. We are certainly intentionally violating the rule of one 'miracle' per mission."

Some experts not directly involved with ARM think that the challenges may be even greater than what NASA acknowledges. "I think there are a lot of benefits that can come from this mission, but I believe that we are, collectively, ostriches at this point, and have not begun to scratch the surface of what this mission would entail," said Gentry Lee, chief engineer of JPL's Solar System Exploration Directorate.

Lee in particular is skeptical of NASA's plans to carry out the ARM to allow astronauts on the first crewed Space Launch System (SLS)/Orion mission, already planned for 2021, to visit that captured asteroid, and to do so for an overall mission cost of as low as $1 billion. "There is no way that this project can be done on this schedule and this cost by any group of people in the world," he said. "The schedule is not attainable unless the mission goals are so flexible as to be laughable."

Asked what he felt a more reasonable schedule would be, Lee said it would be tied to the available funding. "Right now, I would say the earliest reasonable launch date is some time in 2019, and that would be a big push," he said. "2019, for this mission, is bold." Since it would take several years for the ARRM spacecraft to arrive at a NEO and redirect it into a distant retrograde lunar orbit, that would appear to rule out an asteroid visit for the 2021 SLS/Orion mission—unless, of course, that mission slips as well.

"There is no way that this project can be done on this schedule and this cost by any group of people in the world," Lee said.

The challenges of ARM have led to some creative thinking about alternatives. Bottke suggested that, instead of redirecting a NEO to lunar orbit, NASA instead mount a mission to what he called a "minimoon": a NEO temporarily captured in the Earth-Moon system, such as in the vicinity of a Lagrange point. "They're objects where nature has done most of the work for us to bring them back to the kinds of orbits that we're getting from the ARM mission," he said. At any given time, he said there are on average two one-meter-class minimoons, some in orbits that can be stable for years or decades. "This really gives us a chance to do a human mission to these objects."

Science versus exploration and technology development

There is also the question about the priority science would have in the ARM. Some people at the meeting were alarmed by the potential that actually returning an asteroid might not be considered part of the "mission success" criteria for ARM; that is, demonstrating technologies and operations by flying a robotic spacecraft into deep space and back into lunar orbit, which is then visited by astronauts, might be sufficient to meet the goals to support NASA's broader exploration efforts.

"The Asteroid Redirect Mission is aligning some key activities we already had going on within the agency, both in the science, space technology, and human exploration and operations mission directorates," said Bill Gerstenmaier, NASA associate administrator in charge of the Human Exploration and Operations Mission Directorate (HEOMD) mission directorate. "It's an effective way to utilize activities that were already moving forward."

Asked about the scientific justification for the ARM, Gerstenmaier focused instead on its benefits for human exploration. “This is a way for us to advance significantly capabilities we’re going to need in human exploration and operations, build skills and build hardware to allow us to go further into the solar system,” he said. “That’s the justification I see for this activity, but you need to help us with what the right scientific pieces are.”

Greg Williams, Gerstenmaier’s deputy at HEOMD, explained in a panel session at the end of the workshop that the ARM concept was driven by technical and financial challenges NASA encountered with original plans to send a crewed Orion spacecraft to a NEO in deep space by 2025. “We looked at that and said that it might be a bigger bite than we can pull off right now,” he said. The ARM concept “we can do in the near term, and do it more cheaply, recognizing that, some day, we do indeed need to go to those deeper space objects with astronauts.”

This left some scientists in a conundrum: frustrated to some degree that the ARM concept emerged without the usual peer review and selection process used for other science missions at the agency, but also concerned that ARM could take funding from an already constrained planetary science budget at NASA, especially if they lobby for greater scientific content for the mission.

“We’re faced, I think, with the situation where this asteroid redirection mission is perhaps the only candidate that NASA can offer in the next 10 to 15 years that can achieve humans in deep space in contact with a planetary surface,” said Jones.

“I would not carve up any other NASA accounts to pay for this endeavor. It should come out of the human spaceflight budget and if the resources cannot be found within it, I think we should go back to the drawing table,” said Tom Jones, a former astronaut and long-time advocate of human asteroid missions.

“It’s coming out of something,” Doug Cooke, former NASA associate administrator for exploration, said of the cost of ARM. “I don’t know if we’re going to get new money to do this unless Congress gets excited about it.”

Right now, the prospect of “new money”—additional funding devoted to the mission—seems unlikely as Congress is not particularly excited about ARM so far. Last week, the space subcommittee of the House Science Committee approved a NASA authorization bill that includes language strictly forbidding NASA from spending any money on the mission.

“This asteroid retrieval mission has not been through any kind of mission formulation review, and as recently as two weeks ago, NASA was still soliciting ideas on how to do the mission without any clear direction on its purpose, budget, or technical requirements,” said Rep. Steven Palazzo (R-MS), chairman of the space subcommittee, in his opening statement at the July 10 markup of the bill. “Further, the hesitation from the scientific community to embrace such a concept should give us reason to pause in these tight budget times.”

Despite these concerns, there was still interest at the Target NEO workshop on pursuing ARM, with the understanding that science was just one component of several to justify the mission, including public outreach. “We recognize that it has the potential to re-energize public support for human exploration,” said Jim Bell, president of The Planetary Society.

Jones said ARM could have benefits for space resource utilization and commercialization, by giving companies an easily accessible target to extract resources from. “This is both a practical and affordable option for NASA to consider at this point,” Jones said of the mission.

It might also be, he added, perhaps the only option for NASA’s human space exploration program given current severe budget constraints. “We’re faced, I think, with the situation where this asteroid redirection mission is perhaps the only candidate that NASA can offer in the next 10 to 15 years that can achieve humans in deep space in contact with a planetary surface.”

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