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Why asteroids beckon: NASA and near-Earth objects

NEAR-EARTH OBJECTS (NEOS), GENERALLY speaking, are asteroids and comets that approach or cross Earth's orbit. As the White House and Congress take up the details of NASA's future, NEOs are grabbing attention on several fronts. From a minor scientific curiosity two decades ago, these denizens of the inner solar system have been recognized as both a hazard and a major option for NASA's human exploration program.

Even before the release of NASA's FY11 exploration budget, NEOs had emerged as realistic destinations for U.S. astronauts. Six months ago, the Augustine commission put the exploration of NEOs at the center of its Flexible Path options for human spaceflight. The committee's attraction to piloted NEO missions was based on their accessibility, scientific value, operational challenge and potential for tapping space resources. Late last year, asteroid missions were front and center with NASA managers, at the Office of Science and Technology Policy and in White House discussions of the agency's future direction.

One superficial reason for heightened NEO visibility was that "they're not the Moon." More substantively, NEOs comprise an attractive suite of deep space destinations that will enhance NASA's human exploration effort and deliver cutting-edge scientific and technical benefits.

Charles Bolden (l.) and Anatoly Perminov met last October at Mission Control Center Moscow in Korolev. (NASA photo; Bill Ingalls.)

Close encounters with NEOs

NEOs were garnering plenty of attention outside NASA as well. In early January, ROSKOSMOS head Anatoly Perminov told reporters that Russia would begin planning a robotic mission to deflect asteroid 99942 Apophis. "I don't remember exactly, but it seems to me it could hit the Earth by 2032," Perminov said. "People's lives are at stake. We should pay several hundred million dollars and build a system that would allow us to prevent a collision, rather than sit and wait for it to happen and kill hundreds of thousands of people."

Perminov's worries, like Apophis itself, are a little wide of the mark: The NASA NEO program's latest orbital analysis gives Apophis only a four-in-a-million chance of striking Earth in 2036. Still, it was noteworthy that the head of Russia's space agency views NEOs as a distinct hazard to our planet, and offered Russian leadership to demonstrate an asteroid deflection. If NASA moves toward extensive robotic and eventual human exploration of NEOs, Perminov plainly does not intend Russia to be left on the ground.

In a letter to the Russian administrator, Rep. Dana Rohrabacher (R-Calif.) applauded Perminov's proposal: "It would be foolish and irresponsible for America to cede our responsibility on this critical threat to all of humanity. You can count on me to try to make this a joint project with the United States." Rohrabacher's missive was plainly aimed at NASA, too. He has long cajoled the agency to take a more active role in planetary protection from NEOs.

Apophis is clearly not a threat, but a botched deflection could put it on an impact trajectory. Perminov was quickly advised by his scientists that Russia should choose a NEO with zero chance of striking Earth for a demonstration.

The boulder-studded surface of Itokawa, about 500 m long, loomed toward Japan's Hayabusa spacecraft in 2005. (JAXA image.)

As the growing catalog of known NEOs approaches 7,000 (see http://neo.jpl.nasa.gov/stats/), we are aware of more frequent close encounters with small asteroids. A recent attention-getter was 2010 AL30, some 10-15 m across, which streaked by on January 13 just 130,000 km from Earth. A NEO this size will pass within the Moon's orbit about once a week on average.

If smaller than 30 m, asteroids generally will be too small to penetrate the atmosphere; nonetheless, 2010 AL30's close approach reminds us that some 2 million NEOs roam the inner solar system. The random rock that caused the 1908 Tunguska explosion, estimated at about 5 Mt of TNT-equivalent energy, was just 30-40 m across; there are more than 100,000 future Tunguskas out there, and one of them will strike Earth every 300-500 years. On a bad day, hitting in the wrong place, such an explosion would destroy a city.

You can get there from here

We are undoubtedly in some undiscovered NEO's gunsight. By exploring these objects, we gain an opportunity not only to reduce the future impact hazard, but to turn these potential blockbusters to our advantage, through benefits in science, operations, space resources and planetary protection.

These benefits all stem from one practical characteristic of a small but special group of NEOs: their accessibility. A small fraction of NEOs circle the Sun in Earth-like orbits. Of this "attractive" group, with orbital inclinations, eccentricities and semimajor axes close to Earth's, nearly 60 known NEOs would have been within the reach of the Orion crew exploration vehicle. More than half of those could be reached for a round-trip delta-V less than that of a lunar round trip (about 9 km/sec). Any system sized to reach lunar orbit or the Earth-Sun gravitational Lagrange points can also reach a set of the best-situated NEOs. NASA has already identified a few Orion can reach in a single heavy-lift launch. With cancellation of the Constellation program, however, they remain beyond our grasp.

The list of these accessible objects will only grow as new search capabilities become operational (such as PanSTARRS and LSST; see http://pan-starrs.ifa.hawaii.edu/public/; http://www.lsst.org/lsst). Thousands of new asteroids will be found in the coming decade.

The key long-lead-time capability for expanding this NEO target set is early and sustained funding for the next-generation search systems. NASA should step forward to provide this, given its mission requirements, but DOD, NSF and international support should also help. The more NEOs we discover, the larger the number of opportunities for reaching them with robotic and human explorers.

NASA's Constellation program, in studying NEO missions in 2007, found that with minor modifications the Orion spacecraft can support crews on deep space missions lasting up to six months. NEOs a few hundred meters across have almost no surface gravity, so Orion missions would not require development of a separate, expensive lander. For a crew of just two or three, astronaut comfort and safety could be improved by adding a small (perhaps inflatable) habitation module, including an airlock. NASA has also considered adding more propellant capacity to Orion's service module, which would expand the target set of accessible NEOs.

Are NEOs worth visiting?

Previous robotic touchdowns by the NEAR-Shoemaker and Hayabusa spacecraft demonstrate that NEOs represent a strange and varied zoo of solar system relics whose materials have been unaltered for more than 4.5 billion years. Some will be loosely bound piles of fragmented rubble; some, solid chunks of iron and nickel. Some will be of uniform composition; others, like Itokawa with its sprinkling of very dark boulders, display dramatic signs of surface heterogeneity. Each NEO, with its own story of formation, collision and orbital evolution, represents a surprise package of untapped knowledge.

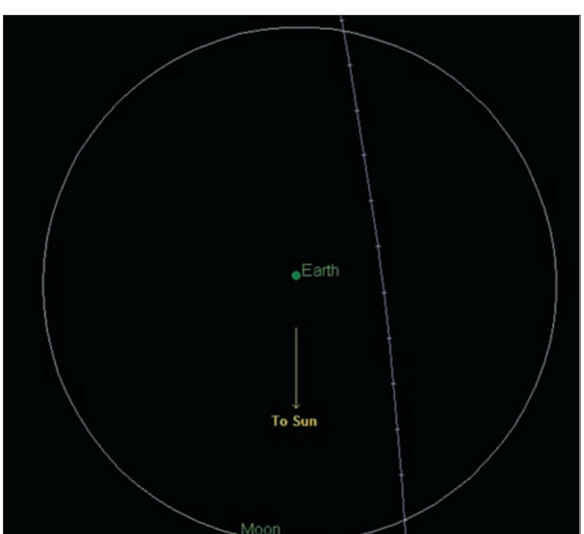
After rendezvous, astronaut field geologists will survey the object while stationkeeping. Initial remote sensing will pinpoint a few prime "docking" sites on the low-gravity surface. Using EVA jetpacks, or piloting Orion to a physical touchdown, astronauts will collect tens of kilograms of the NEO regolith. They'll not only sample the surface but also probe crater floors and snoop under the bulk of nearly weightless boulders.

As in Apollo, crews will emplace instruments such as tracking transponders, active seismometers and heat transfer probes. An Orion-mounted radar might probe the asteroid's internal structure (Itokawa's interior turned out to be 40% empty space). Measuring such physical properties will be essential to devising engineering methods for deflecting future Earth impactors.

NEO explorers will also experiment with resource extraction technologies, demonstrating practical recovery of asteroidal water, volatiles and rare metals. These technologies are the key to moving space exploration from total logistical dependence on Earth to harnessing off-planet raw materials for propellant and industrial feedstock.

We are just beginning to learn about NEOs up close, and are bound to be surprised by the results of robotic and human expeditions. By exploring NEOs, we will immediately add an independent, third "planetary" surface to our ongoing lunar research and expanding investigation of Mars.

Astronauts using EVA jetpacks could visit NEOs and collect samples of regolith.



Asteroid 2010 AL30, discovered by MIT's Lincoln Laboratories LINEAR survey on Jan. 10, 2010, came within 125,000 km of Earth on Jan. 13. JPL says the NEO was about 10-15 m across. (JPL image.)

Learning the ropes for deep space exploration

Deep space operations experience is one of the most valuable benefits of venturing well beyond the Moon. Multimonth NEO expeditions will stress all areas of mission operations. Designers will have to produce reliable, fault-tolerant systems for life support, computing and communications. Millions of kilometers from Earth, the communications lag will force a high degree of on-board autonomy and decision-making. Mission planning and vehicle control specialists must conduct intense exploration campaigns while maintaining situational awareness and safety.

By taking on these challenges at NEOs, we will be better able to explore the Moon, build a thriving space economy and confidently send astronauts to Mars.

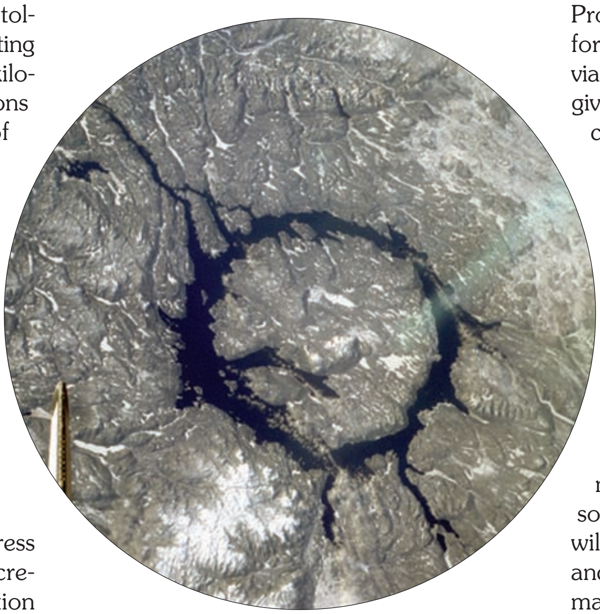
Outward momentum

Since the close of Apollo, our progress in human exploration has been incremental. The shuttle and space station have been effective classrooms in space, teaching us how to live and work there with confidence. To what purpose do we apply our hard-won education?

The 2004 Vision for Space Exploration, stripped of funding, has yet to propel us outward. Sending astronauts to NEOs will be an unmistakable commitment to long-term, ambitious exploration. Reaching and returning from these ancient landscapes will demand the best talents of NASA's exploration, operations and scientific organizations.

Our choices are excellence or failure; "muddling through" will not be a successful strategy. NASA will have to scour the government and nation for the young engineers and scientists driven to break new ground in human and machine performance.

Political momentum will be as important as technical progress if out-of-LEO exploration is to succeed. NASA will have to deliver highly visible technical and programmatic results on a scale suited to our short political attention spans. A NEO exploration program will start with robotic precursors surveying the varied compositions and structure of several potential NEO destinations. While the new Orion spacecraft and heavy-lift launcher are tested, first in LEO and then in lunar orbit, engineers will prove life support and crew health systems on the ISS. These incremental efforts will give policymakers a cumulative record of milestones, building momentum toward a commitment to true deep space expeditions.



Formed almost 212 million years ago by a NEO impact, the 100-km-wide Manicouagan Reservoir is located in a heavily timbered area of the Canadian Shield in Quebec. Astronauts aboard STS-9 took this photo in 1983.

The timing of our beyond-LEO efforts will clearly be budget driven. If the Augustine commission recommendation for a space budget worthy of a great nation is realized, we could be ready for NEO missions even before 2020. Between now and then, NASA will have to accumulate the public, congressional and executive support needed to make its first trans-NEO injection burn.

One element of creating that support is international cooperation. Although it might add political and technical complexity, some of our ISS partners could provide a NEO campaign with propulsion modules, habitation systems, EVA mobility systems and scientific hardware. Buttressed by these international commitments, a NEO exploration program would be less vulnerable to political turbulence during the decade or more required for execution.

NEOs: An offer we can't refuse

The public understands today that protecting Earth from a future NEO catastrophe is a worthy mission for NASA. Proving technologies and gathering information to head off an Earth impact, via robotic and human NEO exploration, gives the agency's efforts in deep space a commonsense foundation. When those efforts take the form of astronauts drifting across the rocky surface of a NEO under a gleaming, BB-sized Earth 5 million miles distant, our imaginations will be fully engaged.

With the White House's direction to NASA just released, we cannot yet gauge the prominence NEOs have taken in the agency's revised exploration charter. But I believe we should seize the opportunity to include these science- and resource-rich objects in our plans. NEOs will reinforce the scientific, economic and technical strengths of the U.S. human exploration program. We would reap the benefits of synergistic scientific return from a "new" planetary surface, substantially different in origin, age and composition from those of the Moon or Mars. Explorers would also assay NEO resources potentially vital to future U.S. economic activity in space.

In coming decades, the global community will certainly face a decision to deflect a hazardous NEO. Impact prevention is a fundamental, "know your enemy" mission, and a commonsense rationale for NEO exploration. Grappling with these objects at a distance, before we are faced with such a threat, will provide us the operations experience and civil engineering data needed for a successful future deflection.

Finally, in the event that policymakers defer a U.S. return to the Moon, NEOs provide NASA with a challenging exploration alternative. Less expensive to reach than the lunar surface, NEOs will nevertheless stretch our capabilities and set the U.S. on an ambitious and rewarding course of unapologetic human exploration.

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