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Better asteroid alerts

NASA plans to spend $3.8 million over the next four years adding two telescopes to its asteroid search network to do a more complete job of detecting small objects as they are closing in on Earth. Astronaut and planetary scientist Tom Jones explains how the expanded system can provide last-minute warning of an asteroid impact.

▲ **The final trajectory for** the small asteroid 2018 LA, showing its orbital position with the time (UTC) as it headed for impact on June 2 over southern Africa. ATLAS observations were key to localizing the impact site at the western end of a line of possible entry points from New Guinea to Africa.

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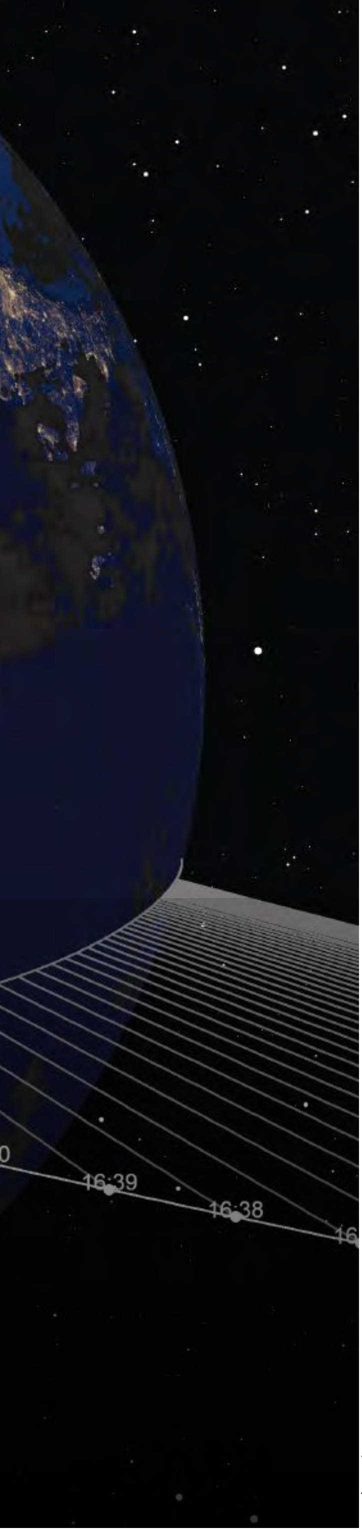

Tom Ruen/Wikipedia

With the number, location and performance limitations of today's search telescopes, astronomers often discover small near-Earth asteroids only after they've had a close encounter with our home world. NASA is taking steps to improve its ability to find these NEAs in time to issue warnings, given that even an object as small as 20 meters in diameter can deliver enough impact energy to flatten a city center.

The agency is in the process of erecting two telescopes in the Southern Hemisphere that will join the two in the Northern Hemisphere that since 2017 have operated as ATLAS, the Asteroid Terrestrial-Impact Last Alert System.

The new pair, one destined for Chile and the other for South Africa, will add the important ability to detect objects coming from the half of the sky not visible from Maui and the island of Hawaii, where the current ATLAS telescopes are.

"From Chile, we can see all the way down to the south celestial pole, a unique vantage point," Larry Denneau, the ATLAS co-principal investigator, tells me. "Because the skies should be clear over at least one of the four sites, we'll get more frequent sky scans and better warning."

Today's ATLAS system works well where it can see. For example, the telescopes provided key information to pinpoint the possible impact site of an asteroid discovered June 2 by the NASA-funded Catalina Sky Survey telescope, operating near Tucson, Arizona. Preliminary orbit calculations showed that the object, designated as 2018 LA, had a high probability of striking Earth within hours. Follow-up observations refined the orbit and confirmed a pending impact, while brightness measurements showed the object was probably too small to survive atmospheric entry. Based on the refined orbit, NASA's Jet Propulsion Laboratory in California calculated a narrow band of possible atmospheric impact points stretching from New Guinea west across the Indian Ocean to southern Africa.

JPL sent out automated alerts guiding asteroid observers toward further observations, and notified NASA's Planetary Defense Coordination Office in Washington, D.C. No ground warnings were issued, but the news alerted sky watchers along the entry trajectory. Sure enough, at about 16:44 Coordinated Universal Time on June 2, observers on the Botswana/South Africa border reported a brilliant fireball slashing across the early evening sky.

From the explosion's brightness and the infrasound waves it generated, scientists estimated that 2018 LA, traveling at 17 kilometers per second, released 0.4 kilotons of energy in the atmosphere. Its diameter was an estimated 2.6 to 3.8 meters. The asteroid's disintegration caused no ground damage but did shower fragments over the landscape below. Within weeks, meteorite hunters recovered several small pieces for analysis.

ATLAS observations were important in refining 2018 LA's orbit, and confirmed that this object generated the fireball over southern Africa.

How ATLAS works

Operated by the University of Hawaii and its Institute for Astronomy, the ATLAS system is part of NASA's larger, congressionally mandated search


ATLAS

An ATLAS camera on its mount in Hawaii. The 0.5-meter-diameter telescope was built by DFM Engineering in Colorado. Working together, a pair of cameras scans the entire sky visible from Hawaii every two nights, searching for asteroids on their final dive toward Earth.

program to discover 90 percent of the estimated 25,000 near-Earth asteroids that are 140 m or larger in diameter.

The two existing ATLAS telescopes are atop lofty volcanoes 160 km apart on Maui and the island of Hawaii. The two two telescopes weren't specifically looking for 2018 LA; the object turned up during the system's routine nightly sky scans. Spurred by the Catalina discovery, a check of the most recent and the previous night's ATLAS data also pinpointed the fast-moving 2018 LA, adding vital precision to calculations of the asteroid's orbit. The modest ATLAS camera apertures of 0.5 m mean they can't detect distant, dim asteroids, but they can catch small, fast-moving objects that might be sizeable enough to cause damage on the ground.

The current two-telescope system went operational in early 2017. Each telescope is a Wright Schmidt reflector, with a solid-state, digital imager mounted just behind the primary mirror. Each camera can capture images of a swath of the night sky 5.6 degrees on a side, spanning 11 times the apparent diameter of the full moon.

Other NEA search telescopes have larger mirrors to detect fainter, more distant objects, but ATLAS' cameras combine respectable sensitivity with a much wider field of view, rapidly sweeping adjacent patches of sky. In one 20-second time exposure, an ATLAS camera can image objects down to 20th visible magnitude, equivalent to detecting a burning match in New York while observing from San Francisco. Each sector is scanned again 30 minutes later; software compares the images and flags any objects that move or change brightness. Weather permitting, the telescopes cover 500 sky footprints every night, scanning the entire sky visible from Hawaii every two nights.

Denneau, the co-principal investigator, says that ATLAS is set up specifically to complement NASA's other systems, detecting "NEAs that are close, bright, and only a few days out from impact or close approach."

ATLAS can see a 100-m-diameter NEA 40 million km away (a quarter of the distance to the sun), and a 10-m NEA at 4 million km (10 times the distance to the moon). At average asteroid speeds, that's two days of warning for a 10-m object, typical of the small asteroids that were slipping past NASA's other telescopes, making it impossible to alert policymakers and emergency managers. An asteroid that small won't make it through the atmosphere, but its 50-kiloton energy release might damage infrastructure or hurt people below.

Software within the ATLAS network screens moving objects against known asteroids, comets and satellites. Any possible NEA discoveries are checked against the previous night's data to refine the calculated orbit and rule out slower-moving, main belt asteroids. ATLAS then notifies the Minor Planet Center in Cambridge, Massachusetts, part of the International Asteroid Warning Network, about any new objects, especially those that appear headed toward Earth. If the center confirms a high impact probability, it sends an email alert to the observer community and JPL to obtain further observations and refine the impact prediction.

JPL's asteroid-tracking software, called Scout, calculates the range of possible impact points and times. If the asteroid is large enough and the orbit prediction is confirmed by further observations, NASA informs the U.S. government of the potential impact. Meanwhile, the Minor Planet Center shares the prediction with observers and space agencies around the globe.

Today's asteroid surveys will usually provide a few days' warning of a Tunguska-sized asteroid, a reference to the estimated 40-m asteroid that exploded over Siberia in 1908, leveling 2,000 square km of uninhabited forest. An expanded ATLAS will stretch the warning period to a week or so, enough time to evacuate people along the projected impact trajectory. But deflecting a last-minute asteroid is impossible, because mounting a deflection mission would require five to 10 years.

Looking wide, not deep

According to Denneau, ATLAS complements other NASA asteroid search systems, which can see farther into space but have relatively narrow fields of view, by monitoring "shallow but wide" sections of space close to Earth. "The ATLAS telescopes do not go as deep [where asteroids are dimmed by distance] as the other NASA-funded survey telescopes, but they can catch smaller asteroids on an impact trajectory that are not otherwise discovered," says Kelly Fast, NASA's Near-Earth Object Observations program manager. Bigger telescopes continue the hunt for objects 140 m and larger, while ATLAS can address the millions of smaller asteroids that could do isolated damage at Earth's surface. "Complementary survey strategies can make progress on both fronts at the same time," says Fast.

In 2017, ATLAS found 98 NEAs, making it the third-most productive NASA asteroid survey. With an operating budget of about $740,000 annually, the system discovers each year about 100 NEAs larger than 30 m — "small" but still big enough to destroy Honolulu on impact. As of October, ATLAS had discovered 193 NEAs (of which 18 are potentially hazardous) and 12 comets. That's a fraction of the more than 18,000 NEAs now cataloged, but the system is building up valuable statistics on smaller objects, far more numerous yet little observed.

Peter Jenniskens

▲ **This meteorite** is one of the fragments of asteroid 2018 LA, which collided with Earth on June 2 and produced a fireball over Botswana a few seconds after entering the atmosphere.

ATLAS also cues larger telescopes for follow-up NEA observations, which refine the orbit and can sometimes yield spectroscopic compositional information.

Status check

The new funds for ATLAS, programmed through careful planning of NASA's near-Earth object survey budget, total about $1 million per year over four years.

The third ATLAS telescope is headed for the South African Astronomical Observatory some 370 km northeast of Cape Town, with the fourth planned for a site to be determined in Chile. The five-person ATLAS team is still searching for the right site there, one with the highest percentage of clear nights for observing.

The South African ATLAS site will begin operations in 2020, with the Chilean site opening in 2021.

Faster, better surveys needed

With its $60 million annual survey and research program budget, NASA is pursuing the population of 140-m-and-larger objects, those that could devastate a multistate region in the U.S. NASA's Fast says the agency pursues as one of its missions "safeguarding and improving life on Earth, which would include warning about smaller, imminent impactors like Chelyabinsk [which struck Russia in 2013], only about 20 meters in size." That's where ATLAS comes in.

A space-based infrared telescope would greatly speed the search for NEAs large and small, and mainly complete the 140-m goal with 10 years of observations. Such a mission, however, faces uncertain funding and may not fly for a decade. Until then, an expanded ATLAS provides an affordable chance to warn of a last-minute bullet from space. ★