An artist's concept shows two asteroids colliding and creating numerous smaller asteroids.

NASA/JPL-Caltech

Apophis caused a stir in the astronomy community when it was discovered in June 2004. For a brief period in December of that year, astronomers feared the more than 300-meter-diameter asteroid was on a collision course with Earth in 2029. Better observations of the asteroid's orbit helped scientists dispel that notion. But the fact remains that Earth would be defenseless against an object like Apophis on a slightly different course.

U.S. scientists are working quietly to solve our vulnerability to asteroids and comets, known collectively as NEOs, for near-Earth objects. Ideas range from imparting gentle tugs or nudges to objects spotted far away, to deploying nuclear devices against large objects or those discovered too late for subtler approaches. The work is modestly funded at this point and consists mainly of modeling and simulating. Success would mean the first planetary defense from rare but potentially devastating collisions.

Experts calculate that Earth will be struck on average once every 100 million years by an object like the estimated 10-kilometer-diameter

Leonid Kulik expedition

Hundreds of square miles of trees were felled by the 1908 explosion of an asteroid over the Tunguska region of Siberia. The blast is estimated to have been 1,000 times more powerful than the atomic bomb dropped on Hiroshima.

Planetary defense

Stopping asteroids from hitting Earth will require time to put a plan in place. Brian Steiner examines the options under study in universities and a national lab.

rock that slammed into what is now the Yucatan Peninsula and probably killed off the dinosaurs. A collision with a 1-kilometer asteroid could be expected once in a million years. Time would afford the best protection against such collisions.

"Our whole strategy is to find hazards years in advance," says NASA's Lindley Johnson, the agency's Near Earth Objects program executive. Scientists from NASA, the European Space Agency and other organizations, including the universities of Arizona and Hawaii, are scanning the skies for NEOs. When one is found, the coordinates are stored in a catalog at the NASA-funded Minor Planet Center at the Smithsonian Astrophysical Observatory in Massachusetts. Experts then get to work predicting the NEO's trajectory. So far, scientists have found 10 to 15 percent of the objects larger than 100 meters, Johnson says.

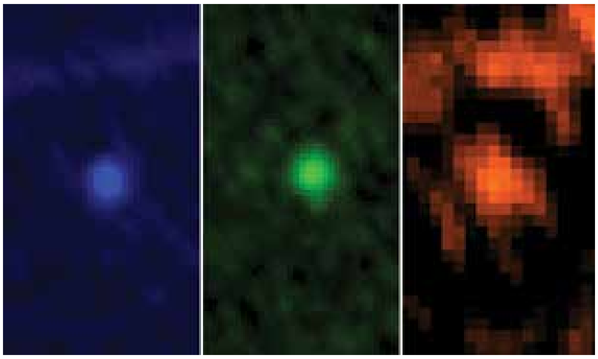
As events in February 2013 showed, the unexpected can happen. On the same day that a refrigerator-sized meteoroid flew over the Russian city of Chelyabinsk and exploded, injuring more than 1,500, an even larger object dubbed DA14 flew by Earth uneventfully, as predicted. The notable thing about DA14 was that it was discovered just 12 months earlier by a team of experienced amateur astronomers in Spain. Had it been on a different course, there would not have been much time to dodge its 2.4-megaton impact, which would have been like the 1908 asteroid explosion over the Tunguska region of Siberia that leveled trees across 820 square miles.

"One of the reasons we didn't know about the Chelyabinsk [meteoroid] is because it came from the direction of the sun. You just can't see them when they're close to the sun," Johnson says. Some scientists are working to change this. The B612 Foundation, founded by former astronauts Ed Lu and Rusty Schweickart, is raising private funds to build a space-based telescope to improve our ability to see NEOs, notes Johnson.

About 300 scientists from around the world meet every two years to discuss concepts for protecting the planet from these objects. For a relatively small object spotted far away, one idea would be to hover a plasma-powered spacecraft (sometimes called a gravity tractor) next to it and

by Brian Steiner

European Space Agency



Images captured by the Herschel Space Observatory in 2013 show the asteroid Apophis in wavelengths, from left, of 70, 100 and 160 microns. In 2029 Apophis will pass within about 20,000 miles of Earth — closer than satellites in geostationary orbits.

use the craft's gravitational pull to slowly tug the object off course.

Another option would be to steer a spacecraft, called an impactor, into the object at high speed. Jay Melosh of Purdue University has studied the options and he calls kinetic deflection "the most obvious" technique and the one that's most ready in terms of technology. The technique was tested in 2005 when the Deep Impact spacecraft plowed into comet Tempel 1. Scientists believe Tempel 1 was deflected, but the change in its orbit was too small to measure due to the very large size of its nucleus (about 6 kilometers in diameter) and the fact that its orbit constantly changes anyway due to venting gas and dust, Melosh says. NASA and ESA want to launch two probes, collectively known as AIDA for the Asteroid Impact Deflection Assessment, to further study the use of impactors on asteroids. One spacecraft would impact an asteroid and the other would observe the crater. Johnson says the plan is to launch the probes in 2020.

For larger objects closer to Earth, a bigger jolt would be required.

If the object were far enough from Earth, it wouldn't be necessary to make the entire object go BOOM, says David Dearborn, a physicist at Lawrence Livermore National Lab. "A nuclear standoff burst would vaporize a thin portion of the [NEO] to push it to a slightly different orbit. You just need about a centimeter-per-second speed change," he says, to change the object's orbit. Done 10 or more years ahead of time, the NEO would harmlessly pass us by. "Detecting it early has a real advantage," he says.

One-two punch

What if the warning time were months, as was the case with DA14? Without a notice of more than five years, the only way to stop an NEO would be with a nuclear device, says Bong Wie, a professor of aerospace engineering and founding director of the Asteroid Deflection Research Center at Iowa State University in Ames.

"In a study we did for NASA, our conclusion was the following: When we don't have sufficient warning time, we cannot gently deflect an asteroid using non-nuclear options. There's only one option: segmentation or disruption using a nuclear device," Wie says. "Whether someone likes it or not, there is no other option."

Wie and his graduate students are using computer models to simulate how such a mission might unfold and what the effect on NEOs of various sizes would be. They have a novel plan. Launch two spacecraft tethered together. The vehicles separate as they close in on the NEO, with the first one approaching at high speed until it hits the object's surface with force, making a crater 50 meters wide and 10 meters deep. The second vehicle, carrying a nuclear device, detonates just inside the crater.

"If we can do that, the efficiency of the explosion is 20 times more effective than having an explosion outside the crater," Wie says. "It's similar to removing an old building to build a new one. If you want to explode a building, would you want to put the dynamite inside the building or on the outside?"

With lead times as short as one month, Wie says it's possible to explode an NEO outside of lunar orbit. At that distance, he says, it's unlikely any debris would fall to Earth. Shorter than one month, though, and it's likely at least some incoming debris would not burn up completely in Earth's atmosphere and instead fall to the ground. But in that case, he argues, it's still better to act and destroy the NEO than to do nothing.

Melosh, the Purdue professor, disagrees with the nuclear option because of a broader risk he sees.

"New weapons would need to be developed because there's nothing in our arsenal big enough to do the job. I think that, of the threats to humanity, the threat from the weapons themselves is greater than the threat from the asteroids," Melosh says.

"A big asteroid could annihilate most of the people living on Earth. However, the chance of an asteroid about 1-kilometer in diameter hitting Earth is one in a million years."