National Space Society

Position Paper:

Protecting Earth from Cosmic Impacts

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"The dinosaurs became extinct because they didn't have a space program."
– Larry Niven

Summary

Millions of objects in space, including asteroids and comets, are in orbits around the Sun that cross the orbit of Earth. When they approach Earth, they are referred to as Near-Earth Objects (NEOs). Some NEOs are large enough to cause significant damage to our civilization.[1] If we do nothing, roughly two percent of these objects will eventually hit Earth,[2] and pose a threat from destruction of a city to the complete extermination of civilization, if not humanity. Many such objects have struck Earth in the past, inflicting damage ranging from trivial up to and including global catastrophe. While a future large strike with catastrophic consequences is certain,[3] we do not know when it will happen; it could be 150 million years or fifteen months.[4]

Humanity has the technical capacity to discover and track the vast majority of dangerous NEOs at very reasonable cost. Developing deflection capability is somewhat harder, but is well within our abilities.[5] The United Nations has organized an international effort to coordinate policies on asteroid warning and deflection activities, and the US has a critical role. In addition, NEOs represent vast resources that may be exploited to enable settlement of the solar system.[6]

The National Space Society (NSS) urges all space faring nations to add an amount of at least one percent of their civilian space budget for planetary defense against these threats. One percent is chosen because it is sufficient for a first class program even though the severity of the threat would warrant a much larger sum. A constant level of effort is chosen since while this threat can be minimized, it is extremely difficult to remove completely. Constant vigilance is the price of survival.

The immediate task before us is to find and track the NEOs large enough to cause damage on the ground, those about 20 m in diameter or greater.[7] To this end,

current US ground-based searches should continue, including use of the Arecibo radio telescope. The Large Synoptic Survey Telescope (LSST) should be fully funded and encouraged to vigorously pursue NEO detection. The B612 Sentinel and the JPL NEOCam infra-red NEO space telescopes should be fully funded.

Additionally, threat from impacts by long period comets and their deflection has received little attention, even though their damage potential upon impact is comparable to or even greater than that from asteroids, because they fell into the "too hard" category given their approach from the far reaches of the solar system, high velocity, and changing orbits near the Sun. But with advancing technologies and good progress addressing the asteroid threat, it is time now to address the timely detection and deflection of long period comets, as well continuing the efforts with respect to asteroids.

Studies and tests of NEO deflection, including NEO characterization, should begin, although the focus of this paper is on ensuring that a solid bedrock of detection technology is put in place on which deflection efforts can build.

We face an existential threat. We can develop the ability to remove it. There is little or no benefit to waiting. Let's do it.

Background

On the 15th of February 2013 a NEO, the Chelyabinsk meteor, struck Russia and exploded. The blast damaged over seven thousand buildings and almost 1,500 people suffered injuries requiring treatment, mostly cuts from flying glass as windows were blown out. The Chelyabinsk meteor was probably about 20 meters in diameter. As we cross the anniversary of that event, it is important to understand its significance and what it means for the United States.

We know that there are millions of such objects that cross Earth's orbit, and that others have also hit the Earth, some with tremendous consequence.

In 1908, a small asteroid or comet exploded near the Podkamennaya Tunguska River in Russia. It is estimated that the Tunguska explosion knocked down some 80 million trees over an area of 2,150 square kilometers, and that the shock wave from the blast would have measured 5.0 on the Richter scale. An explosion of this magnitude would be capable of destroying a large metropolitan area, but due to the remoteness of the location few if any fatalities were documented.

The Chicxulub crater in Mexico is 180 kilometers across. It was probably created 66 million years ago by a 10 km diameter NEO that exterminated most of the species on this planet, including the non-avian dinosaurs.[8]

It is certain that similar impacts will happen in the future, but we do not know when. On average, we should expect city killers (>20 m diameter) on a time scale of decades to 100 years or so. Every million years or so we should expect a regionally devastating strike with global consequences from 1 km diameter NEOs, and every 100 million years or so to experience a global catastrophe from 10+ km diameter NEO impacts that could be fatal to civilization, if not humanity.[9]

Unlike most natural disasters, we have the technology and knowledge to prevent nearly all major NEO strikes at very reasonable cost. We know how to build telescopes that can detect NEOs and we have identified a wide variety of approaches to nudging the offending rocks so they miss Earth.[10] Under the auspices of the United Nations, the International Asteroid Warning Network coordinates the search for asteroids and other space objects that threaten the Earth, and the Space Mission Planning Advisory Group (SMPAG) focuses on the space missions and technology needed to address the threat.[11]

NSS has been a consistent supporter of actions to defend our home planet from such events. Moreover, we believe that the United States has the capability and resources to significantly improve global preparation for these threats from space. However, we are concerned that insufficient attention and resources are being devoted to this problem. The funding allocated to planetary defense is tiny compared to the importance of the task. For example, in 2013 NASA spent approximately 0.1% of its budget ($20 million) on planetary defense. There are other missions, such as an asteroid sample return that relate to planetary defense, but that is not the mission driver and from a planetary defense perspective these funds are not optimally spent. On the basis of importance one might argue that a quite large fraction of our space budget should be allocated to planetary defense.

Needed US Actions

Notwithstanding the vast importance of protecting the Earth from strikes by asteroids and comets, we believe that a relatively small part of the US federal budget is sufficient to fund a first class program. The funds should be used to address critical problems first.

The most important task is to discover and track the vast majority of NEOs that could impact Earth. If we do not see the next NEO coming we cannot deflect it. Once a NEO is found with a date-certain impact, funding for deflection should be essentially unlimited.

There is a network of ground telescopes currently being used to discover and track NEOs, and they have discovered around 900 (about 90%) of the most dangerous objects (diameter > 1 km).[12] Such objects will cause global damage if they impact Earth. We have found less than 1% of the millions of NEOs large enough to produce significant damage on the ground.[13] The observations of these telescopes are sufficient to predict NEO location, including potential collision with Earth, for about a century.[14] **NSS urges that the existing ground-based telescopic NEO searches be continued.**[15] [16] [17] This should include funding the Arecibo radio telescope for this mission as it can obtain very good orbit and size data for NEOs within range.[18] [19] [20]

There is a new ground telescope particularly well suited to NEO discovery in development, the LSST (Large Synoptic Survey Telescope).[21] It is intended to support four major applications, one of which includes NEO detection. **NSS urges that LSST be fully funded and the NEO discovery function have a strong advocate within the LSST community.** This is essential to ensure that the cadence of observations, when and where observations are made, and data processing resources are well tuned to NEO discovery. LSST is being funded by the National Science Foundation (NSF).[22]

Ground telescopes have large blind spots. They cannot see in the direction of the Sun, near the Moon, during daylight, or through clouds, and the best frequencies to detect NEOs (infra red) are absorbed by the atmosphere. Thus, space telescopes are best for NEO discovery and tracking. The best place for such telescopes is inside of Earth's orbit so that NEOs in the sunward direction from Earth can be detected.

The Earth orbiting WISE infra-red satellite telescope is being used for NEO discovery, but it was not designed for that task and will find only a tiny fraction of the threatening objects.[23] There are two space telescopes designed for NEO detection in the early stages of development: B612 Foundation's Sentinel[24] and JPL's NEOCam.[25] [26] Sentinel is expected to cost $450 million[27] and NEOCam $600 million over a number of years.[28] Neither is funded for full-scale development. **NSS urges that both Sentinel and NEOCam should be fully funded.** The primary difference between these missions is the orbit chosen. The Sentinel is planned for a Venus-like orbit that is optimized for coverage and finding the most damaging NEOs well before they strike. NEOCam's planned orbit is at the Earth-Sun L1 point, locked to Earth. While less optimal for long-range detection, NEOCam has a better warning efficiency because it can see much smaller objects close to Earth, including just before impact. Also, NEOCam is able to detect small NEOs in orbits very similar to Earth's, which is important for asteroid mining. If both were built, spacecraft commonality should allow for significant cost reduction.

A vigorous planetary defense will discover and track essentially all NEOs above a certain size threshold. NEOs contain large quantities of water, metals and other materials that may be exploited. There are two basic strategies for mining them: removing part of a large NEO for return to cis-lunar space, or capturing an entire NEO whole, which is only practical today for small NEOs (<10 meters diameter). The water can be processed to produce rocket propellant and the metals can be used for space construction. Thus, a catalogue of NEOs developed for planetary defense is also a map of resources that may be mined to fuel settlement of the solar system.

There may even eventually be a terrestrial market for NEO metals if the cost of delivery can be brought down sufficiently.

There is one class of NEOs—long period comets that pass through the inner solar system—that Sentinel and NEOCam are not well suited to discover in time to avoid impact. LSST may be of some value. These objects spend the vast majority of their lifetime in the outer solar system, but some occasionally pass Earth's orbit and may exhibit spectacular 'tails' visible to the naked eye. Approximately three per year pass near Earth's orbit. Unlike most NEOs, with current telescopes long period comets cannot typically be discovered until a few months before impact, probably too late for deflection missions to succeed. While comets are much less dense than asteroids, impact velocities are much higher so damage is perhaps 30% greater than for the same diameter asteroid, and many long period comets are far larger than most asteroids. Long period comets are believed to be roughly 1% of the total NEO threat,[29] but this number may not be very accurate. Even if accurate, by the time the Sentinel and NEOCam missions are complete, and 90-99% of short-period potentially dangerous NEOs have been discovered, long period comets may represent a large fraction of the remaining threat, and most if not all of the objects with globally catastrophic effects of collision.

Discovery of other NEOs and determination of their orbital path would benefit highly from placing larger optical telescope sensors in space. The apertures of such sensors need to be large in order to collect sufficient energy for reliable detection, since the NEOs could readily be somewhere inside the orbit of Venus or in the main asteroid belt between Mars and Jupiter; but the sensors also need to have a large focal plane and thus a large field of view in order to perform rapid and efficient search over large solid angles. Many designs exist for sensors meeting one of these criteria, and some that might meet both. These designs include very large single apertures based on gossamer membranes to attain low weight, and use of a number of cooperating independent optical telescopes operating in the visible or infrared spectrum flying in sparsely populated arrays whose received energy is coherently added, thus synthesizing a much larger aperture than that of the individual telescopes. The sparse telescope arrays as well as the gossamer membrane sensors also have the potential for much faster discovery of NEOs as well as to be able to detect some long period comets at sufficient distances to yield many months of warning to activate a previously emplaced defensive system.[30] These types of systems should be considered as part of a longer term study of how to best detect NEOs, and especially long-period comets.

NSS recommends that studies should be undertaken to thoroughly understand the long-period comet threat and measures to detect and mitigate it. While space-based instruments would likely play a major role, LSST's capabilities for this task should be assessed and, if substantial, supported.

It should be noted that NEO detection and tracking to protect the planet also has substantial scientific value. The knowledge gained will help understand the origin and evolution of the solar system.

The immediate recommended discovery and tracking actions (existing efforts, LSST NEO search, and funding Sentinel and NEOCam) would require less than an amount equal to one percent of the US civil space program budget. NSS recommends this be new money, not taken from existing space activities. If an amount equal to one percent of the civil space budget were allocated to this problem, this would be sufficient to fund current search programs (LSST, NeoCam, and Sentinel). Enough remaining funds would be available to make a good start on long period comet detection, deflection research including characterization of NEOs, and deflection missions to NEOs for practice with no chance of harming Earth. Other nations should make a similar commitment; this is a global problem that requires global participation.

Summary of Recommendations

In summary, **NSS recommends that the space faring nations of Earth devote an additional amount of at least one percent of their civil space program budget to planetary defense**. On-going UN efforts[31] to develop an international approach and policies for NEO detection and deflection deserve continued support by all nations. While the importance of planetary defense merits a much higher budget, one percent represents sufficient funds for a very robust program.

Specifically regarding near term US activities, NSS recommends that

1. Current Earth based searches continue, including the Arecibo telescope.
2. The LSST receive full funding for NEO discovery.
3. The NEOCam and Sentinel space telescopes specifically designed for NEO detection both receive full funding.
4. That the threat from long-period comets be addressed.
5. Any remaining funds be allocated to deflection activities, including characterization.

Footnotes/References

[1] *Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies* (2010), Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; Space Studies Board (SSB); Aeronautics and Space Engineering Board (ASEB); Division on Engineering and Physical Sciences (DEPS); National Research Council.

[2] There are approximately 1,000 NEOs with diameter greater than 1 km. These objects are believed to have a lifetime of 10 million years. Furthermore, objects of this size are expected to strike Earth roughly every 500,000 years (*Defending Planet Earth …*). This works out to 20 objects, out of 1,000, or about two percent. Obviously, this number is not precise.

[3] It is common to describe major asteroid strikes as very unlikely. This is only true for relatively short time periods. While the chance of a large strike this year is small, in the long run such a strike is all but certain, absent our efforts. It should be noted that there was only a tiny probability of an asteroid strike in the year a NEO doomed the dinosaurs.
[4] Impact of a long period comet could occur with only a few months warning.
[5] *Defending Planet Earth …*
[6] Globus, Al. "Paths to Space Settlement." *NSS Space Settlement Journal*, November 2012.
[7] While the literature estimates 50-140 m diameter as the threshold for severe ground damage, the Chelyabinsk meteor, a 20 m object, recently struck Russia damaging thousands buildings and injuring about 1,500 people. "Chelyabinsk Airburst, Damage Assessment, Meteorite Recovery, and Characterization," Olga P. Popova, et al., *Science* 29 November 2013, Vol 342, no. 6162, pp. 1069-1073.
[8] "The Chicxulub Asteroid Impact and Mass Extinction at the Cretaceous-Paleogene Boundary," Peter Schulte, et al., *Science*, March 2010, Vol 327, no 5970, pp 1214-1218.
[9] *Study to Determine the Feasibility of Extending the Search for Near-Earth Objects to Smaller Limiting Diameters*. Report of the Near-Earth Object Science Definition Team, NASA, August 22, 2003.
[10] *Defending Planet Earth …*
[11] David, Leonard. "United Nations Takes Aim at Asteroid Threat to Earth." Space.com, February 12, 2014**.**
[12] *Defending Planet Earth …*
[13] *Defending Planet Earth …*
[14] *Defending Planet Earth …*
[15] NSS does not recommend construction of new ground telescopes for NEO detection (other than LSST) as we expect ground telescope NEO search to be phased out when space telescopes become available, with the possible exception of LSST.
[16] Johnson, Lindley. "Near Earth Object Observations Program." NASA, April 15, 2010.
[17] Near Earth Object Search Programs, nasa.gov
[18] Johnson, Lindley. "Potentially Hazardous Asteroid Workshop." NASA, May 29, 2012.
[19] Ju, Anne. "Report calls Arecibo Observatory 'uniquely powerful' for detecting near-Earth objects." *Cornell Chronicle*, September 29, 2009.
[20] "Plan to operate the Arecibo Planetary Radar for Near-Earth Object Characterization and Spacecraft Mission Support: 2009-2013." December 26, 2012.
[21] Large Synoptic Survey Telescope, lsst.org
[22] National Science Foundation FY 2014 Budget Request to Congress, nsf.gov
[23] WISE NEA/Comet Discovery Statistics, nasa.gov. WISE has found about 134 NEOs to date and is expected to find about 150 more. See also "NASA Spacecraft Reactivated to Hunt for Asteroids," *Space Daily*, September 9, 1013.
[24] Lu, Edward T, et al. "The B612 Foundation Sentinel Space Telescope," *New Space* 1, 2013.
[25] NEOCam: Finding Asteroids Before They Find Us, Jet Propulsion Laboratory, caltech.edu
[26] NASA-Funded Asteroid Tracking Sensor Passes Key Test, nasa.gov, April 15, 2013.
[27] Leone, Dan. B612 Foundation Puts a Price on Asteroid Mission, *Space News*, April 16, 2013.
[28] Johnson, Lindley. "Near Earth Objects: Overview of the NEO Observation Program." NASA, June 21, 2013. In this talk NeoCAM is estimated at $500 million or less; we have added $100 million launch costs to total $600/million.
[29] *Study to Determine the Feasibility …* (see footnote 9)
[30] Private Communication from Ivan Bekey, February 10, 2014.
[31] Working Group on Near-Earth Objects, United Nations Office for Outer Space Affairs.

About the National Space Society (NSS): NSS is an independent non-profit educational membership organization dedicated to the creation of a spacefaring civilization. NSS is widely acknowledged as the preeminent citizen's voice on space, with over 50 chapters in the United States and around the world. The Society publishes *Ad Astra* magazine, an award-winning periodical chronicling the most important developments in space. To learn more, visit www.nss.org.