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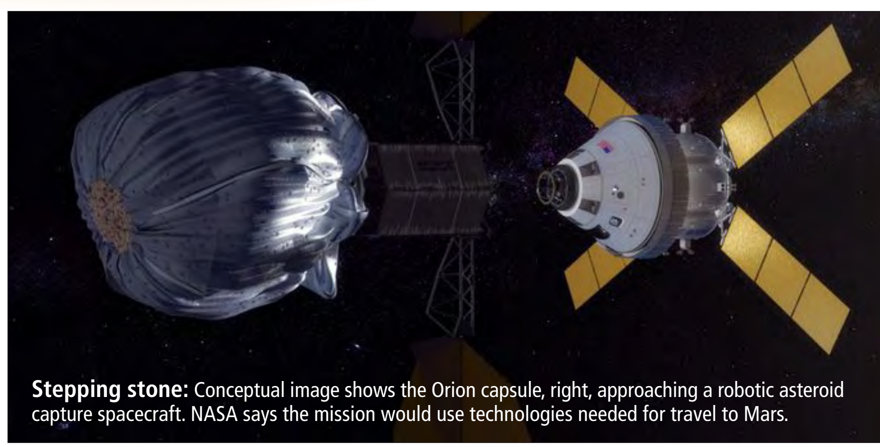
Explaining the asteroid mission

NASA's proposal to grab an asteroid and move it closer to Earth is far from a done deal. Proponents of the Asteroid Redirect Mission want to be sure public perceptions and policy decisions about the mission's future are made based on the facts. Veteran astronaut Tom Jones, who worked on the study that proposed ARM, looks at some of the questions the mission has sparked.



NASA

Stepping stone: Conceptual image shows the Orion capsule, right, approaching a robotic asteroid capture spacecraft. NASA says the mission would use technologies needed for travel to Mars.

Two years ago the concept seemed like science fiction: A solar-powered robot half the length of a football field would approach and snare a 500-ton asteroid, tucking it into a 10-meter fabric duffle bag. The robot craft would tug its catch into a stable, high lunar orbit, waiting for an Orion spaceship and crew. Orion would dock with the robotic asteroid retrieval vehicle, still nestling the captured asteroid in its grip. A pair of spacewalkers would then unwrap their shiny present and reveal the asteroid's secrets.

In brilliant sunshine, they would tap and probe the rock's 4.6-billion-year-old surface, marveling at a crescent Earth and moon hovering silently in the endless void. Where else might this road to an asteroid lead?

The controversial Asteroid Redirect Mission, ARM, got its launch in 2012 with a report from the Keck Institute for Space Studies. I was a member of that study team. In spring 2013 NASA adopted the concept, but it has faced strong headwinds in Congress. The agency held a public forum on ARM in March, and I've joined another Keck Institute study on applying ARM technology to deep space exploration. ARM has generated lots of questions; here are a few answers:

■ Is the Asteroid Redirect Mission real?

The president requests $133 million in NASA's 2015 budget to advance solar-electric propulsion, examine asteroid capture technologies and develop ARM mission design and operations. In early April, the House Science Committee's space subcommittee quickly passed a NASA authorization bill that notably does not bar spending on the asteroid mission. However, the bill does require that NASA report to Congress on the mission's proposed cost and schedule. It also directs the agency to identify advances in technologies that move us closer to human expeditions to Mars, as well as technologies and experience that could not be gained from lunar exploration.

> **The story behind the name**
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> The R in ARM stood for retrieval when the concept was announced in 2013, but NASA quickly swapped retrieval for redirect. The agency believes this term more accurately reflects how the robotic spacecraft will gently shift an asteroid's natural orbit toward capture by lunar gravity, rather than suggesting it would physically tug a 500-ton rock back using brute force. —**Tom Jones**

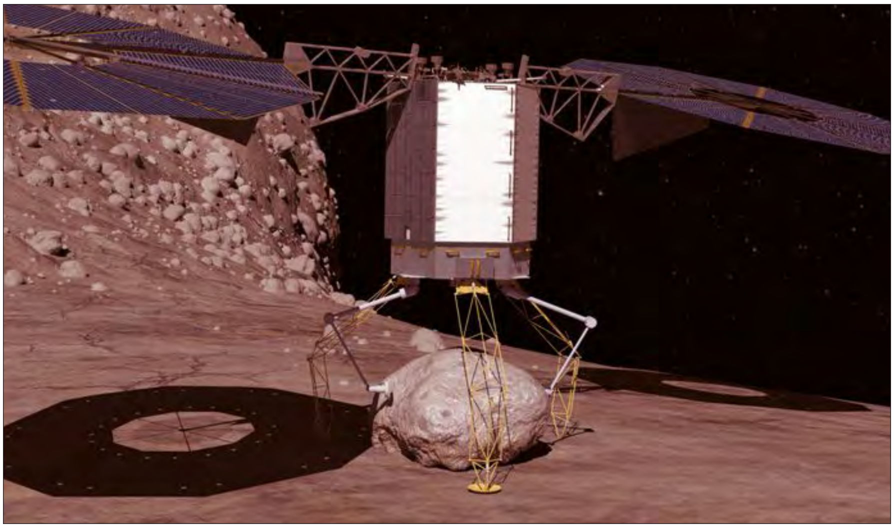
The agency views ARM as its best bet for returning astronauts to another celestial body for the first time since Apollo; NASA also says ARM technology would play a key role in getting to the Mars system in the mid-2030s. NASA's March 26 Asteroid Initiative Opportunities Forum laid out the current mission status and the progress expected before the Robotic Mission Concept Review, scheduled for early 2015.

■ What is the current mission concept?

The ARM robotic craft would launch in 2019, rendezvous with a roughly 7-meter near-Earth asteroid, or NEA, demonstrate one or more planetary defense deflection techniques, then capture and redirect the asteroid into lunar orbit. An alternate approach NASA planners are evaluating would be to visit a larger NEA (easier to spot and characterize) and retrieve a large boulder from its surface. Astronauts would rendezvous with the robotic craft around 2023 and begin scientific sampling, instrument emplacement and resource activities, work that future crews would continue for a decade on the ancient, water-rich object.

NASA says the mission would provide systems and operations experience required for Mars exploration. ARM would demonstrate advanced solar-electric propulsion, improve the detection, tracking and characterization of NEAs and demonstrate some basic planetary defense techniques. It would also enable close scientific examination and prospecting of a small celestial body, opening the door for in-situ resource production, says NASA.

NASA/AMA



Boulder plan: In this concept drawing, the spaceframe legs capture a piece of a large asteroid. The craft would then carry the boulder back to lunar orbit.

■ Has NASA chosen an asteroid target?

NASA's NEA search program, now funded at $40 million annually, is aimed at finding not just hazardous asteroids but also potential ARM candidates. The ideal target would have an Earth-like orbit, be on a course to visit Earth's neighborhood in the 2020s, have a mass between 500 and 1,000 tons, spin more slowly than 2 rpm, and have a composition like that of water- and organic-rich carbonaceous chondrite meteorites. These small, dark asteroids are tough to see, but a handful have surfaced as suitable candidates.

One such NEA is 2009 BD, which rotates slowly and will approach Earth in the 2020s at relatively low velocity.

JAXA

Plan B: Boulders strewn across Itokawa. Asteroids this size are too large to bag, but a rock from one of their "rubble pile" surfaces could be plucked up robotically and carried away for analysis.

But infrared measurements from NASA's Spitzer Space Telescope indicate the asteroid is smaller than 5 meters in diameter, with a mass of just 30-145 tons. Its high albedo — the amount of light it reflects — also suggests its silicate minerals harbor little or no water.

Getting infrared spectra to identify small, water-rich asteroids is even harder than finding them in the first place. There are currently about seven potential ARM capture targets; the upgraded search program should add one or two every year between now and the 2019 launch.

■ Is more than one approach being considered?

Because these small target asteroids are so elusive, NASA is also weighing the tactic of going to a larger NEA and returning a multi-ton boulder from its surface. Japan's Hayabusa probe visited asteroid 25143 Itokawa in 2005 and found the surface studded with hundreds of boulders. ARM could return a block of up to 50 tons from Itokawa's orbit. Radar observations suggest boulders are present on 101955 Bennu, a dark, possibly water-rich carbonaceous asteroid about half a kilometer across. NASA's OSIRIS-REx sample return mission, launching to asteroid Bennu in 2016, should confirm this. ARM could return up to about 20 tons from Bennu's orbit in the mid-2020s.

Six boulder-retrieval candidates are currently known, and the number is expected to double by 2019.

■ How will ARM capture an NEA?

ARM's targets are fragments of larger, rubble-pile asteroids and so are likely to be highly fractured blocks of material harboring some surface dust and gravel. To snare and retain an asteroid and associated debris, the capture craft would use a flexible, tough fabric bag. The ARM craft would fly the bag, held open by inflatable struts, over the asteroid and then close the bag's mouth around it, trapping it inside. With any debris hazard contained, the retrieval craft would despin the NEA using thrusters, then begin thrusting toward its lunar and astronaut encounter.

In the boulder-grab alternative, the ARM spacecraft would hover some 20 meters over a suitable block resting on a large asteroid's surface. Thrusters off, the ship would slowly free-fall to the surface, absorbing the very light contact forces with a set of articulating landing/capture legs. Once down, the spacecraft would retract several legs to enfold the boulder, or grapple it with a pair of capture arms. Springs or thrusters would pop the craft and its prize off the surface.

NASA is studying which approach — bag or boulder-grab — offers the best chance for success. The agency's Robotic Mission Concept Review in early 2015 will decide which system moves into development.

■ Why place the asteroid in a distant lunar orbit?

ARM's 50-kilowatt solar-electric propulsion system must tweak the captured NEA's natural solar orbit just enough to arrange an encounter with Earth's moon. A pair of lunar gravity swing-bys would loop the stack into a distant retrograde orbit. At an orbital radius of 71,433 kilometers and a period around the moon of 14 days, even an uncontrolled asteroid would be stable for at least a century.

■ What would astronauts do there?

Performing their own lunar swing-by, the Orion astronauts would arrive nine days after launch and spend five days docked to the ARM craft. During two extravehicular activities, the crew would sample the asteroid, place instruments on it, outfit it for future crew and robotic visits. Then the astronauts, having ventured farther from Earth than any other humans, would use another lunar gravity assist to return home. Mission duration would be just under four weeks.

■ What comes after ARM?

The crew's return with several tens of kilograms of asteroid samples would be only the beginning of a long investigation and exploitation campaign. The instruments placed on the asteroid might examine its interior structure and physical properties, or demonstrate water and volatile extraction. International and commercial probes might arrive, along with follow-on astronaut crews, to further dissect the object and test resource processors. In parallel, NASA would be aiming at more distant NEAs and the Mars system.

■ Will ARM advance human exploration of Mars?

Asteroid capture and exploitation would use many of the techniques and technologies needed to reach Mars. Solar-electric-powered tugs could haul multi-ton cargoes — habitats, landers or propellant — to the Mars system. Proximity operations and extravehicular activities would pave the way for expeditions to more distant NEAs. Those journeys would last a year or more and take crews several million miles from Earth. Finally, low-gravity asteroid experience from ARM would prepare astronauts for work on the Martian moons Phobos and Deimos. With possible water resources and an advantageous location for Mars surface expeditions, these asteroid-like moons could host human explorers by the 2030s.

Most important is that asteroids and the Martian moons may offer us propellant and water sources where we need them, in cislunar space and in the Mars system. Tapping those resources would be a breakout move for NASA, human exploration and commerce. We could break our dependence on Earth for the hundreds of tons of propellant that each human venture to Mars would require.

■ Is nabbing a small asteroid the best we can do?

Asteroids are the only deep-space destinations for NASA approved by the administration. The International Space Station faces decommissioning in 2024, and NASA has no plans for humans in low-Earth orbit after that. If Orion and the Space Launch System don't have a defined mission for the early 2020s, they will likely be canceled. Waiting for a better offer than ARM would guarantee that U.S. astronauts won't return to deep space until the late 2020s at best. At worst, we'll wait and watch as the nation abandons human spaceflight.

Meeting the ARM's propulsion, operations and extravehicular goals would take us to another celestial body and position us for interplanetary voyages. Keeping our sights on Mars, we could use ARM to unlock the native resources that would take us not only there, but anywhere we choose to go.

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