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A Planetary Defense Policy

By Al Globus

"If the dinosaurs had a space program, they would still be here." – Anonymous

Whereas,

1. Millions of Near Earth Objects (NEOs) large enough to cause significant damage to people and their work cross Earth's orbit.[1]
2. If we do nothing, very roughly 2% of these objects will eventually hit Earth.[2]
3. Many such objects have struck Earth in the past, inflicting damage ranging from trivial up to and including global catastrophe.
4. While if we do nothing a future large strike with catastrophic consequences is certain,[3] we do not know when it will happen; it could be in millions of years or 15 minutes.
5. Humanity has the technical capacity to discover, track, and deflect dangerous NEOs at very reasonable cost.[4]
6. NEOs represent vast resources that may be exploited to enable settlement of the solar system.[5]

Resolved,

1. I urge all spacefaring nations to devote at least 1% of their civilian space budget to planetary defense.

   1% is chosen because it is a sufficient for a first class program, even though the severity of the threat would warrant a much larger sum, the threat being anything from the destruction of a city to the complete extermination of civilization, if not humanity. 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.

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[1] National Research Council, *Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies* (Washington, DC: National Research Council, 2010).

[2] There are approximately 1,000 NEOs with diameters 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 (NRC, *Defending Planet Earth*). This works out to 20 objects out of 1,000, or about 2%. 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] NRC, *Defending Planet Earth*.

[5] Al Globus, "Paths to Space Settlement," *NSS Space Settlement Journal* (November 2012). http://www.nss.org/settlement/journal/.

2. The most important task right now is to find and track the NEOs large enough to cause damage on the ground, those about 20 meters in diameter or greater.[6] To this end,
   a. Current ground-based searches should continue, including the use of the Arecibo radio telescope.
   b. The Large Synoptic Survey Telescope (LSST) should be fully funded and encouraged to pursue NEO detection vigorously.
   c. The B612 Sentinel and the JPL NEOCam infra-red NEO space telescopes should be fully funded.

   All this can be done for well under 1% of the global civil space program budget; indeed it would be less than 1% of NASA's budget.

3. The threat from long-period comets should be studied.

4. Studies and tests of NEO deflection, including NEO characterization, should begin, although this is secondary to discovery efforts as one cannot deflect what one cannot see.

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

Discussion

On February 15, 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. It is likely that there are millions of such objects that cross Earth's orbit.

The Chicxulub crater 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.[7]

It we do nothing, it is certain that similar impacts will happen in the future, but we do not know when. It could be in millions of years, or in 15 minutes. On average, we should expect city killers (> 20 m in diameter) on a time scale of many decades. Most should fall in the oceans or sparsely inhabited regions, but that is not guaranteed.

Every half a million years or so we should expect a devastating strike with global consequences (> 1 km diameter).[8]

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[6] 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 of buildings and injuring about 1,500 people. Olga P. Popova et al., "Chelyabinsk Airburst, Damage Assessment, Meteorite Recovery, and Characterization," *Science* 342, no. 6162 (November 29, 2013): 1069-73.

[7] Peter Schulte et al., "The Chicxulub Asteroid Impact and Mass Extinction at the Cretaceous-Paleogene Boundary," *Science* 327, no. 5970 (March 2010): 1214-18.

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.[9]

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 civil space budget should be allocated to planetary defense. However, a very small part, around 1%, is sufficient to fund a first-class program.

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).[10] Such objects will cause global damage when they impact Earth. We have found that less than 1% of the millions of the NEOs are large enough to produce significant damage on the ground.[11] The observations of these telescopes are sufficient to predict NEO location, including potential collision with Earth, for about a century.[12] **I recommend that the existing ground-based telescopic NEO searches be continued.**[13] 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.[14]

There is a new ground telescope particularly well suited to NEO discovery in development, the Large Synoptic Survey Telescope (LSST).[15] It is intended to support four major applications, one of which is NEO detection. **I recommend that LSST be fully funded and the NEO discovery function have a strong advocate within the LSST community.** This is essential to insure that the cadence of observations, when

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[8] "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. neo.jpl.nasa.gov/neo/neoreport030825.pdf
[9] NRC, *Defending Planet Earth*.
[10] Ibid.
[11] Ibid.
[12] Ibid.
[13] 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. See also www.nasa.gov/pdf/467238main_20100415_NEOObservationsProgram_Johnson.pdf and neo.jpl.nasa.gov/programs/.
[14] See www.news.cornell.edu/stories/2009/09/report-calls-arecibo-capabilities-unmatched, neo.jpl.nasa.gov/neo/2011_AG5_LN_intro_wksp.pdf, and es.convdocs.org/docs/index-16822.html
[15] See www.lsst.org/lsst/.

and where observations are made, and data-processing resources are well tuned to NEO discovery. LSST is being funded by the National Science Foundation, totaling $465 million.[16]

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.[17] There are two space telescopes designed for NEO detection in the early stages of development, B612 Foundation's Sentinel[18] and JPL's NEOCam.[19] Sentinel is expected to cost $450 million[20] and NEOCam $600 million over a number of years.[21] Neither is funded for full-scale development. **I recommend that both Sentinel and NEOCam be fully funded.** The primary difference between the 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 in 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 provide fuel for 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.

[16] See www.nsf.gov/about/budget/fy2014/table.jsp.
[17] WISE has found about 134 NEOs (neo.jpl.nasa.gov/stats/wise/) and may find about 150 more (www.spacedaily.com/reports/NASA_Spacecraft_Reactivated_to_Hunt_for_Asteroids_999.html).
[18] See b612foundation.org/wp-content/uploads/2013/02/B612-Foundation-Sentinel-Space-Telescope.pdf.
[19] See www.nasa.gov/mission_pages/asteroids/news/neocam20130415.html#.UuMfVbROk1I and neocam.ipac.caltech.edu/.
[20] See www.spacenews.com/article/civil-space/34885b612-foundation-puts-a-price-on-asteroid-mission.
[21] Lindley Johnson, "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.

There is one class of NEOs that pass through the inner solar system, long-period comets, 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. Long-period comets are believed to be roughly 1% of the total NEO threat,[22] 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. **I recommend that studies should be undertaken to understand the long-period comet threat thoroughly**. **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, do not require nearly 1% of the global civil space program budget. The remaining funds might be used for long-period comet detection, deflection research, including characterization of NEOs, and deflection missions to NEOs to practice with no chance of harming Earth.

In summary, **I recommend that the spacefaring nations of Earth devote at least 1% of their civil space program budget to planetary defense**. While the importance of planetary defense merits a much higher budget, 1% represents sufficient funds for a very robust program. Specifically, in the near term, NSS recommends that

1. Current ground searches continue.
2. The LSST receive full funding for NEO discovery.
3. The Sentinel and NEOCam space telescopes specifically designed for planetary defense be fully funded.
4. That the threat from long-period comets be assessed.
5. Any remaining funds be allocated to deflection activities, including characterization.

[22] G. Stokes, D. Yeomans, W. F. Bottke, S. Chesley, J. B. Evans, R. E. Gold, A. W. Harris, D. Jewitt, T. S. Kelso, R. McMillian, T. Spahr, and S. P. Worden. "A Study to Determine the Feasibility of Extending the Search for Near Earth Objects to Smaller Limiting Magnitudes." Report Prepared at the Request of NASA Headquarters Office of Space Science's Solar System Exploration Division (Washington, DC: NASA, 2003).

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About the Author. In 1978 Al Globus read the space settlement issue of Co-Evolutionary Quarterly. It blew his mind. He had to build these things, so he went to work as a contractor at NASA Ames to work on the Hubble, ISS, X37, Earth observation, TDRSS, cubesats, lunar teleoperation, spaceflight effects on bone, aerospace computational fluid dynamics visualization, molecular nanotechnology, space solar power, asteroid mining, and space settlement. He founded and has run the annual NASA Ames Space Settlement Student Design Contest for 21 years.

Editors' Notes: As one of the Space Community's thirty-five-year professionals, Al Globus's recommendations deserve, and have been given, attention by decision makers. He is a frequent expert participant for the Lifeboat Foundation web site discussions and produces documentation aimed at ameliorating or removing dangerous threats to Earth's humanity. If we fail in Planetary Defense, the majority of other priorities will be irrelevant***. Bob Krone and Gordon Arthur***.