APPRECIATION 7
Rudolf E. Kalman

Q&A 10
Lockheed Martin's Antonelli on Mars planning

UNMANNED AIRCRAFT 28
The Navy's carrier drone debate

AEROSPACE

★ ★ ★ AMERICA ★ ★ ★

Planet spotting

Getting serious about finding and photographing an Earthly world PAGE 20

SEPTEMBER 2016 | A publication of the American Institute of Aeronautics and Astronautics | www.aerospaceamerica.org

AIAA
Shaping the Future of Aerospace

8 ★ ★ ★ AEROSPACE AMERICA ★ ★ ★ SEPTEMBER 2016 aerospaceamerica.org

An asteroid companion

A newly discovered asteroid will orbit in loose formation with Earth for centuries. Its presence reminds NASA exploration planners of attractive opportunities for robotic and human exploration as they examine varied paths toward deep space and Mars.

By Tom Jones | skywalking1@gmail.com | www.AstronautTomJones.com

University of Hawaii's Panoramic Survey Telescope & Rapid Response System in April detected a near-Earth asteroid, designated 2016 HO3, that has been orbiting in Earth's celestial backyard for almost a century — and will be around for centuries longer.

In April, astronomers sifting through images from the University of Hawaii's Panoramic Survey Telescope & Rapid Response System in Maui discovered a faint near-Earth asteroid, now designated 2016 HO3. Analysis of its orbit soon showed that the 50- to 100-meter-wide object circles the sun on a path very much like Earth's, flying formation within a few million miles of our planet for at least the next century.

The discovery of HO3 underscores the practical possibility of exploring nearby asteroids as a way to gain valuable deep-space experience in preparation for journeys to Mars. A skeptical Congress seems unwilling to fund NASA's proposed Asteroid Redirect Mission, a crewed mission to an asteroid fragment placed in lunar orbit. HO3 and other, even more accessible asteroids may serve as alternate destinations: far enough beyond the moon to test astronauts on a multi-month, deep-space expedition, but not nearly as challenging and risky as a full-up, multi-year journey to the red planet. A reasonable path toward Mars may take astronauts from a lunar orbit outpost, to one or more near-Earth asteroids, and then to the Mars system in the 2030s.


Rob Ratkowski


Pat Rawlings

Upper right: This painting by artist Pat Rawlings shows astronauts exploring a near-Earth asteroid. Asteroids could serve as alternate destinations to Mars and provide deep-space experience.

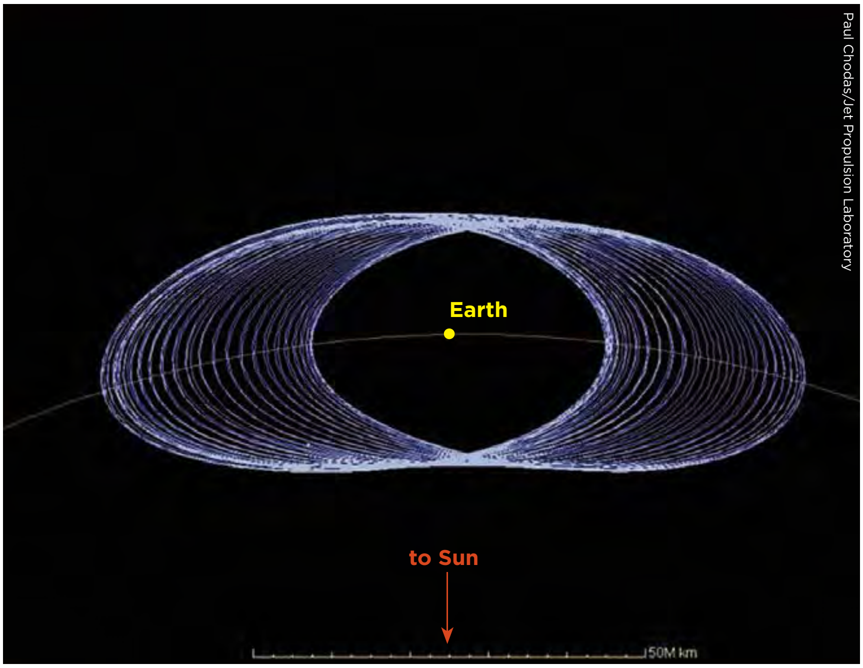
Because of HO3's relative proximity, ªwe refer to it as a quasi-satellite of Earth,º Paul Chodas, manager of NASA's Center for Near-Earth Object Studies at the Jet Propulsion Laboratory in Pasadena, California, said in an article on nasa.gov. ªOur calculations indicate 2016 HO3 has been a stable quasi-satellite of Earth for almost a century, and it will continue to follow this pattern as Earth's companion for centuries to come.º

As HO3 alternately races ahead of and falls behind Earth in its yearly trek around the sun, it ranges out to about 100 times the moon's distance, then closes to as few as 38 lunar distances: from 38 million down to 14.7 million kilometers.

Other asteroids make closer approaches to Earth, and can be reached with less rocket propellant. But what makes HO3 special is that it's always around for a visit: It offers a launch opportunity every year for the next few decades. Other typical near-Earth asteroids offer only periodic, infrequent launch windows. HO3's discovery is a timely reminder to NASA that if it wants to get astronauts out beyond the moon in the 2020s or early 2030s, either HO3 or another attractive target is nearly always within range.

Sifting the skies

HO3's discovery resulted from NASA's ongoing survey of the inner solar system for potentially hazardous objects. Since 1998, when Congress directed NASA to search for near-Earth objects such as comets and asteroids large enough to cause global damage if they struck Earth, the space agency has been funding a growing array of dedicated search telescopes and the astronomers who operate them. Today, the NASA search program's $50 million annual budget covers search, orbit cataloging, asteroid deflection research and spacecraft mission definition. It also identifies candidate targets for NASA's planned Asteroid Redirect Mission, ARM, in which robotic spacecraft would lift a 10- to 20-ton boulder from an asteroid and nudge the fragment into lunar orbit. Once stabilized there, an Orion astronaut crew



Paul Chodas/Jet Propulsion Laboratory

Left: Asteroid 2016 HO3 has been orbiting the sun in near proximity to Earth for decades. For an observer looking down on Earth as it orbits the sun, the blue lines track the asteroid's movement relative to Earth between 1960 and 2020.

Center: Artist's rendering of Asteroid Redirect Mission, NASA's proposed crewed mission to an asteroid fragment placed in lunar orbit. Congress seems unwilling to fund the mission, providing impetus to send astronauts to nearby asteroids instead.

would rendezvous with the object, examine it, and carry samples to Earth.

NASA-funded telescopes are discovering close to 2,000 near-Earth objects each year; the program has found 98 percent of the nearly 15,000 of those cataloged so far. NASA today is working to fulfill a 2005 congressional mandate to find asteroids capable of causing regional damage on Earth, meaning those 140 meters or larger in diameter. It has already cataloged an estimated 95 percent of those larger objects (based on near-Earth object population statistics and the rate at which search telescopes "rediscover" known objects). As of July 13, 1,714 objects in the catalog — some 12 percent — were termed "potentially hazardous," capable of colliding with Earth in the distant future. None poses a significant threat of impact within the next century.

Accessible asteroids

HO3 joins dozens of other known near-Earth asteroids, NEAs, accessible to human explorers. NASA filters NEA discoveries through its NEO Human Spaceflight Accessible Targets Study, or NHATS, identifying objects whose orbits make possible roundtrip expeditions by robots or humans in 450 days or less, and a total mission velocity change, rV, of 12 kilometers per second or less (think of rV as a stand-in for how much rocket fuel you'll need to fly the mission). President Obama set a goal of an astronaut expedition to an asteroid in its native, solar orbit by mid-2020s. But when it became evident under the president's budgets that the combination of Orion, the Space Launch System booster, deep-space propulsion and a habitation module would not be ready by the end of the 2020s, NASA proposed the Asteroid Redirect Mission instead. With ARM, astronauts could visit an asteroid fragment delivered to lunar orbit no earlier than 2026, but NASA would still fulfill the presidential asteroid directive, after a fashion.

NAMING ASTEROIDS

An asteroid's initial designation is assigned by the Minor Planet Center following a formula based on the year of discovery, two letters and, if need be, further digits. 2016 HO3, for example, was discovered in 2016, in the second half of April (H), and was the 90th object discovered in the latter half of April (O3).

Does HO3 offer NASA a new, game-changing asteroid target? Veteran astrodynamicist and former NASA Johnson Space Center flight dynamics officer Dan Adamo told me in an email that although 2016 HO3 has long-term proximity going for it, it's hardly the most attractive target out there. Writes Adamo: "As of July 11, 2016, a total of 1765 NHATS-compliant near-Earth objects was known. Of these, 566 near-Earth objects can be accessed with shorter round-trip durations than any 2016 HO3 mission. Likewise, 184 NHATS-compliant near-Earth objects can be accessed with less delta-V than any 2016 HO3 mission."

In fact, HO3's orbital tilt, or inclination, of 7.77 degrees imposes a significant velocity-change penalty on visiting spacecraft. By contrast, the NEA 2000 SG344 has an inclination of just 0.11 degrees, yielding a minimum mission velocity change of 3.56 kilometers per second, according to Adamo. In 2029, for example, a five-month roundtrip to SG344 requires a velocity change of only about six kilometers per second.

NASA

Dan Durda/Southwest Research Institute

Right: Rendering of a near-Earth asteroid. A handful of asteroid candidates exist that astronauts could reach in the next two decades at a lower propellant cost than going to the lunar surface.

Nevertheless, HO3's loitering behavior makes it a regularly accessible exploration target Ð a launch window to it is always handy. In any given year, for example, a 154-day round trip to HO3 could be mounted for a total velocity change of roughly 12 kilometers per second. Stretching the mission duration to one-year reduces the velocity change to 6.1 kilometers per second Ð significantly less than landing that same spacecraft on the moon, which takes about 9 kilometers per second. Both HO3 missions would include eight days of surface exploration time at the asteroid.

Where next Ð if anywhere?

Although far from the optimum candidate, HO3's discovery in our celestial backyard keeps asteroids, along with the moon, in the conversation as targets for science, human exploration and possible commercial exploitation. It's a timely discussion: If ARM does not win support in 2017 from a new administration and a skeptical Congress, near-Earth asteroids like HO3 represent the closest physical destinations for astronauts beyond the moon.

By the mid-2020s, NASA should have flown its Orion spacecraft and SLS booster several times. By adding habitation and propulsion modules to Orion, NASA would then be able to dispatch astronauts to nearby objects like HO3.

NASA is already conducting habitation module studies, and such extra living space could be available a decade from now for an asteroid roundtrip. But such a deep-space journey will still confront planners with many of the risks of a Mars expedition: radiation exposure, the effects of prolonged free-fall, and psychological isolation as Earth recedes to the size of Carl Sagan's ªpale blue dot.º Supply considerations are daunting, too: a crew of four would need to pack almost 2.5 metric tons of food for a one-year asteroid roundtrip.

Still, an asteroid expedition would be less challenging in terms of time, distance, and logistics than the two-plus-year journey to the Martian moons and back. An NEA mission could offer NASA just the right-sized first step on the road to Mars.

Carpe diem

More accessible NEAs like HO3 and SG344 will be found in the coming decade, offering NASA more asteroid targets of opportunity. NASA could team with robotic mining companies to send small robotic scouts to a promising few. By the mid-2020s, Orion and SLS should be ready. If ARM delivers its asteroid boulder to lunar orbit, astronauts should visit it forthwith. But in case ARM is detoured, NASA is probably already thinking of how to reorient its exploration hardware: from lunar orbit, to ªlocalº near-Earth object missions, to eventual journeys to the Mars system.

Although I think NASA's interest in human Mars exploration is genuine, the proof of that commitment will be its willingness to seek approval and funding for an earlier deep-space foray, millions of kilometers beyond the Earth-Moon system. A near-Earth asteroid expedition is just such a ªno kiddingº step toward Mars, far more daunting than a return to the moon (whose advantages I've discussed in recent columns). A NASA serious about Mars must move beyond talk, and actually do. Near-Earth asteroids represent just the terra incognita needed to demonstrate that seriousness of purpose. ★