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LINEAR Is On the Watch for Potentially Hazardous Asteroids

Division 9: Space Systems and Technology | Lincoln Laboratory

NASA estimates that an asteroid the size of a car enters Earth's atmosphere about once a year, creating a great fireball while burning up before reaching Earth's surface; and roughly every 2,000 years, a football-stadium-sized meteoroid strikes Earth potentially causing significant damage. When will the next dangerous asteroid penetrate the atmosphere and seriously impact the Earth? Could that next asteroid be large enough to jeopardize civilization or the future of the human species?

To answer these questions, scientists first need to know what asteroids are orbiting the Sun. Then, their orbits can be calculated to estimate how close any particular asteroid will come to Earth. The Laboratory has been working since the late 1990s to help with the discovery and characterization of potentially hazardous asteroids. Laboratory researchers have found approximately one quarter of all known near-Earth objects (NEOs) that are at least 140 meters (460 feet) in size—large enough to have significant regional effects were they to impact the Earth.

In the mid-1990s, the Laboratory developed a charge-coupled-device (CCD) focal plane upgrade for the U.S. Air Force's Ground-based Electro-Optical Deep-Space Surveillance (GEODSS) system; this upgrade replaced the aging GEODSS cameras that used vacuum tube detectors called Ebsicons. The new back-illuminated, large-format CCDs, built at the Laboratory, and prototype cameras were tested on two developmental GEODSS telescopes at the Laboratory's Experimental Test Site (ETS) at the White Sands Missile Range located near Socorro, New Mexico. These new focal planes both improved the GEODDS system sensitivity and sped up the readout of the collected images. After validating that the new focal planes were capable of wide-area, highly sensitive detection and tracking of satellites, technology transfer of the GEODSS upgrade was initiated, and the prototype CCDs and cameras on the ETS GEODSS telescopes became available for use on other efforts.

The Space Surveillance Telescope was located at North Oscura Peak on the White Sands Missile Range in New Mexico until 2017 and is currently being relocated to Australia.

In 1996, the Laboratory research team, under the leadership of Dr. Grant Stokes, Division Head, Space Systems and Technology, Division 9, experimented with using the GEODSS telescopes to detect asteroids (or as astronomers say, minor planets) and comets. In 1998, the Laboratory initiated the Lincoln Near-Earth Asteroid Research (LINEAR) program in collaboration with the Air Force and under NASA sponsorship, and LINEAR began using the GEODSS test systems equipped with the large-format CCDs for wide-area search for asteroids and comets. In the first month during which the LINEAR program operated this advanced system, more than 151,000 observations were produced and submitted. All discoveries and observations of asteroids and comets are reported to the International Astronomical Union's Minor Planet Center (MPC) at the Smithsonian

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Astrophysical Observatory, which is responsible for the verification, designation, orbit computation, and official archive for all known asteroids and comets, as well as for other natural objects orbiting the major planets. At the time, the rest of the asteroid search systems operating on the planet produced and submitted approximately 10,000 observations per month in total.

Also in 1998, NASA established a major program to discover how many natural objects come within the region termed "near-Earth" and thus could represent collision threats. This Near-Earth Object (NEO) program, now the Near Earth Object Observations (NEOO) program, began with a goal of finding and cataloging 90 percent of NEOs larger than 1 kilometer (about 0.6 miles) in diameter—a size at which scientists believed an impact would have worldwide effects.

"As part of the NASA effort to find 1 km and larger Near-Earth Objects, LINEAR was incredibly successful," said Stokes, the principal investigator of the LINEAR program. "In fact LINEAR discovered more of the 1 km and larger NEOs than any other program, and since most of them have now been discovered, that record will stand."

In 2005, as the 1 km and larger goal was nearing completion and search technology was improving, the search goal was extended to discovering 90 percent of NEOs greater than 140 meters in diameter. That goal, now directed to NASA by Congress, was recommended by a Laboratory-led study conducted for NASA.

In 2013, the LINEAR program began transitioning asteroid search operations to the Space Surveillance Telescope (SST), then located at White Sands Missile Range. The 3.5-meter SST was developed by the Laboratory under sponsorship from the Defense Advanced Research Projects Agency for advanced space surveillance applications. The SST is a highly capable telescope whose innovative curved focal plane enables sensitive, wide-area searches of the night sky to detect small objects in geosynchronous orbits. These capabilities are also well suited to searching for asteroids and comets.

This meteor crater in Arizona, about 3,397 feet wide and 558 feet deep, was created by the impact 50,000 years ago of an asteroid estimated at 130 to 164 feet in diameter, about 35 percent of the size of the asteroids the NEOO program focuses on. (Photo Credit: NASA)

Since the SST began observations in January 2014, the LINEAR program has reported more than 14 million observations of asteroids and comets to the MPC and has found 6,001 new objects, including 142 previously undiscovered NEOs and eight new comets. In 2015, the LINEAR team submitted 7.2 million observations to the MPC, making SST the most productive asteroid search instrument ever in terms of number of observations submitted in a single calendar year.

The SST was recently relocated from New Mexico to the Naval Communication Station Harold E. Holt on the North West Cape in Western Australia, where, as part of the U.S. Space Surveillance Network, it will be operated jointly by the U.S. Space Force and the Royal Australian Air Force. Discussions between NASA and the U.S. Space Force are in progress for extending the current LINEAR asteroid search effort to SST, with the goal of SST continuing to contribute to NASA's asteroid search and discovery mission.

The LINEAR program has been a reliable, prolific discoverer of NEOs, comets, unusual asteroids, and main-belt asteroids. It achieved its success by using advanced telescopes, detectors, and detection algorithms and by aggressively scheduling the telescopes for as many nights as possible each lunar month—thus covering the entire available sky at least once each month, weather permitting.

"All together, the LINEAR program is responsible for discovering more than 24 percent of all currently known potentially hazardous asteroids," said Stokes.

Researchers working in the LINEAR program have also contributed to the scientific characterization of the NEO population through their analysis of the number, orbital properties, albedo properties (i.e., reflection of solar radiation), sizes, and impact hazards of NEOs. The archive of LINEAR images, generated from the 1-meter GEODSS telescopes located at ETS (amounting to more than 6 million images), has been used by scientists to accomplish numerous astronomical investigations.

Originally, the discovery of new asteroids was driven by astronomers' curiosity. Now an important motivation is scientists' desire to reliably discover any asteroids that may eventually be a collision threat to Earth. With knowledge of the number, composition, and behavior of the vast population of asteroids, scientists gain a better understanding of the likelihood and the potential for such collisions. One goal of NASA's continuing NEOO program is to provide warning and other data that could help nations prepare for impending collisions and thus to reduce the casualties and other damages caused by an asteroid impacting Earth's surface.

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