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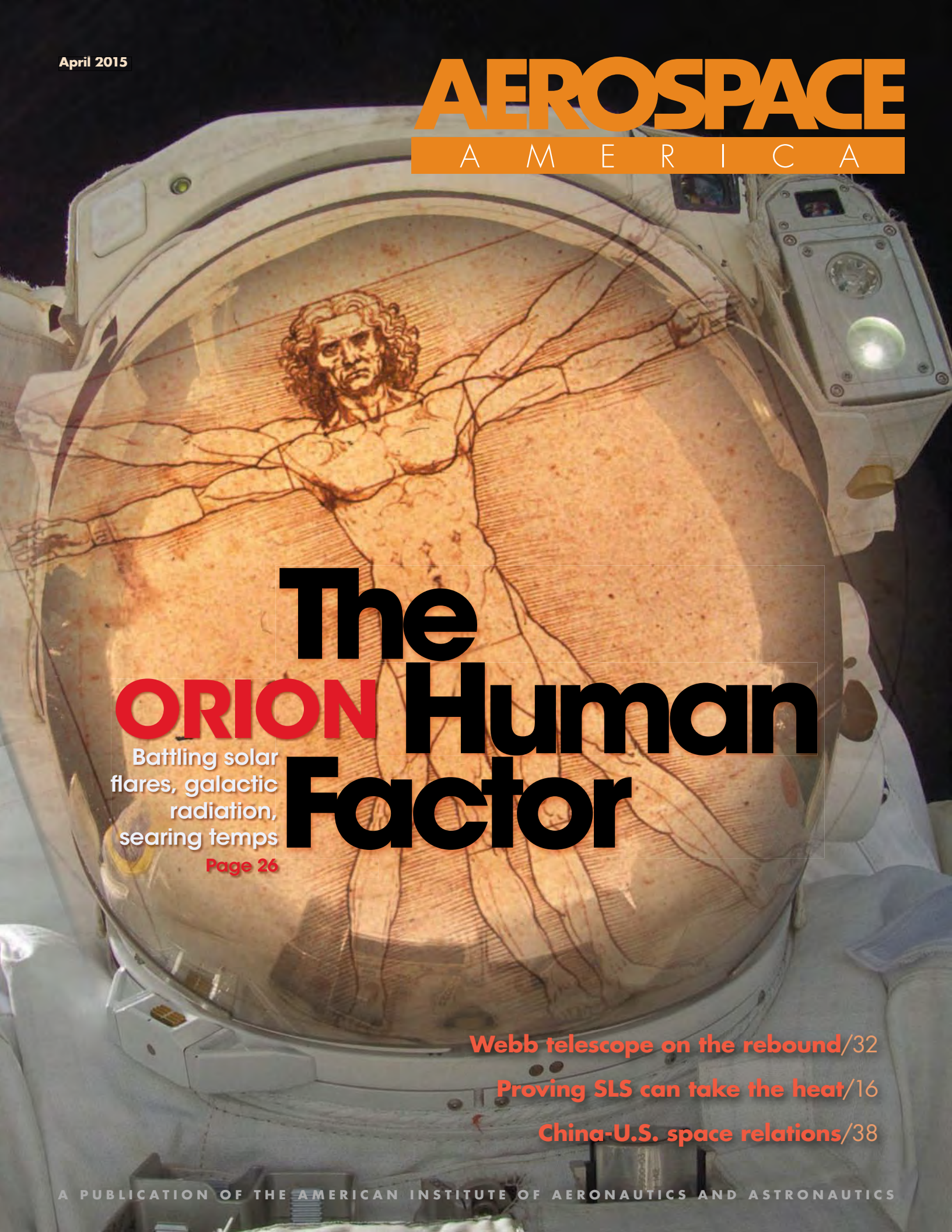

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NASA's bid to grab an asteroid – 9 things to know

The Asteroid Redirect Mission, or ARM, is the only human deep space mission on NASA's planning horizon, but the proposal faces deep skepticism among some in Congress. With the budget season in full swing, planetary scientist and former astronaut Tom Jones examines the ARM proposal, its political prospects and the stakes of cancellation.

ARM is two missions in one >>

ARM consists of two components: a robotic asteroid capture mission to nudge the object into lunar orbit, and a later astronaut sortie to visit and sample the asteroid. The Asteroid Redirect Vehicle is the robotic craft planned for launch between 2019 and 2021. It will nab a small asteroid or, alternatively, pluck a boulder off a larger one and deliver the object to lunar orbit. ARM would open the way to dissecting and exploiting hundreds of tons of ancient rock, potentially rich in water, organic compounds and metals — feedstock that could jump-start in-space propellant production and asteroid mining.

As of mid-March, NASA was closing in on a decision about a preferred asteroid retrieval technique for ARM. Option A proposes to snare a freely orbiting, 7-meter near-Earth asteroid by enclosing it in an inflatable, fabric capture bag. Option B would send the redirect vehicle to the surface of a larger, well-characterized near-Earth asteroid (easier to detect and determine the object's composition) and retrieve a multi-ton boulder for return to the Earth-moon system.

An interim step to "deeper space" missions >>

With the NASA budget driving the first piloted mission of the Orion/Space Launch System combination out to 2021, the White House realized in 2012 that NASA wouldn't be able to send astronauts to a near-Earth asteroid in its native orbit by 2025, a goal set by President Barack Obama two years earlier. So the White House and NASA shifted course and acted on a study showing that within a decade astronauts could visit a small asteroid nudged into lunar orbit. Sending astronauts to the captured asteroid would be an interim step toward future deep-space operations at the moon, more distant asteroids and Mars. ARM would follow the 2021 Space Launch System/Orion flight test as NASA's next (and currently only) piloted deep-space mission. The mission would technically meet the Obama administration's goal of getting humans to an asteroid by 2025.

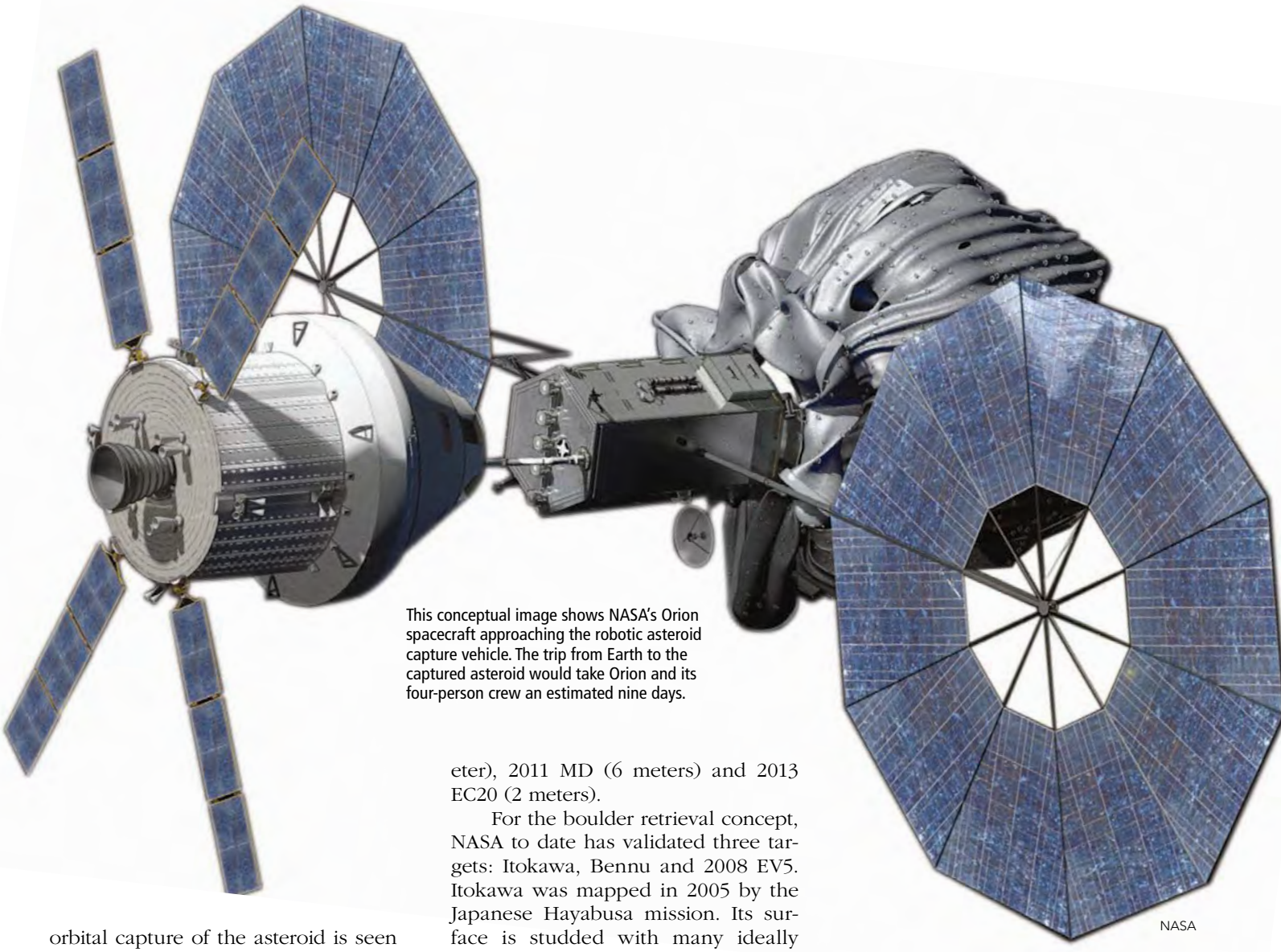
Ground testing the retrieval options >>

Last year, NASA built a 1/5-scale Asteroid Capture Testbed at Jet Propulsion Lab for Option A, the proposal to engulf and move an entire asteroid to lunar orbit. NASA engineers tested the capture bag's deployment sequence, moved it over a mocked-up asteroid, and measured the forces on the bag's fabric as it retracted around the rotating asteroid.

For Option B — plucking a boulder from a larger near-Earth asteroid — Langley Research Center in Virginia last year employed a full-scale robot arm testbed to simulate gripping a boulder, subjected the arms and landing legs to the forces required to "lift" a surface boulder, and ran closed-loop simulations of descent, surface and ascent operations. These tests show that the redirect vehicle's sensors can meet landing accuracy requirements and that the retrieval spacecraft can sustain the loads predicted for a wide range of asteroid surfaces and boulder masses.

The agency would prefer to capture and redirect a small near-Earth asteroid with a mass up to 500 tons (Option A), but those asteroids are the toughest to detect and characterize (estimate its mineral composition, links to known meteorites, shape, spin rate, etc.). Ideally, NASA would like to redirect a water- and organic-rich object for its scientific and resource potential.

If an attractive, approximately 7-meter asteroid cannot be identified in time for a launch around 2019, or if



This conceptual image shows NASA's Orion spacecraft approaching the robotic asteroid capture vehicle. The trip from Earth to the captured asteroid would take Orion and its four-person crew an estimated nine days.

NASA

orbital capture of the asteroid is seen as too technically risky, NASA is protecting Option B: robotically landing on a larger (thus brighter and easier to characterize) asteroid, and returning a multi-ton boulder to the Earth-moon system. Landing, boulder retrieval and departure pose difficult engineering challenges, but Option B offers the return of tens of tons of the "right kind" of asteroid material. For example, NASA might return a boulder from the well-studied 550-meter diameter 25143 Itokawa asteroid. But Itokawa is known to lack the water and organic material preferred for ARM targets.

NASA has target candidates in mind >>

NASA's three valid candidates so far for Option A — capturing an entire asteroid — are 2009 BD (4-meter diameter), 2011 MD (6 meters) and 2013 EC20 (2 meters).

For the boulder retrieval concept, NASA to date has validated three targets: Itokawa, Bennu and 2008 EV5. Itokawa was mapped in 2005 by the Japanese Hayabusa mission. Its surface is studded with many ideally sized boulders roughly 3 meters across. Radar observations of both 2008 EV5 and Bennu suggest that both near-Earth asteroids possess appropriate-sized boulders. NASA will probably not choose its final asteroid target until a year before the Asteroid Redirect Vehicle launch, circa 2019. NASA would like to identify a slate of candidates, each approximately 7 meters in diameter with a mass of 500 tons. Spotting small objects like these is a difficult challenge for ground-based telescopes, but NASA estimates it will find three to five suitable candidates annually between now and 2019. No new candidates were found in the last half of 2014.

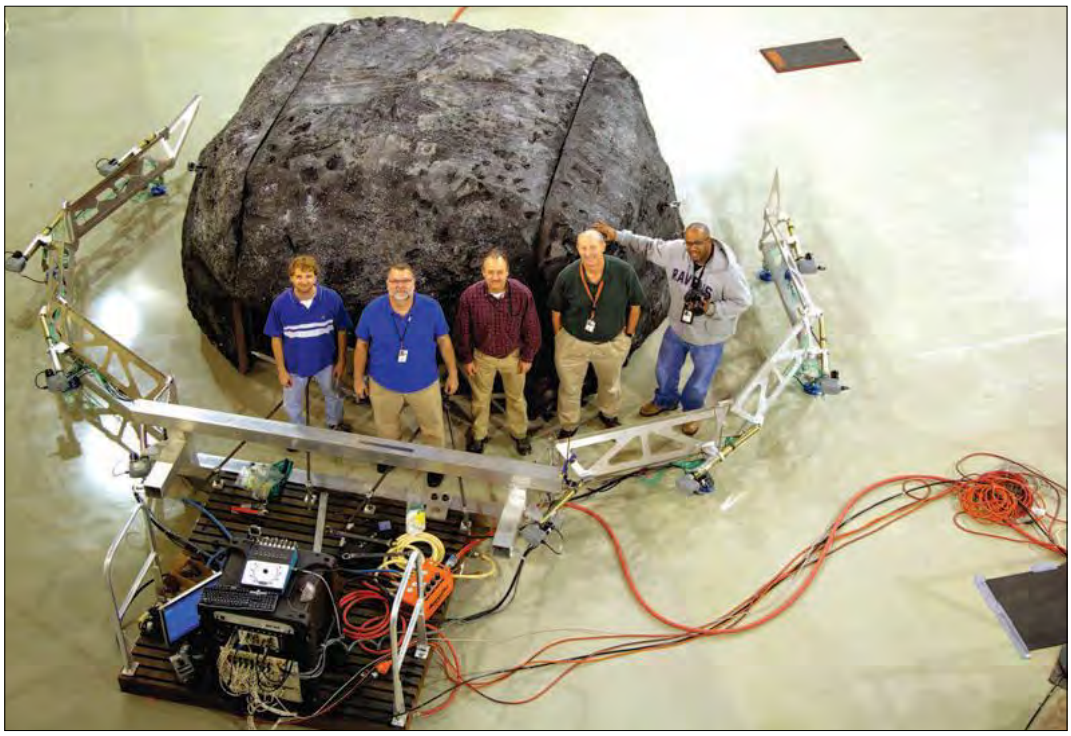
Scientists recommend that NASA choose a previously unexplored near-Earth asteroid with a composition rich in water and prebiotic organic materials, similar to carbonaceous chondrite meteorites. A carbonaceous asteroid also offers the highest commercial potential, particularly for water extraction demonstrations. Water can furnish oxygen and hydrogen for propellant, provide oxygen for life support and serve as efficient radiation shielding.

Growing cancellation risk >>

NASA requests $220 million for ARM in the fiscal 2016 budget. Funding for the redirect vehicle would need to ramp up sharply by 2017 to meet a 2019 launch date, an increase that depends on NASA convincing Congress that ARM is a wise choice. NASA wants to launch the retrieval

vehicle between 2019 and 2021, with the date depending on how long it takes to develop the vehicle and which target is selected. Orion astronaut sorties would be conducted between 2023 and 2027.

With members of Congress likely to question ARM funding, the robotic capture craft's 2019-2021 launch window is in serious jeopardy. Because the robotic mission can take up to four years to rendezvous with, capture, and redirect an asteroid into lunar orbit, the follow-on astronaut visit would also be delayed. NASA is concerned that prolonged ARM delays risk outright cancellation by Congress or the next administration.



NASA

Option B test: NASA engineers at Langley Research Center used an air-bearing floor to gauge how well a pair of full-scale robot arms can grasp and extract a simulated asteroid boulder; plucking a boulder is one capture option.

Congressional skepticism runs deep >>

The Obama administration's decision to rule out the Bush return to the moon and revamp human spaceflight policy continues to stir opposition in Congress. Cancellation of the Constellation rocket and crew vehicle program in February 2010 earned the ire of Sen. Richard Shelby, R-Alabama, and Rep. Lamar Smith, R-Texas, whose states are home to NASA's Marshall Space Flight Center and Johnson Space Center, respectively. Smith criticized ARM in an op-ed soon after it was announced, writing that the country needs a goal "worthy of a great space-faring nation," and ARM "is not it."

Some in Congress oppose ARM simply because its asteroid focus ignores the nearby, accessible moon. The Obama administration has directed NASA managers to not pursue lunar exploration as a human spaceflight option. Others reject NASA's contention that ARM will help advance Mars exploration.

The link between ARM tech and a human Mars mission >>

In response, NASA is trying to rally congressional support by reporting progress in its ARM technology testing and by detailing how ARM feeds into Mars exploration plans. NASA argues that ARM will deliver tested hardware and invaluable experience that will smooth the path toward Mars. Solar electric propulsion, capable of redirecting hundreds of tons of near-Earth asteroid mass during ARM, can deliver large cargoes, such as surface elements, propellant and astronaut habitats, to Mars or its moons, Phobos and Deimos.

Deep space rendezvous, complex orbital maneuvers into and out of planetary gravity wells, and extended deep-space extravehicular activities are part of the complex robotic and human deep-space operations necessary for projected Mars expeditions.

For example, ARM experience in proximity and surface operations in low gravity fields, anchoring and surface sampling in near freefall, and emplacement of surface equipment can all be applied to the exploration of Phobos or Deimos.

At NASA's fiscal 2016 budget briefing in early February, NASA Administrator Charles Bolden said technologies developed for ARM "will be applicable to commercial satellite servicing, future exploration, resource extraction, mining, in situ resource utilization and planetary sample return…and will demonstrate advanced high-power Solar Electric Propulsion, critical for future NASA and commercial uses."

NASA still has some convincing to do. Bolden discussed ARM with NASA's Advisory Council on January 14; Council member and retired aerospace executive Thomas Young flatly responded: "Proving that we can redirect an asteroid has nothing to do with going to Mars."

Critics have few good alternatives >>

President Obama said in a 2010 speech at Kennedy Space Center that "by 2025, we expect new spacecraft designed for long journeys to allow us to begin the first-ever crewed missions beyond the Moon into deep space."

A big lift: A half-buried "boulder" is extracted from a simulated near-Earth asteroid in a test at Kennedy Space Center. The test rig allows designers to estimate the force required to retrieve a boulder from a larger asteroid in Option B of the Asteroid Redirect Mission.

NASA Kennedy Space Center Swampworks

Yet the White House's outyear budgets do not include funds for a spacecraft capable of multimonth journeys into deep space (Orion is limited to one-month missions). With no projected capability to reach a near-Earth asteroid in solar orbit, NASA adopted ARM, putting a small asteroid within reach of Orion. Barred from even studying the design of a human-capable moon lander, NASA sees ARM as the only near-term initiative that will materially advance its human spaceflight capabilities. If American astronauts visit such an asteroid in a retrograde lunar orbit, the United States will have sent humans farther into space than any nation in history — with hopes of expanding that capability toward Mars.

Some in Congress have bolder ambitions for NASA, but those plans are hamstrung by NASA's projected budget, even with a proposed increase to $18.5 billion. Because the Obama administration will not acquiesce to a rewrite of its human spaceflight policy or a wholesale reallocation of NASA's budget, the most Congress can do is reprogram funds to accelerate the advent of Orion and the Space Launch System. While Congress and NASA wait for the next presidential administration to arrive with a new round of "expert" recommendations, the only practical piloted deep-space mission the agency can advance is ARM.

Cancellation would erode U.S. human space program >>

If ARM is canceled, NASA with current funding could do little more with the Space Launch System and Orion than fly astronauts around the moon or visit empty Lagrange points in the Sun-Earth or Earth-moon system — this while China orbits a station and lands astronauts on the moon. If the International Space Station is decommissioned in the mid-2020s, the U.S. will also have ceded low-Earth orbit activity to other nations, and to exclusive commercial tourism operators. ARM is a stopgap and child of necessity, but if successful, should be a springboard to more ambitious deep space expeditions. If canceled, its demise might well signal NASA's decision to abandon human space exploration altogether.

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