September 2015

# AEROSPACE AMERICA

## Two views on Russian space

### Bright future or...program in decay?

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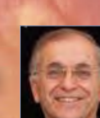



A PUBLICATION OF THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

***Don't worry too much about giant asteroids menacing Earth. Astronomers have their eyes on most of those. It's the smaller objects that pose the greatest risk. Tom Jones explains the race to detect these asteroids, so the dangerous ones can be deflected.***

The flash above Chelyabinsk, Russia, from a 20-meter asteroid streaking through the sky on Feb. 15, 2013.

**In Hollywood's depictions** of asteroid disasters, Earth is invariably menaced by a chunk of cosmic debris the size of Texas. In reality, asteroids smaller than 100 meters in diameter represent a newly realized and significant threat.

Earthlings received a reminder of this hazard on July 7, when an asteroid named 2015 HM10 approached within 440,000 kilometers, little more than the distance between our planet and the moon. HM10, which measured 40 meters by 80 meters, posed no danger of a collision on this pass. But Earth's orbit takes it continually through a swarm of millions of other inner solar system asteroids, some of which could annihilate a city. Today, astronomers estimate they know the whereabouts of less than one percent of near-Earth asteroids, or NEAs, with diameters from 40 meters to about a kilometer.

The HM10 incursion came a week after the June 30 commemoration of Asteroid Day, which coincides with the anniversary of the 1908 Tunguska explosion over Siberia, thought to have been caused by 40-meter-diameter NEA. That blast — estimated at between three and five megatons, the biggest documented asteroid impact of the last century — stands as a fearful example of the power of even a relatively small object moving at cosmic velocity.

Detecting asteroids capable of causing global harm (those 1 kilometer in diameter and larger) has been the focus of NASA's Near-Earth Object Program since 1998, and scientists estimate that more than 95 percent of those large NEAs have been found. None are on a near-term course to strike Earth. But research presented at April's Planetary Defense Conference in Frascati, Italy, showed that the much more numerous asteroids smaller than 140 meters are a worrisome lot. They strike very frequently and can cause greater damage than previously thought. I attended the conference, representing the Association of Space Explorers.

The heightened concern over smaller NEAs is based on new near-Earth-asteroid population estimates and a better understanding of the physics of the 2013 asteroid airburst over Chelyabinsk, Russia. Finding and cataloging the millions of small NEAs, however, will take a significant step up in technology and funding.

I believe NASA now has the technology in hand that could detect a large fraction of these smaller NEAs. A small-asteroid survey would be affordable — just a fraction of one percent of NASA's budget — and would give us the warning time we need to mount an effective response to a predicted impact.

### Small, but still dangerous

Geologists realized that asteroids and comets posed a real threat to Earth only 55 years ago. And it wasn't until about 15 years ago that NASA began a focused search for NEAs larger than 1 kilometer. The agency spends $40 million annually on NEA detection and research programs, more than any other space agency. But the dramatic explosion of a small, 20-meter asteroid over the Urals in February 2013 has prompted other nations to increase their search and technology contributions.

The Chelyabinsk airburst came from an asteroid that no one saw coming. It released 450 kilotons of TNT-equivalent energy, and produced a shock wave that sent more

NASA

than a thousand to the hospital with injuries from flying glass and collapsed structures. The event spurred better modeling of the physical effects of small asteroid impacts. Objects smaller than about 40 meters usually break up under entry forces and explode. An asteroid's downward momentum, however, can carry the resulting blast wave to the ground, with increased damage potential relative to a nuclear airburst of the same size. Chelyabinsk taught us that smaller objects, while broken up by the atmosphere, can still inflict significant damage to an urban area.

Astronomers now estimate that there are about 20 million 10- to 40-meter NEAs, twice the previous estimates. That means an object at least as large as Chelyabinsk will strike Earth every 30 years to 50 years, and a 40-meter, Tunguska-sized impactor will pass inside the moon's orbit several times a year. A collision with a small asteroid, striking without warning, is the likeliest impact scenario we face today.

NASA's Near-Earth Object Program discovered 1,477 NEAs in 2014, but the agency lacks adequate tools to go after the smaller NEAs, which are usually distant, dim and hard to spot. NASA-funded ground-based telescopes like the University of Hawaii's Panoramic Survey Telescope and Rapid Response System and the University of Arizona's Catalina Sky Survey can only observe on clear, dark nights, missing asteroids in the daytime sky. NASA's Wide-field Infrared Survey Explorer satellite is not optimized for NEA searches. Even when a second Pan-STARRS telescope is erected in the Hawaiian islands and observations begin with the Large Synoptic Survey Telescope in Chile in 2021, NASA will find it impossible to meet the congressionally directed goal of finding 90 percent of all NEAs bigger than 140 meters by 2020.

Planetary Defense Conference organizers issued a strong recommendation that given the new awareness of the damage potential, NEA search efforts should aim at increasing the discovery rate for these smaller bodies. Raising the discovery rate will require a dedicated, space-based infrared telescope with an aperture about 50 centimeters in diameter. The instrument would fly in an orbit like that of Venus, from where it could look outward and scan all the NEAs in a swath centered on Earth's path around the Sun. A private group called the B612 Foundation is trying to raise funds to build and launch a telescope called Sentinel into this orbit. A second option is to have NASA's proposed Near Earth Object Camera spacecraft station-keep a million miles sunward from Earth at the L1 Lagrange point, one of the locations where competing gravitational forces make it relatively easy to orbit. That would ease the telescope's data communications challenges. Such a telescope should cost half a billion dollars over 10 years, including hardware and operations, just a third of one percent of NASA's budget over that span. Ideally, the cost could be shared among other space agencies interested in addressing the global NEA hazard.

Once discovered, these small NEAs are then prime targets for follow-up observations by ground-based instruments, which can further refine their orbits and characterize their surface composition via spectroscopy. For close approachers, ground-based radar can obtain precise orbital elements and deduce asteroid shapes. For example, NASA's radar telescope in Arecibo, Puerto Rico, observes about 70 NEAs annually, some at 7.5-meter spatial resolution. Depending on distance, NASA's Goldstone radar can image such NEAs at a resolution of 3.5 meters per pixel, even revealing boulders on their surfaces.

### Deflecting the threat

The technical options for diverting an NEA are expanding. One is kinetic impact — slamming an asteroid with a hypervelocity spacecraft — that works by transferring momentum to the target NEA, changing its orbit. Momentum transfer comes not only from the spacecraft colliding with the NEA, but also from the resulting debris plume, which adds an additional shove. The European Space Agency, the German Aerospace Center, NASA and the Applied Physics Lab hope to demonstrate ki-

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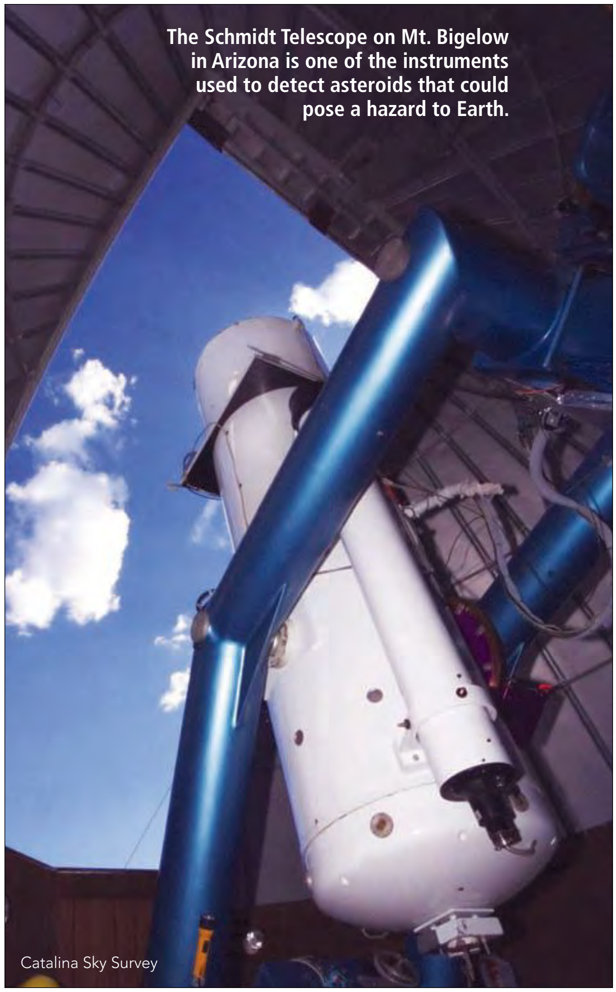
netic impact in 2022 in a two-pronged mission called AIDA, for Asteroid Impact and Deflection Assessment. ESA would launch a spacecraft called AIM, for Asteroid Impact Mission, toward a binary asteroid system called 65803 Didymos, which consists of an 800-meter-diameter object orbited by a 150-meter object nicknamed Didymoon, which is thought to be a collisional fragment of the larger object. AIM would monitor the binary system while NASA's Double Asteroid Redirection Test (DART) spacecraft slams into Didymoon at 6.25 kilometers per second, blasting out a crater and jetting a high-speed debris plume into space. By detecting the change in Didymoon's orbital period, AIM will measure the impact-driven velocity change, and help refine models of how asteroid materials react to hypervelocity impacts. If the joint mission is funded, AIM would be launched in 2020, and DART would follow a year later toward its Didymos intercept.



**The Schmidt Telescope on Mt. Bigelow in Arizona is one of the instruments used to detect asteroids that could pose a hazard to Earth.**

Catalina Sky Survey

Another option could be directed energy deflection in which an ion beam or a laser would precisely target the asteroid. With the ion beam method, a solar-powered spacecraft would aim charged ions toward the surface, striking the asteroid with these very tiny kinetic impactors to impart a velocity change. If a laser were used, it would be pulsed rapidly to vaporize or ablate a small spot on the surface, creating a near-continuous jet of rock vapor that would slowly alter the object's velocity. The time and distance required to guarantee that the object would miss Earth would depend on the target size, delivered power and the beam's accuracy.

## The Big Bang

Then there is the big-screen favorite: obliterating asteroids with nuclear explosives. Scientists would deploy a nuclear explosion differently than this Hollywood vision. A nuclear device would be detonated near the target to emit x-rays and neutrons that would vaporize a thin layer of dust and rock across a wide swath of the asteroid's surface. The resulting gas jet would propel the asteroid away from the explosion. Because nuclear explosives pack a more energetic punch than kinetic impactors or slow-push methods, they can be used to deflect a broad size range of hazardous asteroids. Experts from the U.S. Department of Energy laboratories noted that the U.S. has nuclear explosives on the shelf today that could fly aboard a spacecraft to deflect an asteroid found too late or too large for kinetic impactor or slow-push methods to work. In June, NASA and the National Nuclear Security Administration agreed to study spacecraft delivery techniques and NEA deflection concepts employing nuclear explosives. However, if NASA is able to mount a thorough, space-based search for smaller NEAs, the resulting increase in warning interval would give non-nuclear techniques more time to work, reducing the necessity to resort to a nuclear explosive.

**Learn more**

**Asteroid exercise:**

See how participants at the 2015 International Planetary Defense Conference in Frascati, Italy, prepared for a hypothetical asteroid impact.
http://neo.jpl.nasa.gov/pdc15/

Conference materials are available here:
pdc.iaaweb.org/

## Coping with catastrophe

Illustrating how much work lies ahead, attendees at the conference in Italy participated in an exercise in which they were asked to assess the threat from a hypothetical asteroid impact in 2022 and propose technical and policy responses. As events unfolded with impressive detail, role-playing "policy makers" encountered mistrust, planning delays and the partial failure of a kinetic impact deflection attempt. An 80-meter fragment of the asteroid remained on a collision course, and the exercise ended with the object's predicted explosion over Dhaka, Bangladesh, the world's 10th-largest city. Astronomers in the exercise could give only a week's warning of this probable 18-megaton airburst, which would have devastated an area inhabited by 15 million people. The sobering results of the mock response demonstrated the urgency of accelerating asteroid searches and the development of NEA deflection technologies. Equally important will be a cooperative, international policy approach to prevent the low probability, high consequence effects of an avoidable asteroid catastrophe.

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