# Planetary Defense

## Potential Mitigation Roles of the Department of Defense

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EARTH'S ORBIT AROUND the sun is a hazardous location, and our collective safety so far has been purely a matter of luck. Despite the image of a pristine "harmony of spheres" that we inherited from the ancients, the solar system is a cosmic shooting gallery filled with leftover debris from planetary formation. This debris, including asteroids and comets, orbits the sun at relative velocities of 11–25 kilometers (km) per second or 10 times faster than a speeding bullet.[1] As our planet transits this dangerous ocean, we have established no worldwide security network to warn of or mitigate collisions with space debris.

Both a position paper by the American Institute for Aeronautics and Astronautics entitled "Protecting Earth from Asteroids and Comets" (2004) and a 2007 planetary-defense conference in Washington, DC, examined the issue of finding a home in government for asteroid defense, designating it a top priority.[2] This article advocates establishing a lead agency, such as US Strategic Command (STRATCOM), for handling mitigation procedures, creating lines of communication, and defining planetary-defense policy for the United States and perhaps for the United Nations.

### Background Data

According to the National Aeronautics and Space Administration (NASA), "Every day, Earth is bombarded with about 25 tons of dust and sand-sized particles. About once a year, an automobile-sized asteroid hits Earth's atmosphere, creat[ing] an impressive fireball."[3] US missile-warning satellites annually record as many as 30 bolides (meteoroids that detonate in the atmosphere, otherwise known as fireballs), often releasing as much energy as a nuclear blast (see fig. 1, which includes several years of data superimposed over Earth's surface).[4] Composed of ice-rock mixtures, these bolides range in size from a few meters in diameter up to 50–60 meters. It is important to emphasize that objects smaller than 50–60 meters seldom penetrate the entire depth of the atmosphere to create impact disasters.[5] However, more massive objects occasionally do so, causing greater concern.

We shouldn't become complacent because even larger objects intersect Earth's orbit. The surfaces of the moon, Mercury, and Mars show that debris has hit with relative frequency. Unlike these heavenly bodies, Earth is an active

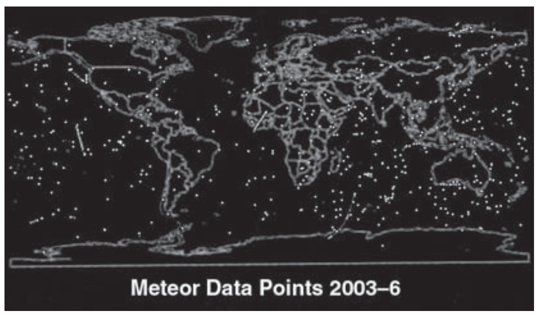


**Figure 1. Satellite-observed bolide atmospheric entries**. Image courtesy of Air Force Future Concepts.

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planet with tectonic and erosion forces that largely obscure impact craters. Nevertheless, geologists have now confirmed that asteroids or comets have scarred Earth with 160 craters (fig. 2), and they discover more each year. Although we have found impact craters mostly on land (fig. 2), bolides can occur anywhere on our home planet (fig. 1).

This article divides potential Earth-impacting asteroids into four categories. Generally, asteroids with a density less than or equal to that of rock and less than .5 km across can cause "local damage," defined as destruction of an area equivalent to a moderate-sized city, such as Kansas City, Missouri. These "city-killers" would reduce most houses and buildings to rubble, and any combustible material within 8 to 16 km of the impact would burn. Debris would scatter for tens of kilometers, possibly causing widespread fires. If the asteroid fell into the ocean, it could produce tsunamis more powerful than the Indian Ocean earthquake of 2004, leaving thousands dead. Based on lunar-cratering studies, local-damage asteroids collide with Earth every 200 to 300 years, on average.[6] (Other studies indicate every few thousand years. A defined planetary defense would refine such estimates of the danger of impact.)[7] A city-killing asteroid hit Tunguska, Siberia, in 1908, missing Moscow, Russia, by only three hours.[8] This atmospheric explosion flattened a forested area three times as large as the District of Columbia.[9] Definitive research published in *Nature* magazine indicates that the Tunguska bolide had asteroid origins and detonated approximately 10 km above the ground with a force of 10 to 20 megatons of TNT, making it over 1,000 times more powerful than the first atomic weapons.[10]

Asteroids with diameters between .5 and 2 km, known as "nation destroyers," can create


**Figure 2. Locations of 160 impact craters on Earth**. (From Lunar and Planetary Institute, http://www.lpi.usra.edu/publications/slidesets/craters/slide_2.html [accessed 10 January 2007].) Image created as an illustration for the Terrestrial Impact Crater slide set. Reprinted by permission from the Lunar and Planetary Institute.

"regional destruction," wiping out countries such as the United Kingdom or India. Having the potential of killing and injuring a substantial portion (up to 25 percent) of the human population, these asteroids could significantly disrupt our modern way of life.

Asteroids between 2 and 10 km in diameter could cause "global effects" due to impact casualties and debris thrown into the atmosphere. Clouds of ash and dust might circle Earth, devastating crop production for months or even years. They could also induce acid rain, which would pollute fisheries and contaminate farming. The consequent elimination of more than 25 percent of the human population would greatly affect civilization, setting it back several decades.

Finally, asteroids more massive than 10 km can become "planet killers," imparting kinetic energy equivalent to 100 million megatons of TNT—hundreds of times greater than all the nuclear weapons in the world (fig. 3).[11] Impacts of this size would destroy the entire ecosystem and cause mass extinctions. Earth might have suffered a few of these since life began. An impact nearly 65 million years ago that created the Chicxulub crater off the Yucatan peninsula might have eliminated the dinosaurs.[12]

Zipping near Earth's orbit, most of these potentially hazardous objects travel in predictable orbits, allowing us to spot them decades in advance. However, we have only begun to comprehend the threat. Comets such as Shoemaker-Levy 9 orbit too infrequently for us to characterize them and arrive with very little warning. This particular one hit Jupiter in 1994, raining down approximately 20 fragments several hundred meters in size and delivering several hundred megatons of explosive power per fragment.[13] Furthermore, city killers can arrive without warning due to the spotty nature of our current surveillance. One such minimal warning occurred on 18 March 2004, when an asteroid came within 3.4 Earth diameters or 43,000 km from Earth, having been identified only 48 hours prior.[14] This distance lies just outside the geostationary orbits of satellites circling our home.

Since detection efforts began in the mid-1990s, NASA and supporting teams (using only ground-based telescopes and a meager budget of $5 million/year) have catalogued over 4,000 near-Earth asteroids (NEA).[15] The discovery rate has increased each year during the past decade (fig. 4). We predict that a subset of the total NEAs shown in figure 4—potentially hazardous asteroids (PHA)—will come within 750,000 km of our home, less than two times the distance between Earth and the moon. PHAs are too massive to burn up in

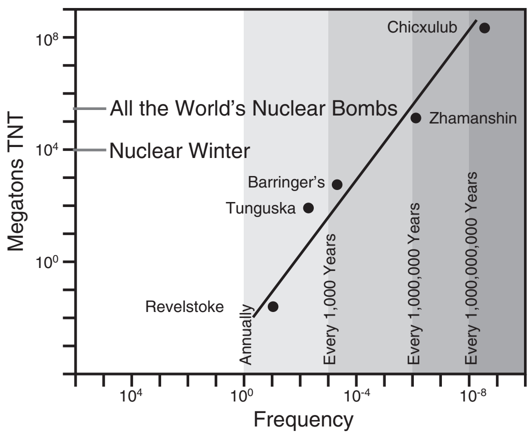


**Figure 3. Megatons of TNT compared to impact frequency**. (From NASA and National Resources of Canada, "Impact Hazard," 10 February 1999, http://liftoff.msfc.nasa.gov/Academy/SPACE/SolarSystem/Meteors/ImpactHazard.html [accessed 17 January 2007].) Courtesy of NASA and National Resources of Canada. The Zhamanshin crater formed nearly 1 million years ago from an asteroid, leaving a bowl 14 km in diameter near Zhamanshin, Kazakhstan. The Barringer or "Meteor Crater" formed from a small, stony asteroid nearly 50,000 years ago in Arizona, leaving behind a basin 1.5 km in diameter. After examining what was previously thought to be a volcano, renowned geologist Eugene Shoemaker proved that it was in fact an impact crater, based on the presence of coesite and stishovite. These minerals are rare, dense forms of silica, found only where quartz-bearing rocks have been severely compressed. They are not created by volcanic action; rather, an impact event is the only known mechanism for creating these minerals. The Revelstoke fireball flashed across the British Columbian sky in 1965. No impact occurred, but several people felt an atmospheric explosion.

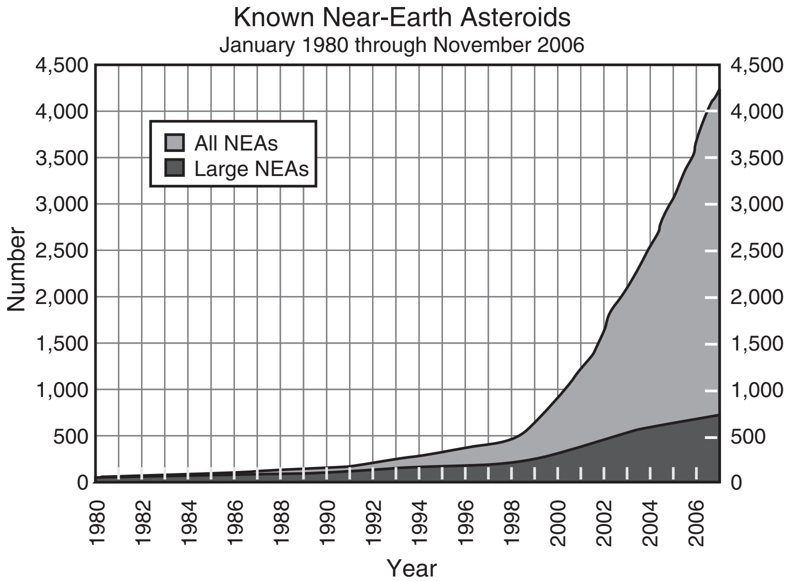


**Figure 4. Discovered NEAs**. (From Alan Chamberlin, "Near-Earth Asteroid Discovery Statistics," *NASA: Near Earth Object Program*, http://neo.jpl.nasa.gov/stats [accessed 4 February 2007].) Courtesy of NASA/Alan Chamberlin. The gray area shows all NEAs, and the darker area shows only the large ones (those with diameters roughly 1 km and larger).

Earth's atmosphere. As of November 2006, we have detected 843 of them, 700 larger than 1 km and capable of regional destruction.[16]

No known asteroids target Earth now or for the next several years. However, this information can change rapidly. Nobody knows how long Earth will be spared. Our planet has not been so fortunate in the past. With 843 PHAs and counting, we must seriously consider mitigation options. Rather than debate *whether* we need planetary defense, we must determine *when* we will need it. From a policy perspective, we know that at least 843 asteroids prowling our neighborhood could cause local, regional, or global destruction, so we have just begun to understand the total threat. We won't comprehend its full extent until we overcome the "giggle factor" and stop erroneously ascribing such thinking to science fiction. We need to create contingency plans and establish guidelines as an insurance policy—a far less expensive proposition than the consequences of suffering a direct hit.

## Policy Perspectives

The good news is that, unlike predicting earthquakes and hurricanes, we can actually see most asteroids and comets arriving years or decades in advance and do something about it. The technology required to avert a catastrophe lies within our reach, at a comparatively modest expenditure. However, no one is in charge, no one owns the problem, and no one has been assigned the mission—not NASA, Air Force Space Command (AFSPC), or the Department of Homeland Security (DHS). We have no on-the-shelf contingency plans, tabletop interagency scenarios, interagency memoranda of agreements, standard operating procedures, or hardware available for a mitigation mission.

Having a decade of advance warning might seem like plenty of time to construct these policies and a mitigation operation, but it isn't. We would need most of this time to slowly affect the velocity of an asteroid with a low-thrust, high-efficiency tug. Reaching a menacing asteroid will take several years of flight time as well. Clearly, we need mission planning, spacecraft development, and testing. Current Department of Defense (DOD) system development and procurement can easily run longer than a decade. The F-22 fighter aircraft alone has taken nearly 25 years to evolve from a list of requirements to initial operating capability.[17]

Asteroids and comets differ significantly. No two are alike. Rotation rates will affect docking techniques, and different densities and surface compositions will call for varying deflection tactics. Given a very short time until impact, we may have only one option: use explosives to reduce the inbound asteroid into smaller pieces. However, the efficacy of this approach remains subject to technical debate and might result in several smaller impacts scattered across the globe. Even if each meteoroid piece is small enough to burn up within the atmosphere, no nation wishes to have fireballs redirected to its backyard. Before we need these proactive approaches that anticipate such problems, we must research and document them. Because we may have only one opportunity to evade an NEA, we must be prepared.

Planetary defense may seem an abstract and unreal national security risk. However, it proved quite a serious problem for the dinosaurs, who previously inhabited our planet, and it poses no less a threat today. No matter how remote some people might think the chances of having rocks fall on their heads, they should at least be concerned that no government or DOD contingency plan exists to counter an impact or mitigate its consequences.

## Policy Recommendations

Since no US-assigned or -authorized planetary-defense missions exist, the DOD, as an organization, does not have any "impact defense" operations. Few individuals in the DOD perceive this lack of policy as a problem, and those few who do must contend with the giggle factor. This train of thought suppresses any further acknowledgement or research. Assignment of responsibility would rectify this problem, yet who should assume responsibility for a planetary-defense mission? Readers might wonder why the authors mentioned STRATCOM as a possibility. Why not some other part of the DOD? Why the DOD at all? Perhaps NASA could handle detection, reconnaissance, and mitigation missions while trying to replace the space shuttle and return to the moon. Maybe the DHS or Federal Emergency Management Agency (FEMA) represent a better option since impacts might become a national disaster.

Both NASA and the DOD have expertise in space matters and operate space assets, but NASA's core mission is space exploration. The DOD's core missions are maintaining US security, protecting American lives, and ensuring the security of our allies. Expertise aside, planetary defense is clearly a defense mission. Further, since the DOD maintains a robust space mission, the proposed mission appears more closely aligned with the strengths and scope of the DOD than with those of the DHS.

Within the DOD, possible options might include AFSPC, the National Security Space Office, the Missile Defense Agency, and STRATCOM. Several reasons make STRATCOM the best option. For one, STRATCOM's mission calls for "provid[ing] the nation with global deterrence capabilities and synchronized DOD effects to combat adversary weapons of mass destruction worldwide."[18] The command coordinates DOD capabilities to thwart weapons of mass destruction. We can consider an inbound Earth-impacting rock a weapon, despite the absence of an adversary. A combatant command, STRATCOM has the established lines of communication and the authority to react to strategic-level threats. It already maintains global vigilance and space situational awareness. The former US Space Command has been dissolved and subsumed by STRATCOM. Through AFSPC, the command already maintains daily space surveillance for detecting launches of ballistic missiles and tracking artificial satellites and Earth-orbital debris. Although AFSPC maintains space assets, operational control falls under STRATCOM's authority. It also controls all military nuclear capability, perhaps the only option in certain minimum-warning scenarios. Moreover, STRATCOM is well practiced and competent with respect to disseminating rapid warnings to civilian leadership and civil defense networks. Finally, the command has years of experience in negotiating and executing collective security arrangements, such as that of the North American Aerospace Defense Command with Canada and those involving the North Atlantic Treaty Organization.[19]

Some detractors have stated that a planetary-defense program is too expensive for the United States to bear alone and that it belongs in the international arena. Although they make a reasonable point, several considerations remain. First, for such a critical survival issue, the United States should not find itself at the mercy of an internationally delayed or incomplete plan. Second, international cooperation would still imply using US resources but with less US control. Third, significant national security reasons exist for having the United States pursue this capability for the defense of others. America has an interest in preserving its democratic civilization and maintaining international security.

The United States reaps significant economic benefits by providing international security. We have the most to gain by maintaining security and the most to lose if it fails. By visibly pursuing the capability to defend the planet, we make ourselves increasingly essential to international security. Furthermore, we will likely have to pay the bill anyway. The humanitarian crisis that could ensue from an impact with a 300-meter asteroid could easily dwarf the Asian tsunami of 2004. The humanitarian supply, airlift, sealift, and rebuilding costs would be staggering. Economic losses to US investors, huge costs to US insurers, and a possible recession or depression resulting from the loss of a city or nation would likely occur.

Despite concerns about the expense of developing such a planetary-defense system, it would translate into a competitive advantage for the United States. Solving difficult problems would create US intellectual capital, industrial capacity, and new technical areas of leadership critical to maintaining our lead in space.

The technology needed to protect the planet offers other advantages besides a contingency plan. Technologies that appear promising for planetary defense are also attractive for civil and defense applications, which include rapid and responsive high-capacity launchers, high-thrust rockets, long-duration power supply, and autonomous docking.

STRATCOM already maintains a space-surveillance system. Creating a robust and automated system to survey the sky continually for asteroids or comets to complement current discovery programs would likely improve space situational awareness. Such systems could use existing military ground-based sites for electro-optical, deep-space surveillance telescopes to provide follow-up tracking of newly discovered NEAs. By having more resources and people examine the planetary-defense mission, we could develop better systems and solutions.

Although merely assigning the planetary-defense mission to STRATCOM would not constitute a complete fix, it represents the immediate next step to address the issue. Following authorization and assignment of the mission to one specific agency, we can start to examine other milestones. One of these entails conducting a tabletop scenario to assess our reaction capability and reveal significant capability gaps in order to determine useful directions for exploration and the development of a concept of operations (CONOPS). An exercise of this nature would expose a much broader level of designers to the problems of planetary defense and possible options. It would also bring together key agencies to begin a dialogue about how to pursue interagency communication and actions.[20]

Although the central player, STRATCOM would never be the only one. Developing proper interagency coordination—a necessary enabler for this mission—would help identify shortcomings, which might include notification procedures for an inbound asteroid, methods and times for informing the press, and international cooperation roles for altering the trajectory of an Earth-bound asteroid. Proper coordination between internal and external agencies supporting mitigation (AFSPC, NASA, a searching program, etc.) and those agencies dealing with consequences should mitigation fail (FEMA, DHS, etc.) could be effectively explored in the context of a tabletop scenario. Such an effort to coordinate agencies for a massive event would likely bear significant fruit across the full spectrum of operations.

We need to address many adequacy and funding issues. If STRATCOM is tasked with the planetary-defense mission, the command needs to increase space situational awareness significantly in order to characterize the threat. Not only do we need to assess adequacy by analyzing mitigation options, analyzing alternatives, and establishing a contingency plan, but also we must create and execute scenarios between interagency mitigation and disaster response to understand each other's roles. The initial effort need not be large in terms of personnel or dollars. One recommendation calls for establishing an office to create CONOPS plans. Another involves commissioning studies, possibly from major universities, to examine alternative architectures for detection and mitigation similar to the Massachusetts Institute of Technology's Project Icarus.[21] A third would initiate efforts from the Defense Advanced Research Projects Agency and the Air Force Research Laboratory to help establish the best course of action to deflect an inbound asteroid (fig. 5). Further, a small military cadre assigned to NASA and FEMA could aid planning integration and create lines of communication. Funding is less limiting than lack of both authorization and a clear mandate. Much can be accomplished with little investment, which might amount to less than doubling the current $5 million budget utilized to search for PHAs.[22]

**Figure 5. Artist's concept of a planetary-defense mitigation spacecraft deflecting an asteroid with Earth and the moon in the distance**. (*The Asteroid Tugboat*, painting by Dan Durda, in Rusty Schweickart, "Presentation to NASA's NEO Study Workshop," 26 June 2006, slides 9, 10, 21, http://www.b612foundation.org/papers/AT-GT.pdf.) Courtesy of Dan Durda, FIAAA/B612 Foundation. The B612 consists of a group of scientists and technical people concerned about the current lack of international or government action to protect Earth from an impact of NEAs. They seek to "significantly alter the orbit of an asteroid in a controlled manner by 2015" and to establish procedures and protocol in case an NEA is on a collision course with Earth. "The B612 Foundation," http://www.b612foundation.org/about/welcome.html (accessed 30 October 2007).

## Conclusion

The first and most important step in creating a planetary-defense plan is to find a home in the US government for such a program—preferably US STRATCOM. Other organizations would prove dysfunctional or suboptimal for US security. We would enhance our national-defense capabilities by working under STRATCOM auspices to pursue technology that might not be available or easily transitioned if developed by another agency. The United States doesn't need a new dedicated agency or the inevitable duplication of effort that it would create. Once we decide upon a lead agency, we would then turn to developing a CONOPS, including the creation of interagency lines of communication. STRATCOM will not be the lone actor because mitigation policies will demand capabilities found in other organizations. After modifying existing search programs, we would identify the mitigation options that need development and testing. Massive extinctions have occurred in the past and can certainly occur again. Earth is not immune to collisions with asteroids and comets, but we can prepare for these events by establishing a solid planetary-defense plan. ❑

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**Notes**

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