Planetary Defense: Potential Department of Defense Mitigation Roles

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Introduction

Earth's orbit encompassing the Sun is a hazardous location and our collective safety so far is purely a matter of luck. Despite the image of a pristine “harmony of spheres” we inherited from the ancients, the solar system is a cosmic shooting gallery filled with left-over debris from planetary formation. This debris, otherwise known as asteroids and comets, orbit the Sun at relative velocities of 11-25 kilometers (km) per second (7-15 miles per second)[1] or ten times faster than a speeding bullet.[2] As our planet transits this dangerous ocean, there is no world-wide security network established to warn or mitigate collisions with comets and asteroids.

Finding a home in government for the asteroid defense issue had been top priorities from the American Institute for Aerodynamics and Astronautics’ Position Paper “Protecting Earth from Asteroids and Comets” dated October 2004[3] and a recent planetary defense conference in Washington, DC during March, 2007.[4] One potential government agency to take charge is the US Strategic Command (STRATCOM). The goal of this paper is to establish a lead agency for mitigation procedures, create lines of communication, and define planetary defense policy for the US and perhaps for the United Nations.

Background Data

“Earth is bombarded by twenty-five tons of dust and sand-sized particles every day, with objects as large as a car creating an impressive fireball once a year”[5] according to National Aeronautics and Space Administration (NASA) Near Earth Object website. US missile warning satellites annually record as many as 30 bolides (meteoroids which detonate in the atmosphere, otherwise known as fireballs), often releasing as much energy as a nuclear blast.[6] These fireball blasts can be viewed in Figure 1, which has three years of data superimposed over Earth’s surface. These bolides are composed of ice-rock mixtures, ranging as small as a few meters (tens of feet) in diameter up to 50-60 meters (150-180 feet). It is important to emphasize sizes under 50-60 meters are usually too paltry to penetrate the entire atmosphere and create impact disasters.[7] However, more massive objects occasionally impact the atmosphere, causing greater concern.

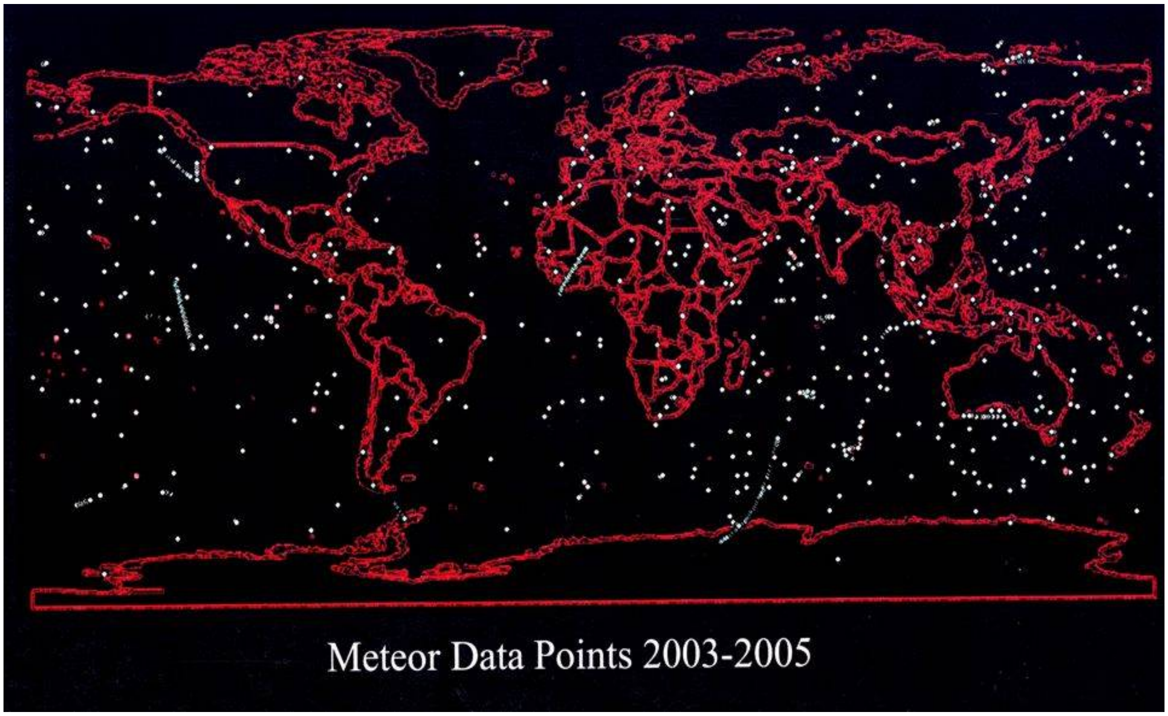

Figure 1. Satellite Observed Bolide Atmospheric Entries. Courtesy, Air Force Future Concepts. [8]

One shouldn't become complacent since there are still larger objects which intersect Earth's orbit. The Moon, Mercury and Mars demonstrate debris has impacted their surface with relative frequency. Unlike these heavenly bodies, the Earth is an active planet with tectonic and erosion forces which largely obscure impact formations. Nevertheless, geologists have now confirmed some 160 craters where asteroids or comets have scarred Earth,[9] with more discovered each year. Figure 2 illustrates impact craters have been found mostly on land, yet Figure 1 highlights impacts can occur anywhere on our home planet.

Figure 2. 160 Earth impact crater locations. Permission granted by the Lunar and Planetary Institute. [10]

For the purpose of this paper, there are four definitions of threatening Earth-impacting asteroids. Generally, asteroids with density less than or equal to rock and less than half a kilometer (1,700 feet) can cause "local damage," defined as destroying an area the size of a moderate-sized city, such as Kansas City. Another term utilized is "city-killer." Most houses and buildings will be reduced to rubble and any combustible material will burn within eight to sixteen kilometers (five to ten miles) of impact. Debris will be scattered for tens of km/miles, possibly causing widespread fires. If the asteroid impacts the ocean, tsunamis more powerful than the 2004 Indian Ocean earthquake can result, leaving thousands dead. Based on lunar cratering studies, "local damage" asteroids impact the Earth on average every 200 to 300 years[11] while other studies indicate every few thousand years.[12] This is one instance why a defined planetary defense is needed - to refine impact dangers. One example of a "city-killing" asteroid occurred during 1908 in Tunguska, Siberia, which missed St. Petersburg, Russia—the beginning of the Bolshevik revolution and the birth-place of the Soviet Union—by only five hours. This atmospheric explosion flattened a forested area twice as large as the District of Columbia.[13] Definitive research published in *Nature* magazine has shown the Tunguska bolide had asteroid origins and detonated approximately five to eight kilometers (three to five miles) above the ground with a force of 10 to 20 megatons of TNT, over a thousand times more powerful than the first atomic weapons.[14]

Asteroids with diameters between one half of a kilometer and two kilometers (1,700 feet to 1.25 miles) can create "regional destruction." These would be known as nation destroyers as countries such as the United Kingdom or India could be wiped out. Human civilization might be disrupted - a significant fraction (up to 25%) of the human population might be killed and injured - disrupting our modern way of life.

Larger asteroids in the range greater than two kilometers yet less than ten (1.25 miles to 6 miles) could cause "global effects" due to impact casualties and debris thrown into the atmosphere. Clouds of ash and dust might circle the Earth, devastating global crop production for months or even years. Acid rain is a possibility, polluting fisheries and contaminating farming. Greater than 25% of the human population could be wiped out. Civilization would be greatly altered, set back several decades.

Beyond the first three definitions, asteroids more massive than 10 km can become "planet killers." A body this size imparts kinetic energy equivalent to 100 million megatons of TNT.[15] This is hundreds of times greater than all the nuclear weapons in the world as illustrated in Figure 3. Impacts of this size would destroy the entire eco-system and cause mass extinctions. Earth might have suffered a few of these extinction-level impacts since life began. An impact nearly 65 million years ago created the Chicxulub crater off the Yucatan peninsula,[16] possibly eliminating the dinosaurs.

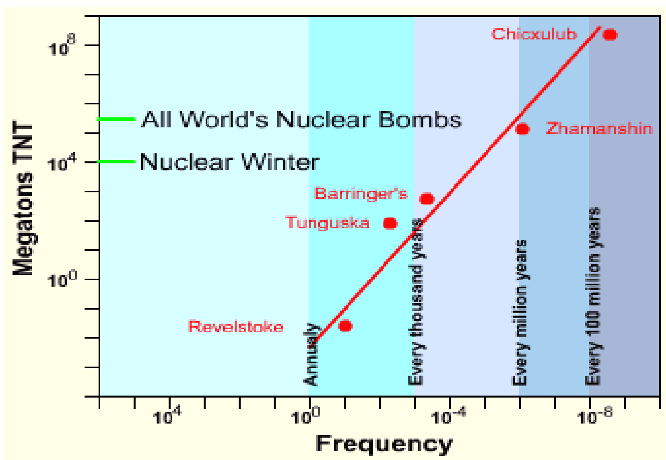

Figure 3. Megatons of TNT compared to Impact Frequency. Courtesy: National Resources of Canada and NASA.[17]

Most of these potentially hazardous objects travel in predictable orbits zipping near Earth's orbit and can be spotted decades in advance. However, we have only begun to comprehend the threat. Comets, such as Shoemaker-Levy 9, orbit too infrequently to characterize and arrive with very little warning. Shoemaker-Levy 9 impacted Jupiter in 1994 with a rain of approximately twenty fragments several hundred meters (few thousand feet) in size, delivering several hundred megatons of explosive per each fragment.[18] Also, "city killers," can arrive without warning due to the spotty nature of current surveillance. One such minimal warning occurred on March 18th, 2004, when an asteroid came within 3.4 Earth diameters or 43,000 km (26,500 miles) from Earth and had been identified only 48 hours prior.[19] This is just outside the 22,300 mile geostationary orbits of weather satellites circling our home.

Since detection efforts began in the mid 1990s, NASA and supporting teams (using only ground-based telescopes, on a meager budget of $5 million/year[20]) have catalogued over 4,000 Near Earth Asteroids (NEAs).[21] Figure 4 demonstrates that the discovery rates have increased each year during the past decade. A subset of the total NEAs in Figure 4 are considered Potentially Hazardous Asteroids (PHAs), meaning that they are both predicted to come within 750,000 km (465,000 miles) of our home, or less than two times the Earth-Moon distance and are too massive to burn up in the Earth's atmosphere. Since November 2006, there have been 843 known PHAs, of which 700 were larger than 1 km (.62 miles or 3,300 feet)[22] capable of regional destruction.

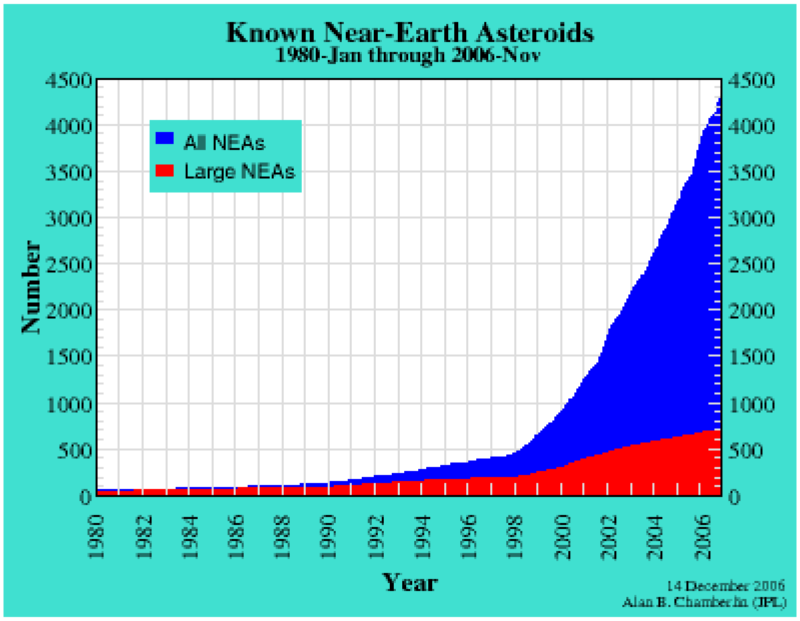

Figure 4. Discovered Near-Earth Asteroids. The black area shows all near-Earth asteroids while the gray area shows only large near-Earth asteroids (those with diameters roughly 1 km/.62 miles and larger). Courtesy, NASA/Alan Chamberlin.[23]

There are no known asteroids targeting Earth now or for the next several years. However, this information can change rapidly and there is no guarantee how many years Earth will be spared. Our planet has not been so fortunate in the past. With 843 PHAs and counting, it is time to seriously consider mitigation options. Now is not the time to debate if we need planetary defense, rather, when we will need. From a policy perspective, knowing there are 843 potential asteroids which can cause local, regional or global destruction prowling our neighborhood, we are only beginning to understand the total threat. We won't comprehend the full extent until we overcome the “giggle factor,” and stop erroneously ascribing such thinking as science fiction. We need to create contingency plans and established policies as an insurance policy. Establishing such an insurance policy is less expensive than suffering a direct hit.

Policy Perspectives

The good news is that we can actually see most asteroids and comets arriving years or decades in advance and do something about it, unlike earthquakes and hurricanes. The technology required to avert such a catastrophe is not beyond our reach with a comparatively modest expenditure. The issue, however, is no one is in charge. No one has ownership of the problem and no one has been assigned the mission - not NASA, the Air Force Space Command (AFSPC) nor the Department of Homeland Security (DoHS). There are no on-the-shelf contingency plans, table-top interagency scenarios to rely on, memoranda of agreements between agencies, standard operating procedures and no hardware presently capable for a mitigation mission.

Having a decade of advance warning might seem like plenty of time to construct these policies and a mitigation operation—it isn't. Most of this time is required to slowly affect the velocity of an asteroid with some low-thrust, high-efficiency tug. Reaching a menacing asteroid will take several years of flight time as well. Mission planning, spacecraft development and testing are needed. Current Department of Defense (DoD) system development and procurement can easily run further than a decade. The F-22 fighter aircraft alone has taken nearly 25 years from a list of requirements to initial operating capability.[24]

Asteroids and comets can vary significantly from one to another. Rotation rates will affect docking techniques, different densities and surface compositions will require varying deflection tactics. If time until impact is very short, there may be only one option; reduce the inbound asteroid into smaller pieces using explosives. However, the efficacy of this approach is still technically debated, and might result in several smaller scattered impacts across the globe. Even if each meteoroid piece is reduced to burn up within the atmosphere, no nation wishes to have fireballs redirected to their backyard. Proactive approaches anticipating these problems need to be researched and then documented before they are required. We may have only one opportunity to evade a NEA, thus we need to be prepared.

Planetary defense of the Earth and of the US may seem like an abstract and unreal national security risk. It proved to be quite a serious problem for the dinosaurs who previously inhabited our planet, and it is no less a threat today. No matter how remote readers might think the chances are of having rocks fall on their heads, they should at least be alarmed that no government or DoD contingency plan exists to counter an impact or impact fallout.

Policy Recommendations

Since there are no US assigned or authorized planetary defense missions, the DoD, as an organization, does not have any "impact defense" operations. Few in DoD perceive this non-policy to be an issue and those few who do must contend with the giggle factor. This train of thought suppresses any further acknowledgement or research. The assignment of responsibility would rectify this problem, yet who should be responsible for a planetary defense mission? The reader might wonder, why was STRATCOM previously mentioned? 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 DoHS is a better option or the Federal Emergency Management Agency (FEMA), since impacts might become a national disaster.

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

Within the DoD, possible options might include the AFSPC, the National Security Space Office, the Missile Defense Agency, and STRATCOM. Several reasons make STRATCOM the best option. First, STRATCOM's mission is to "Provide the nation with global deterrence capabilities and synchronized DoD effects to combat adversary weapons of mass destruction worldwide."[25] STRATCOM is the home for coordinating DoD capabilities to thwart weapons of mass destruction. An inbound Earth-impacting rock, similar to a city or nation-destroying asteroid, could be considered as a weapon, though with no adversary. STRATCOM is a combatant command with established lines of communication and authority to react to strategic-level threats. STRATCOM already maintains global vigilance and space situational awareness. The former US SPACECOM has been dissolved and subsumed by STRATCOM. Through Air Force Space Command, STRATCOM already maintains daily space surveillance for ballistic missile launch detection and tracking of artificial satellites and Earth-orbital debris. Although space assets are maintained by AFSPC, operational control falls under STRATCOM authority. STRATCOM controls all military nuclear capability, which might be the only option in certain minimum warning scenarios. Also, STRATCOM is well practiced and competent with respect to rapid warning dissemination to civilian leadership and civil defense networks. Finally, STRATCOM has years of experience in negotiating and executing collective security arrangements, such as the North American Aerospace Defense Command with Canada (NORAD)[26] and the North Atlantic Treaty Organization.[27]

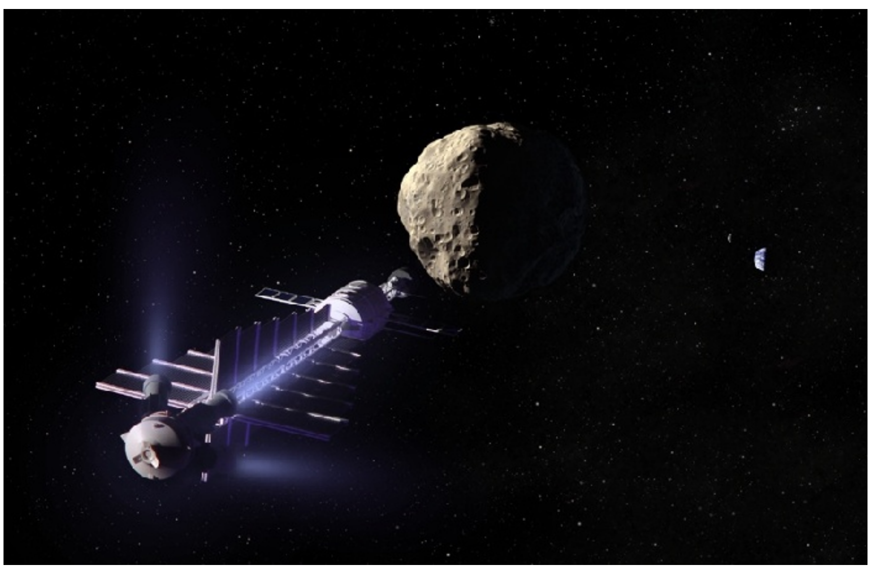

Figure 5. Artist's concept of a planetary defense mitigation spacecraft deflecting an asteroid. Courtesy, Dan Durda, FIAAA/B612 Foundation.[28]

Some detractors have stated a planetary defense program is too expensive for the US alone and belongs in the international arena. True as this statement seems, several key issues remain. First, for such a critical survival issue, the US should not be 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, there are significant national security reasons why the US should pursue this capability for the defense of others. The US has an interest in preserving our democratic civilization and maintaining international security.

The US reaps significant economic benefits by providing international security. We have the most to gain by maintaining security, and the most to lose. By visibly pursuing the capability to defend the planet, we make ourselves increasingly essential to international security. Another reason to pursue defense of others is we will likely have to pay the bill anyway. The humanitarian crisis that could ensue from a 300-meter (900 foot) asteroid could easily dwarf the 2004 Asian Tsunami. The humanitarian supply, airlift, sealift, and rebuilding would be staggering. Economic losses to US investors, the cost to US insurers and a possible recession or depression from a loss of a city or nation would likely ensue.

Despite concerns about the expense of developing such a planetary defense system, the positive aspect is that it translates into a competitive advantage for the US, also creating intellectual capital by solving difficult problems and finding innovative solutions. It creates industrial capacity and technical areas of leadership - critical to maintaining our lead in space.

The technology needed to protect the planet offers other advantages, not just a contingency plan. Technologies which appear promising for planetary defense are also attractive for civil and defense applications. Such applications 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 continually survey the sky for asteroids or comets to work with or complement current discovery programs would likely improve space-situational awareness. Such examples could use existing military Ground-based Electro-Optical Deep Space Surveillance telescope sites to provide follow-up tracking for newly discovered NEAs. With more resources and people examining the planetary defense mission, better systems and solutions can be developed.

While merely assigning the mission of a planetary defense to STRATCOM will not be a complete fix, it is the immediate next step to address the issue. Once the mission is authorized and located to one specific agency, we can start to examine the adequacy, funding, and milestones. One such milestone is to conduct a table-top scenario to assess our reaction capability and reveal significant capability gaps in order to determine useful directions for exploration and development. 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 dialogue how best to pursue interagency communication and actions.[29]

STRATCOM, while the central player, would never be the only player. Developing proper inter-agency coordination is a necessary enabler for this mission and to identify shortcomings. Such shortcomings could be identified as notification procedures if an asteroid is found inbound, how and when to notify the press and international cooperation roles in altering such an Earth bound asteroid. Proper coordination between internal and external agencies supporting mitigation (AFSPC, NASA, searching program, etc.) and those agencies dealing with consequences should mitigation fail (FEMA, DoHS, etc.) could be effectively explored in the context of a tabletop scenario. Such an effort to coordinate agencies for such a massive event would likely bear significant fruit across the full spectrum of operations.

There are many adequacy and funding issues to address. If STRATCOM is tasked with the planetary defense mission, the command needs to significantly increase space situational awareness to characterize the threat. Adequacy needs to be assessed, such as viewing mitigation options, analyzing alternatives and establishing a contingency plan. Scenarios are needed between inter-agency mitigation and disaster response to better understand one another's roles. The initial effort need not be large in either personnel or dollars. One recommendation is to establish an office to create concept of operation plans. Another suggestion is to commission studies to examine alternative architectures for detection and mitigation, possibly from major universities, similar to the Massachusetts Institute of Technology's "Project Icarus."[30] A third recommendation is to 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 inboard asteroid. 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 authorization and a clear mandate - much can be accomplished with little investment – an investment less than doubling the current $5 million budget[31] utilized to search for PHAs.

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. Such a site is the US STRATCOM. Other options have been discussed and would be dysfunctional or sub-optimal for US security. National defense capabilities would be enhanced by pursuing the technology under STRATCOM which might not be available or easily transitioned if developed by another agency. The US doesn't need a new dedicated agency and the inevitable duplication of effort such a new agency would create. Once a lead agency is determined, developing a concept of operations will be the next step, including creating inter-agency lines of communication. STRATCOM will not be the lone agency as mitigation policies will need capabilities found in other organizations. Modifications to existing search programs would be followed by examining which mitigation options need to be developed and tested. There have been massive extinctions in the past and certainly extinctions can occur again. The Earth is not immune to asteroid and comet impacts and we can be prepared by establishing a solid planetary defense plan.

Notes

[1] Michael JS Belton, et al. *Mitigation of Hazardous Comets and Asteroids.* Cambridge University Press, 2004, p167.

[2] G. Elert and M. Pereyra, "Speed of a bullet." URL: http://hypertextbook.com/facts/1999/MariaPereyra.shtml [cited 29 December 2006].

[3] "Protecting Earth from Asteroids and Comets." American Institute for Aerodynamics and Astronautics (AIAA) Position Paper, October 2004. URL: http://pdf.aiaa.org//downloads/publicpolicypositionpapers//Asteroids-Final.pdf [cited 22 January 2007].

[4] "Summary and Recommendations from the 2007 Planetary Defense Conference." Position Paper, March 2007. URL: http://www.aero.org/conferences/planetarydefense/2007papers/WhitePaperFinal.pdf [cited 17 August 2007].

[5] NASA NEO program URL: http://www.jpl.nasa.gov/multimedia/neo/neo_flash2.cfm [cited 29 December 2006].

[6] P. Bobrowsky and H. Rickman, *Comet/Asteroid Impacts and Human Society*. Springer, 2007, p150.

· "Satellite missile warning sensors show a significant number of asteroid impacts in the upper atmosphere, well over 30 per year, often releasing in excess of 10 kilotons of energy in airbursts." (Statement of Brigadier General Simon P. Worden, Deputy Director for Operations, United States Strategic Command before the House Science Committee Space and Aeronautics Subcommittee on Near-Earth Object Threat, 3 October 2002).

[7] Clark R. Chapman, scientist, Southwest Research Institute, Boulder, Colorado. Personal electronic mail, 23 July 2007.

[8] United States Air Force, HQ USAF Future Concepts, Pentagon. Personal electronic mail, 28 December 2006.

[9] Earth crater locations, Lunar and Planetary Institute. URL: http://www.lpi.usra.edu/publications/slidesets/craters/slide_2.html [cited 10 January 2007].

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[11] Alan Harris, "Evaluation of Present and Future Ground-Based Surveys and Implications of a Large Increase in NEA Discovery Rate." Planetary Defense Conference, Washington DC, March 5-8, 2007. URL: http://www.aero.org/conferences/planetarydefense/2007papers/S1-3--Harris-Brief.pdf [cited 20 August 2007].

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[13] Christopher F. Chyba, Paul J. Thomas and Kevin J. Zahnle, "The 1908 Tunguska Explosion: Atmospheric Disruption of a stony Asteroid." *Nature* Magazine, volume 361, pages 40 – 44, 07 January 1993. URL: http://www.nature.com/nature/journal/v361/n6407/abs/361040a0.html [cited 20 August 2007].

[14] Earth crater locations, Lunar and Planetary Institute. URL: http://www.lpi.usra.edu/publications/slidesets/craters/slide_2.html [cited 10 January 2007]. Used with permission from the Lunar and Planetary Institute. Image created as an illustration for the Terrestrial Impact Crater slide set.

[15] P. Bobrowsky and H. Rickman, *Comet/Asteroid Impacts and Human Society*. Springer, 2007, p211-213.

[16] David E. Fastovsky and David B. Weishampel, *The Evolution and Extinction of the Dinosaurs*. Cambridge University Press, 2nd edition, 2005, p425-432.

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[27] US STRATCOM Service Components. URL: http://www.stratcom.mil/organization-svc_comp.html [cited 30 March 2007].

[28] Dan Durda, "Planetary Defense Mitigation Mission." B612 Foundation. URL: http://www.B612Foundation.org/press/press.html [cited 20 January 2007].

- The B612 is a group of scientists and technical people who are concerned about the current lack of international or government action to protect the Earth from an impact of near Earth asteroids (NEAs). Their goal is to "Significantly alter the orbit of an asteroid in a controlled manner by 2015" to establish procedures and protocol in case a NEA is on a collision course.

[29] One agency that could easily host such a war game at a high enough level is the Air Force Directorate of Strategic Planning, which has Title X responsibility to conduct the Air Force Future War Games.

[30] "Project Icarus." Massachusetts Institute of Technology, September 1979. URL: http://mitpress.mit.edu/catalog/item/default.asp?ttype=2&tid=6840 [cited 30 March 2007].

[31] Michael JS Belton et al., *Mitigation of Hazardous Comets and Asteroids.* Cambridge University Press, 2004, p168.