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## Contention 1 – Inherency

### NASA lacks both a mandate and resources for a planetary defense system

Mitchell 7

[William F. Mitchell. March 2007. Financing a Planetary Defense System. AIAA Planetary Defense Conference.

http://www.aero.org/conferences/planetarydefense/2007papers/P5-3--Mitchell-Paper.pdf. ]

Traditional sources of space development funding are not available: NASA has a new presidential Vision to return to the Moon and on to Mars.  It does not have a mandate to develop a planetary defense system.  Even though an Open Letter to Congress in 2003 from Dr. Harrison Schmitt, Dr. Carolyn Shoemaker, David Levy and 10 other prominent authorities warned of the need for a NEO defense system, the President did not include anything about asteroid defense in his Vision.  Furthermore, NASA’s budget is so critical that many in the media and congress doubt that the New Vision for Space can be accomplished. The Democratically controlled US Congress has slashed the NASA 2007 budget by $545 million. No mandate and no place in the budget.  End of discussion. The Military is mired in a war on terror and is grossly over budget in that war. President Bush is asking for another $100 Billion for the war effort.  Again, there is no mandate for space development and no money.

### No clear NEO strategies exist now; early detection and tracking is key to cost effectiveness and avoidance of unneeded expense

Schweickart et al 2010

(Russell L. Chairman, B612 Foundation (Task Force Co-Chair)Report of the NASA Advisory Council Ad Hoc Task Force on Planetary Defense October 6, T http://www.nasa.gov/pdf/490945main\_10-10\_TFPD.pdf)

Findings on Planetary Defense 1. NASA’s search for near-Earth objects has discovered at least 87% of the large asteroids whose impacts could pose a global threat to our civilization. None pose a credible threat of a collision with Earth for the foreseeable future. But the discovery rate of the much more numerous smaller NEOs, representing a regional or local impact hazard, will soon confront us with objects presenting worrisome but uncertain probabilities for a future collision with Earth. Such situations will appear more frequently as the discovery rate increases, and the nation presently has no clear policy on how to address such a situation. 2. The National Research Council’s (NRC) 2010 report, “Defending Planet Earth,” presents a thorough collection of background information describing the hazard of NEO impacts and NASA’s current search, impact analysis, and warning programs. The NRC report authors examined several search options for detecting asteroids down to the 140-meter- size target specified by the George E. Brown NEO Survey legislation. The Task Force recommendations are largely based on the conclusions of the NRC report. 3. However, the NRC report authors had very limited time to examine emerging capabilities to discover, track, and provide warning for near-term impact of the smallest objects with damage potential (ten to several tens of meters in size). The Task Force supplemented the NRC’s work to recognize that short-term warning could enable effective evacuation of affected areas. 4. This discussion of near-Earth objects encompasses active near-Earth comets (NECs) as well as near-Earth asteroids (NEAs). Both short- and long-period NECs comprise ~1 percent of the NEO population. The population of long-period comets, with orbits originating in the outer solar system, represents a small part of the total comet threat, and thus an even smaller part of the total impact hazard. Because the tasks of effectively detecting and deflecting objects of this size and velocity are beyond our present technology, the Task Force report does not address long-period comets. 5. The driving philosophy behind the national and international defense against NEOs should be, “Find them early.” Early detection of NEOs (especially those larger than 140 meters in size) is key to mounting an effective--and cost-effective--Planetary Defense effort. An adequate search, detection, and tracking capability could find hazardous objects several years or decades before they threaten impact. Early detection and follow-up tracking of hazardous NEOs eliminates any need for a standing defense capability by mission-ready deflection spacecraft with their high attendant costs. 6. Accurate orbital predictions based on an adequate and credible search and tracking capability will eliminate many ambiguous impact threats from NEOs, ruling out a collision long before an expensive deflection solution becomes necessary. This requires reducing the uncertainty in any NEO’s observed and predicted position. The Task Force refers to this strategy as “reducing the error ellipse” as rapidly as possible. 7. A relatively low-cost, early investment in search, track, and follow-up observations through ground- and space-based systems (including radar) is a powerful cost-saving strategy. Such a capability will pay off handsomely by enabling more accurate orbit determination; eliminating many predictions of NEOs with a worrisome probability of impact (an uncomfortably high, but uncertain, probability of Earth collision); and avoiding the launch of a deflection or even a transponder tracking spacecraft, each costing hundreds of millions of dollars.\\

## Contention 2 – The Advantage

### Threats from NEO’s are very real and could occur in next 20 years

Borchers 2009

(Brent W., Major, USAF Should the USAF be Involved in Planetary Defense?AIR COMMAND AND STAFF COLLEGE AIR UNIVERSITY <http://www.dtic.mil/cgi> bin/GetTRDoc?AD=ADA539693&Location=U2&doc=GetTRDoc.pdf)

Some numbers do exist to help us quantify the consequences when tied in with the probability of the risk. Again, we know that the Earth will be impacted by a meteorite at some point, but the key is when? The human mind has a hard time grasping the chances of something occurring during our short life span when we talk in probabilities of an event that occurs only once every hundreds of thousands or millions of years. According to scientists, your chance of dying during a civilization ending impact is greater than the following chances:10 - About 300 times greater than the risk of dying from botulism - About 100 times greater than the chance that you will die in a fireworks accident - About 10 times greater than the chance of dying in a tornado - About 1/3 the risk that you will die in a firearms accident - About 1/30th the chance that you’ll be murdered - About 1/60th the chance that you’ll die in an auto accident Putting the risks in these terms certainly makes it more understandable and implies that the risk of death from the impact of a NEO is real and does exist. In fact, the risk and probability seems even more likely and personal when looking at a list of known NEOs that will pass frighteningly close to the earth in the next twenty to thirty years. In a little less than twenty years, our usually quiet Earth-Moon system is going to have a lot of visitors. In August 2027, Asteroid Number (AN) 10 is going to get about one lunar distance from Earth. Estimates for its size range from one half to two kilometers in diameter, or plenty large enough to create a regional or global catastrophe if it strikes the earth. Just six months after AN10 passes by object WN5 will get even closer, just about splitting the difference between Earth and the Moon. At 700 meters in diameter this asteroid has the potential for major damage also. By far one of the most famous among the scientific community of end-bringing objects we know about in our solar system is asteroid Apophasis. Astronomers initially thought for a while that this 270 meter-wide rock had an almost 3% chance of hitting us. Since then, odds have been lowered to 1 in 43,000 that it could slam into Earth in 2029. But if it passes through a gravitational keyhole, a tiny region in space that could tweak its orbit ever so slightly, usually where two large object’s gravitational pulls effectively cancel each other out, an impact could still happen on April 13, 2036.11

### Even if collision is rare we shouldn’t wait to prepare for it

Bridges, 4

[Andrew Bridges, Science Writer, “Scientists call for strategyto fend off space rocks,” MSNBC, 2/23/2004,

http://www.msnbc.msn.com/id/4356390/ns/technology\_and\_science-space/t/scientists-call-strategyto-fend-space-rocks/]

The asteroid believed to have wiped out dinosaurs 65 million years ago was rare but hardly unique, say scientists gathered to discuss ways of aggressively defending our planet from another such space rock, including by detonating nukes in space. Asteroids capable of inflicting damage on a global scale hit Earth roughly every million years, and we shouldn’t dawdle in developing a method of deflecting them, according to the scientists attending a four-day planetary defense conference in suburban Orange County.

### Tunguska event empirically devastating; potentially devastating NEO’s are perilously close to the Earth

Borchers 2009

(Brent W., Major, USAF Should the USAF be Involved in Planetary Defense?AIR COMMAND AND STAFF COLLEGE AIR UNIVERSITY <http://www.dtic.mil/cgi> bin/GetTRDoc?AD=ADA539693&Location=U2&doc=GetTRDoc.pdf)

Besides the general scenarios listed previously there are virtually limitless numbers of scenarios that one could construct to illustrate the potential damage from a NEO striking the earth. However, rather than making up another “Hollywood” scenario, it seems easier and more realistic to illustrate the destructive capability of some events that did occur or almost occurred in our earth’s past. If the previously mentioned 1908 Tunguska event in Siberia had occurred three hours later, Moscow would have been leveled. In 1908, Moscow’s population was approximately 1.36 million persons; imagine the loss of life had this occurred or imagine the loss of life that would occur if the event happened today with Moscow’s population of over 10 million. Keep in mind the Tunguska event was the result of a low density stony type of meteor that exploded 40 kilometers in the atmosphere. Had the meteor been a 40 meter wide iron nickel meteorite the blast would have been much worse. A crater 1 kilometer in diameter would have been created and the explosive force would have been around 12 megatons versus the 3 megaton event previously discussed.23 The threat of impact from NEOs would certainly be treated as a more serious subject had such an event happened in our recent history.24 Another pertinent example to be looked at is in the case of something that could occur presently. As this research paper is being written on, an asteroid tagged as 2009 BK58 is passing by the earth within approximately two times the distance from the earth to the moon at a relative velocity of ten kilometers per second. With an estimated diameter of 30 meters and assuming it was composed of some mix of iron and nickel, it would impact the earth and result in a blast of two megatons of energy. It would leave a crater approximately 400 meters wide with a depth of 75 meters and would create a magnitude 5.7 earthquake in the surrounding areas. The explosive amount of two megatons is equivalent to the test of a British nuclear weapon dropped near Christmas Island on 8 November 1957.25 The blast of a two megaton burst by an object impacting the earth would have the following effects: the heat from such a blast would cause third degree burns fifteen kilometers in radius from the blast, the widespread destruction of structures would occur six kilometers from the center of the blast, and near total fatalities would occur within three and a half kilometers from the blast center. The fireball from such a blast would be at least half a kilometer in diameter.26 However, as we’ll discuss in the following paragraphs, there would be additional effects from this impact. Thus far the only discussion has been on the physical and direct effects of a NEO striking earth. What about the indirect effects on economies and the stability of nations in a post strike world? Especially the country or countries directly struck or affected by the event? As evidenced by history, nations have succumbed to smaller and less catastrophic disasters. What would stop parts of the world from falling into anarchy and chaos if such an impact occurred?27 The indirect effects on governments and nations should be taken into consideration when looking at the consequences of such an event. Even if the event occurs far away from our nation, the resulting social and political effects will be felt around the world and will far surpass the range of the physical trauma suffered.

### It’s not a question of probabilities, absent the plan extinction is inevitable from an asteroid strike

Kunich 97

(Lt. Col. John C. Kunich, Staff Judge Advocate, 50th Space Wing, Falcon Air Force Base – “Planetary Defense: The Legality of Global Survival,” The Air Force Law Review, Volume 41 [41 A.F.L. rev. 119). [Online] LexisNexis) jfs

It is true that destructive impacts of gigantic asteroids and comets are extremely rare and infrequent when compared with most other dangers humans face, with the [\*126] intervals between even the smallest of such events amounting to many human generations... No one alive today, therefore, has ever witnessed such an event, and indeed there are no credible historical records of human casualties from impacts in the past millennium. Consequently, it is easy to dismiss the hazard as negligible or to ridicule those who suggest that it be treated seriously. n32 On the other hand, as has been explained, when such impacts do occur, they are capable of producing destruction and casualties on a scale that far exceeds any other natural disasters; the results of impact by an object the size of a small mountain exceed the imagined holocaust of a full-scale nuclear war... Even the worst storms or floods or earthquakes inflict only local damage, while a large enough impact could have global consequences and place all of society at risk... Impacts are, at once, the least likely but the most dreadful of known natural catastrophes. n33 What is the most prudent course of action when one is confronted with an extremely rare yet enormously destructive risk? Some may be tempted to do nothing, in essence gambling on the odds. But because the consequences of guessing wrong may be so severe as to mean the end of virtually all life on planet Earth, the wiser course of action would be to take reasonable steps to confront the problem. Ultimately, rare though these space strikes are, there is no doubt that they will happen again, sooner or later. To do nothing is to abdicate our duty to defend the United States, and indeed the entire world, and place our very survival in the uncertain hands of the false god of probabilities. Thus, the mission of planetary defense might be considered by the United States at some point in time, perhaps with a role played by the military, including the United States Air Force.

### Asteroid based extinction is categorically different from any other impact

Matheny ‘7

(Jason G., Prof of Health Policy and Management, Bloomberg School of Public Health at Johns Hopkins University, “Reducing the Risk of Human Extinction,” Risk Analysis, v27n5, http://jgmatheny.org/matheny\_extinction\_risk.htm]

Even if extinction events are improbable, the expected values of countermeasures could be large, as they include the value of all future lives. This introduces a discontinuity between the CEA of extinction and nonextinction risks. Even though the risk to any existing individual of dying in a car crash is much greater than the risk of dying in an asteroid impact, asteroids pose a much greater risk to the existence of future generations (we are not likely to crash all our cars at once) (Chapman, 2004 ). The "death-toll" of an extinction-level asteroid impact is the population of Earth, plus all the descendents of that population who would otherwise have existed if not for the impact. There is thus a discontinuity between risks that threaten 99% of humanity and those that threaten 100%.

### Best detection approach is a combination of ground and space based approaches; Congress has not approved the funds

NATIONAL  ACADEMY  OF  SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council <http://www.nap.edu/catalog.php?record_id=12842>)

No combination of telescope systems discussed above can complete this survey within 20 years, although significant progress could be made. Combined ground- and space-based surveys have a number of advantages. Such surveys discover more NEOs of all sizes, including a substantial number smaller than 140 meters in diameter. These combined surveys also provide more characterization data about the entire NEO population. With both infrared and visible data for most targets, it would be possible to obtain accurate diameter estimates for all objects, as well as measurements of their albedos and their surface and thermal properties. These high-value characterization data could help to guide mitigation campaign studies. Additionally, a dual survey provides much information on the population of objects smaller than 140 meters in diameter. Finding: The selected approach to completing the George E. Brown, Jr. Near-Earth Object Survey will depend on nonscientific factors: • If the completion of the survey as close as possible to the original 2020 deadline is considered more important, a space mission conducted in concert with observations using a suitable ground-based telescope and selected by peer-reviewed competition is the better approach. This combination could complete the survey well before 2030, perhaps as early as 2022 if funding were appropriated quickly. • If cost conservation is deemed more important, the use of a large ground-based telescope is the better approach. Under this option, the survey could not be completed by the original 2020 deadline, but it could be completed before 2030. To achieve the intended cost-effectiveness, the funding to construct the telescope must come largely on the basis of non-NEO programs. As noted above, neither Congress nor the administration has requested adequate funding to conduct the survey to identify ␣90 percent of the potentially hazardous NEOs by the year 2020. Multiple factors will drive the decision on how to approach this survey in the future. These include but are not limited to the perceived urgency for completing the survey of 140-meter-diameter NEOs as close to the original 2020 deadline as feasible and the availability of funds to provide for the successful completion of the survey. The combination of a space- based detection mission with a large ground-based telescope could complete the survey in the shortest time, that is, closest to the original 2020 deadline. A space-based mission alone could complete the survey only 2 to 4 years later than a survey conducted with both a space-based telescope and a large ground-based telescope. The cost of optimizing the LSST for NEO detection observations was estimated in 2007 to be an increment of approximately $125 million to the cost of the basic telescope system (Ivezi␣, 2009), becoming the most cost-effective means to complete the survey. (Note that the annual operating cost of a ground-based telescope is approximately 10 percent of the development and construction costs.) The completion date would be extended. The decision to extend this date requires the acceptance of the change in risk over that time.

### Current forms of asteroid deflection using nuclear weapons will fail and the warheads will explode on Earth

IAA ‘9

(International Academy of Astronautics, “Dealing with the Threat To Earth From Asteroids and Comets,” http://iaaweb.org/iaa/Scientific%20Activity/Study%20Groups/SG%20Commission%203/sg35/sg35finalreport.pdf)

There is a persistent notion in lay circles that the way to deal with a dangerous NEO is to simply hit it with an ICBM and vaporize it in space. Unfortunately, reality is far removed from this illusion. While it is likely that we may be able to rapidly reconfigure an ICBM computer guidance system to intercept a point or object in near-Earth space, ICBM propulsion system performance is insufficient to enable intercept beyond a few hundred kilometers above the Earth’s surface. Stages must be added to an ICBM to enable it to achieve the necessary escape velocity and to place the weapon on an intercept trajectory with a NEO. While these upper stage technologies are space qualified, such a system would have too low a reliability for the NEO intercept mission given the potentially horrendous consequences of an Earth impact, and might thus require many sequential launches of several such vehicles to have any reasonable chance of successfully deflecting a NEO. Such attempts would be part of a dedicated “campaign” utilizing several different launch vehicle types, designed with different upper stages, using different end game techniques, and different nuclear warhead types, in order to obtain a high probability of success. Furthermore at least one failed launch attempt is likely if many are required, and with a nuclear payload this could result in serious environmental effects in and of itself. Thus, it is clear that for the nuclear concept several dedicated designs of a inherently highly reliable launch vehicles and multi-stage interceptors would be extremely desirable to loft the nuclear warheads, and thus the use of existing ICBMs, even if outfitted with current technology upper stages, is highly undesirable if not essentially ruled out.

### We need to examine options for NEO deflection is now; must examine all possible options

Borchers 2009

(Brent W., Major, USAF Should the USAF be Involved in Planetary Defense?AIR COMMAND AND STAFF COLLEGE AIR UNIVERSITY <http://www.dtic.mil/cgi> bin/GetTRDoc?AD=ADA539693&Location=U2&doc=GetTRDoc.pdf)

These numbers do not include the additional cost for developing a means to “attack” or defend against an incoming object, but once we know an impact will occur without any action on our part, is there really any price or cost that we wouldn’t be willing to pay associated with our survival? Even with a regional impact that would occur outside the U.S. borders, the cost of providing disaster relief and the loss of lives and real property that the U.S. relies on for manufacturing and raw material trade with such a nation would make it worth our while from an investment perspective to avoid future costs. This is not even taking into consideration the moral responsibility a nation such as the U.S. must feel if we had the power to stop such an act from occurring. If we spend all this extra money on detection and tracking capability, then what good will it do us if we discover an impact is imminent and are powerless to stop it? What exactly are our plans and options when this problem does present itself, as it eventually will? First, from a planning perspective, no nation has a detailed or acceptably thought out or tested plan on how to deflect or destroy an incoming object. We are finally getting somewhere in the tracking and identification portion of the problem as mentioned previously, but we are a long way from solving the problem. Most plans deal with mitigating the damage from an impact by preparing our population for the event through the civil authorities and with sheltering in place measures. The typical response would be to sit in old nuclear fallout shelters, distribute food and water and wait out the effects if possible and provide help and aid to those in need who are most affected by the events in other nations once the initial strike has passed. This scenario involves giving up on the most obvious solution, deflecting or altering the trajectory of the body set to impact the Earth. Even though the task of deflecting a large NEO poses complex technical problems it is surely better than just continuing on and waiting for the inevitable. Here the maxim “an ounce of prevention is worth a pound of cure” surely makes sense. Options for tackling this problem range from obliterating the object with nuclear warheads, slowing it down or deflecting it with pulses from a laser, attaching a solar sail to slow it down, using a gravity tug system to dislodge its orbit, or drilling into its surface to break it apart. Although none of these methods have been proven or even partially developed except in theory, some stand above others as valid courses of action when viewed by engineers, scientists, and space experts in civilian and government circles.

## Contention 3 – Solvency

### Research should go beyond the search and monitoring of NEO’s; it should gain information necessary to develop effective mitigation strategies

NATIONAL ACADEMY OF SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council <http://www.nap.edu/catalog.php?record_id=12842>)

The scope of this research program on NEO impact hazards would ideally be targeted to address all of the areas in which uncertainties stemming from a lack of knowledge and/or understanding hamper scientists’ ability to quantify and mitigate the NEO impact risk. For instance, there is uncertainty as to the magnitude of the impact risk for several reasons. One reason is that the populations of small potential Earth impactors are poorly understood, so there is uncertainty even about the average impact rates by objects greater than 140 meters in diameter or greater than 50 meters in diameter. Another reason for the uncertainty with respect to the magnitude of the risk is that the fundamental natures of these bodies are not known: what they are made of, or to what extent they may be intact objects as opposed to heavily fractured, or even completely separate, components traveling together as loose, gravitationally bound aggregates. Some 15 percent of known NEOs have one or more satellites. Furthermore, even given knowledge of the size, impact energy, and fundamental nature of an impacting object, the effects of the impact on Earth are uncertain. They depend on whether and how high in the atmosphere the impactor may break up before hitting the surface, and on whether an impact occurs on shallow water, on deep water, or on land, or on any of the rock types found there. In addition, the impact effects would not necessarily be limited to local or regional effects near the time and place of the impact, but could include, for large impacts, global climate change or tsunamis. But how large an impact and what kind of impact could cause these effects is still uncertain. A research program is needed to address all of these issues in order to assess and quantify the risks associated with the NEO impact hazard. The ability to mitigate the impact hazard, or even to define appropriate strategies for mitigating the hazard, likewise depends on the acquisition of the new knowledge and understanding that could be gained through a research program. Even if the only viable mitigation approach to an impending impact is to warn the population and to evacuate, better information is needed for making sound decisions. Under what conditions should warning be provided and when, and who should evacuate? If, however, there are available active mitigation options, like changing the orbit of an impactor, again better information is needed: One must be able to predict with confidence the response of an impactor to specific forms of applied forces, impacts of various types and speeds, or various types of radiant energy, such as x rays. The required information goes beyond the basic physical characterization that determines the size and mass of the impactor and includes surface and subsurface compositions, internal structures, and the nature of their reactions to various inputs. Just as the scope of earthquake research is not limited only to searching for and monitoring earthquakes, the scope of NEO hazard mitigation research should not be limited to searching for and detecting NEOs. A research program is a necessary part of an NEO hazard mitigation program. This research should be carried out in parallel with the searches for NEOs, and it should be broadly inclusive of research aimed at filling the gaps in present knowledge and understanding so as to improve scientists’ ability to assess and quantify impact risks as well as to support the development of mitigation strategies. This research needs to cover several areas discussed in the previous chapters of this report: risk analysis (Chapter 2), surveys and detection of NEOs (Chapter 3), character- ization (Chapter 4), and mitigation (Chapter 5). The committee stresses that this research must be broad in order to encompass all of these relevant and interrelated subjects. Recommendation: The United States should initiate a peer-reviewed, targeted research program in the area of impact hazard and mitigation of NEOs. Because this is a policy-driven, applied program, it should not be in competition with basic scientific research programs or funded from them. This research program should encompass three principal task areas: surveys, characterization, and mitigation. The scope should include analysis, simulation, and laboratory experiments. This research program does not include mitigation space experiments or tests that are treated elsewhere in this report.

### US should take the lead in joint efforts to respond to NEO’s

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(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council NATIONAL ACADEMY OF ENGINEERING INSTITUTE OF MEDICINE NATIONAL RESEARCH COUNCIL <http://www.nap.edu/catalog.php?record_id=12842>)

NATIONAL AND INTERNATIONAL COOPERATION Responding effectively to hazards posed by NEOs requires the joint efforts of diverse institutions and individuals, with organization playing a key role. Because NEOs are a global threat, efforts to deal with them could involve international cooperation from the outset. (However, this is one area in which one nation, acting alone, could address such a global threat.) The report discusses possible means to organize, both nationally and interna- tionally, responses to the hazards posed by NEOs. Arrangements at present are largely ad hoc and informal here and abroad, and they involve both government and private entities. The committee discussed ways to organize the national community to deal with the hazards of NEOs and also recommends an approach to international cooperation: Recommendation: The United States should take the lead in organizing and empowering a suitable international entity to participate in developing a detailed plan for dealing with the NEO hazard. One major concern with such an organization, especially in the area of preparing for disasters, is the maintenance of attention and morale, given the expected exceptionally long intervals between harmful events. Countering the tendency to complacency would be a continuing challenge. This problem would be mitigated if, for example, the civil defense aspects were combined in the National Response Framework with those for other natural hazards.

### Most methods of defense are only in planning stages; must research and test to determine effectiveness

NATIONAL  ACADEMY  OF  SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council NATIONAL  ACADEMY  OF  ENGINEERING INSTITUTE  OF  MEDICINE NATIONAL  RESEARCH  COUNCIL http://www.nap.edu/catalog.php?record\_id=12842)

MITIGATION “Mitigation” refers to all means of defending Earth and its inhabitants from the effects of an impending impact by an NEO. Four main types of defense are discussed in this report. The choice of which one(s) to use depends primarily on the warning time available and on the mass and speed of the impactor. The types of mitigation are these: 1. Civil defense*.* This option may be the only one feasible for warning times shorter than perhaps a year or two, and depending on the state of readiness for applying an active defense, civil defense may be the only choice for even longer times. 2. “Slow-push” or “slow-pull” methods*.* For these options the orbit of the target object would be changed so that it avoided collision with Earth. The most effective way to change the orbit, given a constraint on the energy that would be available, is to change the velocity of the object, either in or opposite to the direction in which it is moving (direct deflection—that is, moving the object sideways—is *much* less efficient). These options take considerable time, on the order of decades, to be effective, and even then they would be useful only for objects whose diameters are no larger than 100 meters or so. 3. Kinetic impactors*.* In these mitigation scenarios, the target’s orbit would be changed by the sending of one or more spacecraft with very massive payload(s) to impact directly on the target at high speed in its direction, or opposite to its direction, of motion. The effectiveness of this option depends not only on the mass of the target but also on any net enhancement resulting from material being thrown out of the target, in the direction opposite to that of the payload, upon impact. 4. Nuclear explosions*.* For nontechnical reasons, this would likely be a last resort, but it is also the most powerful technique and could take several different forms, as discussed in the report. The nuclear option would be usable for objects up to a few kilometers in diameter. For larger NEOs (more than a few kilometers in diameter), which would be on the scale that would inflict serious global damage and, perhaps, mass extinctions, there is at present no feasible defense. Luckily such events are exceedingly rare, the last known being about 65 million years ago. Of the foregoing options, only kinetic impact has been demonstrated (by way of the very successful Deep Impact spacecraft that collided with comet Tempel-1 in July 2006). The other options have not advanced past the conceptual stage. Even Deep Impact, a 10-kilometer-per-second impact on a 6-kilometer-diameter body, was on a scale far lower than would be required for Earth defense for an NEO on the order of 100 meters in diameter, and it impacted on a relatively large—and therefore easier to hit—object. Although the committee was charged in its statement of task with determining the “optimal approach to developing a deflection capability,” it concluded that work in this area is relatively new and immature. The committee therefore concluded that the “optimal approach” starts with a research program. FURTHER RESEARCH Struck by the significant unknowns in many aspects of NEO hazards that could yield to Earth-based research, the committee recommends the following: Recommendation: The United States should initiate a peer-reviewed, targeted research program in the area of impact hazard and mitigation of NEOs. Because this is a policy-driven, applied program, it should not be in competition with basic scientific research programs or funded from them. This research program should encompass three principal task areas: surveys, characterization, and mitigation. The scope should include analysis, simulation, and laboratory experiments. This research program does not include mitigation space experiments or tests that are treated elsewhere in this report.

### We have the tech, just need early detection to minimize costs

Atkinson 10

(Nancy Atkinson, Jan 22 2010, Universe Today staff writer, “Asteroid Detection, Defection Needs More Money, Report Says” , <http://www.universetoday.com/51811/asteroid-detection-deflection-needs-more-money-report-says/>) PS

“We have the technology today to move an asteroid,” Schweikart said. “We just need time. It doesn’t take a huge spacecraft to do the job of altering an asteroid’s course. It just takes time. And the earlier we could send a spacecraft to either move or hit an asteroid, the less it will cost. We could spend a few hundred million dollars to avoid a $4 billion impact.” But the report put out by the NRC stresses the methods for asteroid/comet defense are new and still immature. The committee agreed that with sufficient warning, a suite of four types of mitigation is adequate to meet the threat from all NEOs, except the most energetic ones.

# Inherency Extensions

## No PDS

### Current lack of a global planetary defense capability puts humans at risk of extinction

Urias et al 96

[COL (Sel) John M. Urias Et. Al., Planetary Defense: Catastrophic Health Insurance for Planet Earth,” A Research Paper Presented To Air Force 2025,October 1996, http://csat.au.af.mil/2025/volume3/vol3ch16.pdf]

Collectively as a global community, no current viable capability exists to defend the EMS against a large ECO, leaving its inhabitants vulnerable to possible death and destruction of untold proportion and even possible extinction of the human race. In this regard, a planetary defense system (PDS) capability should be resourced, developed, and deployed. At this time Planetary Defense is not an assigned or approved mission of the Department of Defense or the Air Force. Such a system would consist of a detection subsystem, command, control, communications, computer, and intelligence (C4I) subsystem and a mitigation subsystem. There are many potential variations of these subsystems which, with advances in novel technologies, will be available by 2025 to develop a credible PDS. We propose a three-tier system developed sequentially in time and space. Such a system would serve not only as a means to preserve life on earth, but also help to unite the global community in a common effort that would promote peaceful cooperation and economic prosperity as related spin-offs and dual uses of novel technologies evolve.

## No Detection/Tracking

### Only $4 million is spent each year on discovering near Earth objects (NEO’s); not enough to meet mapping goal of 90% by 2020

NATIONAL  ACADEMY  OF  SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council NATIONAL  ACADEMY  OF  ENGINEERING INSTITUTE  OF  MEDICINE NATIONAL  RESEARCH  COUNCIL

http://www.nap.edu/catalog.php?record\_id=12842)

The United States spends about $4 million annually searching for near-Earth objects (NEOs), according to NASA.1 The goal is to detect those that may collide with Earth. The funding helps to operate several observatories that scan the sky searching for NEOs, but, as explained below, it is insufficient to detect the majority of NEOs that may present a tangible threat to humanity. A smaller amount of funding (significantly less than $1 million per year) supports the study of ways to protect Earth from such a potential collision (“mitigation”). Congress established two mandates for the search for NEOs by NASA. The first, in 1998 and now referred to as the Spaceguard Survey, called for the agency to discover 90 percent of NEOs with a diameter of 1 kilometer or greater within 10 years. An object of this limiting size is considered by many experts to be the minimum that could produce global devastation if it struck Earth. NASA is close to achieving this goal and should reach it within a few years. However, as the recent (2009) discovery of an approximately 2- to 3-kilometer-diameter NEO demonstrates, there are still large objects to be detected. The second mandate, established in 2005, known as the George E. Brown, Jr. Near-Earth Object Survey Act,2 called for NASA to detect 90 percent of NEOs 140 meters in diameter or greater by 2020. As the National Research Council’s (NRC’s) Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies noted in its August 2009 interim report (NRC, 2009): Finding: Congress has mandated that NASA discover 90 percent of all near-Earth objects 140 meters in diameter or greater by 2020. The administration has not requested and Congress has not appropriated new funds to meet this objective. Only limited facilities are currently involved in this survey/discovery effort, funded by NASA’s existing budget. Finding: The current near-Earth object surveys cannot meet the goals of the 2005 George E. Brown, Jr. Near-Earth Object Survey Act directing NASA to discover 90 percent of all near-Earth objects 140 meters in diameter or greater by 2020.

### Not enough resources currently allocated to asteroid detection

Atkinson 10

(Nancy Atkinson, Jan 22 2010, Universe Today staff writer, “Asteroid Detection, Defection Needs More Money, Report Says” , <http://www.universetoday.com/51811/asteroid-detection-deflection-needs-more-money-report-says/>)

Are we ready to act if an asteroid or comet were to pose a threat to our planet? No, says [**a new report**](http://www.nap.edu/catalog.php?record_id=12842) from the National Research Council. Plus, we don’t have the resources in place to detect all the possible dangerous objects out there. The report lays out options NASA could follow to detect more near-Earth objects (NEOs) that could potentially cross Earth’s orbit, and says the $4 million the U.S. spends annually to search for NE Os is insufficient to meet a congressionally mandated requirement to detect NEOs that could threaten Earth. “To do what Congress mandated NASA to do is going to take new technology, bigger telescopes with wider fields,” said Don Yeomans, Manager of NASA’s Near Earth Object Program Office, speaking at the American Geophysical Union conference last month. However, Yeomans said work is being done to improve the quality and quantity of the search for potentially dangerous [asteroids](http://www.universetoday.com/32459/asteroids/) and [comets](http://www.universetoday.com/40186/comets/). “We have a long term goal to have three more 1.8 meter telescopes,” he said, “and the Large Synoptic Survey [Telescope](http://www.universetoday.com/14424/telescopes/) with an 8.4 meter aperture in 2016. Once these new facilities are in place, the data input will be like drinking from a fire hose, and the rate of warnings will go up by a factor of 40.” But getting all these facilities, and more, online and running will take continued and additional funding.

### Safeguard survey is only 75% completed of identifying 90% of NEO’s of 1 kilometer size

Borchers 2009

(Brent W., Major, USAF Should the USAF be Involved in Planetary Defense?AIR COMMAND AND STAFF COLLEGE AIR UNIVERSITY <http://www.dtic.mil/cgi> bin/GetTRDoc?AD=ADA539693&Location=U2&doc=GetTRDoc.pdf)

Now that the actual effects have been discussed, we can see that something probably should be done by the U.S. Government in conjunction with other world governments to identify these NEO risks and prevent them to the best of our ability. In this section we’ll address current efforts and if those efforts are enough or if we need to do more. If we have an inbound meteorite the first defense against such an object is time. Time is needed to either destroy it or alter its path, or if none of these options are available, time will be necessary to prepare the earth’s governments and population to survive the impact and stack the odds of survival in our favor. Buying this defense of time requires a method to identify and track these objects that might cross the earth’s path through space. Currently a system exists and a plan is under way to track and categorize as many near earth objects as possible. These efforts form part of the Spaceguard survey chartered by NASA in the early 1990’s. Both optical telescopes and larger radar telescopes are able to track and identify such objects. In fact, most scientists agree that if a more concerted effort was funded and led to identify NEO threats to the earth, we could probably have a 90% chance of gaining twenty years of lead time before an object impacted the earth.28 The original Spaceguard survey that started in 1992 had a goal of identifying 90% of the one kilometer or greater objects that could impact the earth and to have identified these by 2008.29 According to NASA’s Jet Propulsion Laboratory website over 5900 NEOs in total have been discovered as of the writing of this paper.30 Starting with the first object catalogued in 1995, work has progressed steadily and the numbers increase by about 600 new discoveries per year over the past 5 years.31Has the goal identifying over 90% of the objects that exist been reached? NASA studies propose that there are over 20,000 NEOs total to discover and identify.32 So by just looking at the numbers it appears that we haven’t reached our goal yet. However, how do you truly determine when you’ve reached 90% of an unknown number? It’s hard to tell as we’ll never know how many objects out there exist; after all, space is a very big place. However, using some common sense math it’s doubtful that we’ve achieved this goal yet. The number of discoveries per year would have to decline and somewhat represent a bell curve for us to think that we were approaching a 90% detection level. (see figures 3 and 4) Detecting around 600 a year means there are too many out there still to slow down our rate of detection. NASA is working to meet the goal of the Spaceguard survey and is an estimated 75% complete with identifying 90% of the NEO’s one kilometer or greater in diameter.33 The current total of 757 NEO’s that are one kilometer and greater in size has added about twenty five new NEOs per year over the past three years. The bell curve on the graph, (see figure 4) is starting to form and this could suggest that they are approaching the point where they have identified the majority of NEOs in this category.34

## No Funding

### Current radar installations provide promise for detection and measurement; however, funding is not adequate

NATIONAL  ACADEMY  OF  SCIENCES 2009

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CHARACTERIZATION AND THE ARECIBO AND GOLDSTONE OBSERVATORIES Obtaining the orbits and the physical properties of NEOs is known as characterization and is primarily needed to inform planning for any active defense of Earth. Such defense would be carried out through a suitable attack on any object predicted with near certainty to otherwise collide with Earth and cause significant damage. The apparently huge variation in the physical properties of NEOs seems to render infeasible the development of a comprehensive inventory through in situ investigations by suitably instrumented spacecraft: the costs would be truly astronomical. A spacecraft reconnaissance mission might make good sense to conduct on an object that, without human intervention, would hit Earth with near certainty. Such a mission would be feasible provided there was sufficient warning time for the results to suitably inform the development of an attack mission to cause the object to miss colliding with Earth. In addition to spacecraft reconnaissance missions as needed, the committee concluded that vigorous, ground- based characterization at modest cost is important for the NEO task. Modest funding could support optical observations of already-known and newly discovered asteroids and comets to obtain some types of information on this broad range of objects, such as their reflectivity as a function of color, to help infer their surface properties and mineralogy, and their rotation properties. In addition, the complementary radar systems at the Arecibo Observatory in Puerto Rico and the Goldstone Solar System Radar in California are powerful facilities for characterization within their reach in the solar system, a maximum of about one-tenth of the Earth-Sun distance. Arecibo which has a maximum sensitivity about 20-fold higher than Goldstone’s but does not have nearly as good sky coverage as Goldstone can, for example, model the three-dimensional shapes of (generally very odd-shaped) asteroids and estimate their surface characteristics, as well as determine whether an asteroid has a (smaller) satellite or satellites around it, all important to know for planning active defense. Also, from a few relatively closely spaced (in time) observations, radar can accurately determine the orbits of NEOs, which has the advantage of being able to calm public fears quickly (or possibly, in some cases, to show that they are warranted). Finding: The Arecibo and Goldstone radar systems play a unique role in the characterization of NEOs, providing unmatched accuracy in orbit determination and offering insight into size, shape, surface structure, and other properties for objects within their latitude coverage and detection range. Recommendation: Immediate action is required to ensure the continued operation of the Arecibo Observatory at a level sufficient to maintain and staff the radar facility. Additionally, NASA and the National Science Foundation should support a vigorous program of radar observations of NEOs at Arecibo, and NASA should support such a program at Goldstone for orbit determination and the characterization of physical properties. For both Arecibo and Goldstone, continued funding is far from assured, not only for the radar systems but for the entire facilities. The incremental annual funding required to maintain and operate the radar systems, even at their present relatively low levels of operation, is about $2 million at each facility (see Chapter 4). The annual funding for Arecibo is approximately $12 million. Goldstone is one of the three deep-space communications facilities of the Deep Space Network, and its overall funding includes additional equipment for space communications.

### NASA’s asteroid detection programs are drastically underfunded.

Space.com ‘10

(“Earth Not Properly Protected from Asteroids,” Space.com, 22 January http://www.space.com/7817-earth-properly-protected-asteroids.html)

The United States must do more to safeguard the Earth against destruction by an asteroid than merely prepping nuclear missiles, a new report has found. The 134-page report, released Friday by the National Academy of Sciences, states that the $4 million spent by the United States to identify all potentially dangerous asteroids near Earth is not enough to do the job mandated by Congress in 2005. NASA is in dire need of more funding to meet the challenge, and less than $1 million is currently set aside to research ways to counter space rocks that do endanger the Earth - measures like developing the spacecraft and technology to deflect incoming asteroids - the report states. An early draft of the report, entitled “Defending the Earth: Near-Earth Object Surveys and Hazard-Mitigation Strategies,” was released in August 2009. The final report, written by a committee of expert scientists, says NASA is ill-equipped to catalogue 90 percent of the nearby asteroids that are 460 feet (140 meters) across or larger as directed by Congress. The United States should also be planning more methods of defending Earth against an asteroid threat in the near-term. Nuclear weapons should be a last resort ? but they?re also only useful if the world has years of advance notice of a large, incoming space rock, the report states. Likewise, decades of notice are required to build and launch spacecraft to push an asteroid clear of Earth or smash it with a forceful, but non-nuclear, projectile, the committee wrote in the report. Organized evacuations and other civil defense efforts would only be useful in the event of smaller objects with limited advance notice, it added. NASA’s asteroid and near-Earth object experts have said that the agency has found about 85 percent of the largest nearby asteroids, ones that are a half-mile (1 km) wide or larger. But only 15 percent of the 460-foot wide asteroids near Earth have been discovered and tracked to date, and just 5 percent of nearby space rocks about 164 feet (50 meters) across have been found. Lindley Johnson, NASA's manager of the Near-Earth Objects program, has said that NASA needs up to $1 billion in additional funding over the next 15 years in order to meet its goal of finding all nearby asteroids that could threaten Earth. But neither President Barack Obama’s administration, nor that of former President George W. Bush, have set aside funding to support near-Earth object surveys, according to the report.

### US government not committed to funding search program now; justified funding increases could be made without causing budget issues

Borchers 2009

(Brent W., Major, USAF Should the USAF be Involved in Planetary Defense?AIR COMMAND AND STAFF COLLEGE AIR UNIVERSITY <http://www.dtic.mil/cgi> bin/GetTRDoc?AD=ADA539693&Location=U2&doc=GetTRDoc.pdf)

In December 2005 the U.S. Congress and U.S. President upped the ante and passed a NASA authorization act and charged NASA with detecting and cataloguing 90% of the 140 meter and larger NEO’s by the year 2020.35 It seems that the US government has realized the importance of this task and realizes while it is nice to know the status of the one kilometer “planet killer” asteroids, it’s time to move onto the next step and identify the medium sized “destroyer of nations” asteroids. This second survey could cost more than one billion dollars over the next eleven years if all the projects recommended by the scientists are funded. However, the U.S. government is obviously not taking this threat seriously and has only committed funding to the tune of about four million dollars per year. More funding is needed to continue this task that has been handed to NASA. As of Jun 2008, NASA has ID’d 959 asteroids that will come within 20 times the distance from the earth to the moon. Of those, 5 will come between the earth and the moon in the next century. The U.S. government and NASA can’t rest on their laurels now. The U.S. needs a committed and well funded effort to continue these operations and guarantee advance notice of an impending strike by a NEO. We can never detect and identify all of the NEO’s that could impact the earth. New NEO’s are being created outside and inside our solar system constantly. A collision in the asteroid belt or somewhere else in the solar system could create debris and form new objects that are on a collision course with earth. Similarly, the orbit of a current object could be changed by a collision or a piece of it breaking off, or its orbit being adjusted by simply passing near a planet or another object that tugs on it just enough with its gravitational field. Finally, there are comets or other objects that come into our solar system that are out of the view of our optical telescopes until they get too close for us to mount any defensive measures unless we are prepped ahead of time.37 A simple investment increase of tens of millions of dollars per year or even in the single digits would give the U.S. and the world a much higher awareness of the space surrounding our planet and our potential dangers associated with impacting objects. If the four million dollars spent per year so far as part of the Spaceguard survey has allowed us to increase our knowledge from basically zero to now almost 75% of the objects that might impact our planet and cause catastrophic damage, think of the increase in knowledge we’d have of NEOs from a slight increase in a few million dollars. In the government budget millions of dollars easily drop off the radar scope of most legislators. Most “big ticket” items cost in the hundreds of millions or billions of dollars. Most people who are aware of the problem would agree that we can afford the extra expense, even in today’s economy and in these times of shrinking government budgets. In fact, most people aware of the threat would say that we can’t afford not to increase efforts with the stakes so high. For example, the entire budget of NASA is approximately $20 billion dollars in fiscal year 2009. For the same period the U.S. Air Force’s budget for space as the Department of Defense (DOD) executive agent for space is around $18 billion dollars.38 Adding $10 million dollars per year to either of these budgets to track NEOs that are capable of causing a regional catastrophe or the extinction of the human race is drop in the bucket compared to the value. Even if Congress directs NASA or the Air Force through DOD to fund this ten million out of their own pocket, it would only account for .05% of their total space budgets. In some cases we probably have spent more government money in study the mating habits of the fruit fly that we have to ensure our own species’ survivability on this planet.

### PDS funding is consistently rejected by congress

Faith, 7

[Marcus Faith, Yahoo! Contributor Network, “Asteroid Threat Not Top Priority at NASA,” Mar 19, 2007, http://www.associatedcontent.com/article/183551/asteroid\_threat\_not\_top\_priority\_at.html?cat=7]

Although the United States is the only nation with an asteroid tracking program, it hasn't been able to get any money for it. Even modest proposals of $300 million dollars have been rejected by the congress. In 2005 congress asked NASA to come up with a plan to detect and deflect NEO's. NASA is set to release the full report this month, but there will be little for them to do with it. (www.space.com)

## No Mitigation

### Current system not equipped to deal with NEO’s; not as easy as Hollywood makes it out to be

Foust 2007

(Jeff, editor and publisher of The Space Review The three D’s of planetary defense March 19, http://www.thespacereview.com/article/835/1)

To take Hollywood’s word for it, stopping an incoming asteroid or comet from hitting the Earth is fairly straightforward. NASA discovers, or is alerted to the discovery of, an object on an impact course, and quickly cobbles together—either by itself or in cooperation with the Russians—a plan to deflect or outright destroy the intruder with nuclear weapons. Sometimes the job is done by some convenient (if treaty-violating) nuclear weapons already in orbit, but usually it’s a team of astronauts, with some non-professionals with critical skills thrown in, who quickly fly off in a highly modified shuttle to save the day. And save the day they do, although not before some fragments hit the Earth and wreak some havoc. It’s a storyline that has been used and reused a number of times, from *Meteor* to *Deep Impact* and *Armageddon* to, most recently, the pretty awful Sci-Fi Channel film *Earthstorm* (whose twist is that, this time, the asteroid hits the Moon, and threatens to break it up until our intrepid astronauts—and an explosives expert—save the day.) Reality, of course, is a bit more complex than what can be compressed into a two-hour movie. Dealing with an object that’s on a collision course is more complicated than sending some astronauts in a nuclear-powered shuttle to blow it up with an atomic bomb: besides the fact that there are no nuclear-powered shuttles that can zip across the solar system, blowing up or even trying to deflect an asteroid with nuclear weapons can cause more harm than good. Movies also tend to gloss over the difficulty in discovering these objects and refining their orbits to confirm that they indeed pose a threat to the Earth: they’re discovered, their orbits plotted, and that’s it. Also overlooked is the decisionmaking process required to determine how best to deal with that impact threat, and who—besides the United States—should be involved in that effort. Those three areas—detection, decisionmaking, and deflection—are critical to successfully dealing with the problem posed by near Earth objects (NEOs), but as recent events have shown, there’s no consensus yet on how it should be done.

### NASA has no plans or technology to support a deflection mission.

Easterbrook 8

(Gregg Easterbrook, Fellow @ the Brookings Institute “The Sky Is Falling,” The Atlantic, June. [Online] http://www.theatlantic.com/magazine/print/2008/06/the-sky-is-falling/6807/)

Given the scientific findings, shouldn’t space rocks be one of NASA’s priorities? You’d think so, but Dallas Abbott says NASA has shown no interest in her group’s work: “The NASA people don’t want to believe me. They won’t even listen.” NASA supports some astronomy to search for near-Earth objects, but the agency’s efforts have been piecemeal and underfunded, backed by less than a tenth of a percent of the NASA budget. And though altering the course of space objects approaching Earth appears technically feasible, NASA possesses no hardware specifically for this purpose, has nearly nothing in development, and has resisted calls to begin work on protection against space strikes. Instead, NASA is enthusiastically preparing to spend hundreds of billions of taxpayers’ dollars on a manned moon base that has little apparent justification. “What is in the best interest of the country is never even mentioned in current NASA planning,” says Russell Schweickart, one of the Apollo astronauts who went into space in 1969, who is leading a campaign to raise awareness of the threat posed by space rocks. “Are we going to let a space strike kill millions of people before we get serious about this?” he asks.

# Harms Extensions

## Asteroids Coming

The planet’s overdue for an asteroid impact

Ghayur ‘7

[A., Lecturer, University Institute of Information Technology, UAAR, 07 <A., Developing a Three Period Strategy to Face a Global Threat: A Preliminary Analysis <http://www.aero.org/conferences/planetarydefense/2007papers/P5-1--Ghayur--Paper.pdf>]

1694 was the year when a man envisioned a bone chilling scenario after witnessing a Near Earth Object (NEO); “What if it would return and hit the Earth?” The man is now a world renowned scientist, Dr. Edmond Halley, and the object now one of the most famous comets, the Halley’s Comet has returned numerous times without any incident. Human civilization has come a long way since the Dark Ages of mid twentieth century, however, it is only now that the mankind is realizing the veracity of the apocalyptic scenario – a heavenly body colliding with earth – the Hellish nightmare which troubled Dr. Halley. Although the chances of Halley’s Comet plummeting into earth are nearly nonexistent, the chances nevertheless of another NEO colliding head on with earth are very much there. The battle-scared face of moon and the numerous impact craters on earth are a living testament to it. But all this evidence proved insufficient to turn any heads until 1994 when Shoemaker-Levy Nine crashed into Jupiter. The earth-sized storms created on Jupiter surface sent alarms through the echelons of bureaucracy and politics and suddenly a nonexistent apocalyptic nightmare had become a very much possible scenario. 1 Today, we are sitting in the midst of ever increasing human population on this planet Earth, which in turn is sitting amidst ever increasing number of identified NEOs. We are already overdue for our next big hit; last one occurring 65 million years ago at Chixilub. Any impact of that scale would result in deaths and displacement of billions, if not more. Do we have a global network and an institution to respond timely and effectively?

### Asteroid impact is very likely – thousands of undiscovered asteroids exist

Rollins 11

[James, bestselling author, “10 ways the world could end tomorrow” Guyism, 6-20-11, http://guyism.com/lifestyle/ways-the-world-could-end.html]

We all saw this earth-shattering disaster portrayed in movies like Armageddon and Deep Impact. But how likely is it that an asteroid or comet will hit the Earth? The answer: very likely. At this moment, astronomers have identified over 1000 near-earth asteroids that could be a danger. But that’s only those that we know about. Estimates suggest there are actually hundreds of thousands more out there. The Kuiper belt alone (near the planet Neptune) contains over a hundred thousand asteroids, which continually rain comets toward the sun and Earth. It would only take one unlucky hit to end life on this planet. Remember, it was an asteroid that killed the dinosaurs — are we next?

### An asteroid strike is inevitable

Urias et al 96

[COL (Sel) John M. Urias Et. Al., Planetary Defense: Catastrophic Health Insurance for Planet Earth,” A Research Paper Presented To Air Force 2025,October 1996, http://csat.au.af.mil/2025/volume3/vol3ch16.pdf]

Concern exists among an increasing number of scientists throughout the world regarding the possibility of a catastrophic event caused by an impact of a large earth-crossing object (ECO) on the Earth-Moon System (EMS), be it an asteroid or comet. Such events, although rare for large objects (greater than 1 kilometer diameter), are not unprecedented. Indeed, the great upheaval and resulting ice age that marked the extinction of the dinosaurs is thought to have been caused by the impact of a 10 km diameter asteroid. In 1908 a stony asteroid of approximately 50 meters diameter exploded in the air above the Tunguska River in Siberia, producing an equivalent yield of 15-30 megatons of TNT, and leveling over 2,000 square miles of dense forest. Such an event is thought to occur approximately every century. It is only a matter of time before the world finds itself in a crisis situation—a crisis involving the detection of a large ECO, leaving little time to react and resulting in global panic, chaos, and possible catastrophe.

### Asteroids are a clear and present danger

Schweickart et al, ’08

(L. Schweickart, Russell; D. Jones, Thomas; von der Dunk, Frans; Camacho-Lara, Sergio; Association of Space Explorers Near-Earth Object Committee 2008, Asteroid Threats: A Call For a Global Response, “The Coming Wave of NEO Discoveries”, p.11, http://www.nss.org/resources/library/planetarydefense/2008-AsteroidThreatsACallForGlobalResponse.pdf)

As of late 2008, we know of approximately 5,600 Near Earth Objects, and some 967 of those are known as Potentially Hazardous Asteroids: objects 150 m or larger which come within 0.05 astronomical units (about 7.5 million km) of Earth. Current United States law directs the National Aeronautics and Space Administration (NASA) by 2020 to discover, track, catalog and characterize 90% of all near-Earth objects over 140 m in diameter. Advanced telescopes planned for operation within the next 5-7 years will greatly increase our ability to find more and smaller NEOs. Over the next 10-15 years, the NEO discovery rate will increase dramatically. Based on what we know about the statistics of the NEO population, search programs over the next 15 years will add to the NEO database 200,000 to 400,000 potential impactors large enough to do substantial damage to Earth. Approximately 6,000 of these objects will have a “non-zero” probability of impacting Earth within the next 100 years. Generally these “non-zero” probabilities are very small, typically one in several hundred thousand or less, but it is likely that hundreds will have impact probabilities that are worrisome. Dozens of NEOs will likely be threatening enough that they will require a proactive decision about whether to take action to prevent an impact.

### Asteroids aren’t effectively in check

Jewitt 2000

(Jewitt, David, Professor in the Dept of Earth and Space Sciences @ UCLA, 1/28/2000, Asteroid and Comet Impact Hazards, “Astronomy: Eyes Wide Shut”, http://impact.arc.nasa.gov/news\_detail.cfm?ID=44)

It is now clear that asteroids occasionally wander from the main belt beyond Mars because of chaotic instabilities caused by Jupiter. Some of these errant asteroids strike the Earth with terrible consequences. On page 165 of this issue, Rabinowitz et al.1 report that the number of threatening near-Earth objects (NEOs) larger than 1 km in diameter is only half the previous estimates. But we still have no effective means of detecting them all, and no form of self-defense. The Earth bears the scars of previous encounters with NEOs. Hundreds of impact craters, some the size of small American states, have been discovered on the surface of our planet. Each was produced by a devastating explosion that must have been fatal to life in the surrounding areas on scales from local to global (Fig. 1). The Cretaceous-Tertiary mass extinction of 65 million years ago seems to have been triggered by the impact of an asteroid 10 km in diameter2. Ten thousand people killed by 'falling stones' in Shanxi Province, China, in 1490 were possibly the victims of a much smaller and thoroughly fragmented projectile. Still more recently, on 30 June 1908, 1,000 square kilometres of Siberian pine forest in Tunguska were blown flat by a 10-megaton atmospheric blast caused by a 70-metre asteroid. The gradual acceptance of the evidence for impacts by asteroids (and comets) has led naturally to questions about the magnitude of the threat posed by NEOs to life on Earth3,4. Rabinowitz and colleagues1 provide the most recent and best controlled estimate of the number of large, potentially Earth-threatening NEOs.They report that there are nearly 1,000 NEOs larger than 1 km in diameter and that, given the present rate of discovery, it will take 20 years for 90% of these objects to be found. Should we worry? The answer depends on the number of fatalities to be expected, but also on personal assessments of risk. The number of NEOs found by Rabinowitz et al. is within a factor of two of previous estimates based on less-controlled samples, so published estimates of impact mortality are essentially unchanged. Considering events of all energies there is about 1 chance in 20,000 of being killed by an impact during the course of a human lifetime4, similar to the likelihood of being killed in an airplane accident. The perception of risk from impacts is smaller than for being killed in a plane crash because planes crash at a steady rate with (relatively) few deaths per event, whereas lethal impacts are rare but kill a lot of people. At the very least, the potential consequences of impact are large enough to cause concern.

## Asteroids Bad - Extinction

### NEO’s impacts would be devastating, causing extinction

Borchers 2009

(Brent W., Major, USAF Should the USAF be Involved in Planetary Defense?AIR COMMAND AND STAFF COLLEGE AIR UNIVERSITY <http://www.dtic.mil/cgi> bin/GetTRDoc?AD=ADA539693&Location=U2&doc=GetTRDoc.pdf)

How large of an object does it take to produce visible, damaging effects? There are many factors that influence the effects of the object impacting the earth. The size of the object is an obvious one. Objects from tens of meters in diameter to tens of kilometers in diameter exist in the solar system and could come across the orbit of the earth. The density of these objects also varies greatly. Some meteors are made of an almost solid nickel/iron metallic mix, while others are a less solid stony mass. Also, comets can be made of loosely packed together ice, dust and rock matter. The speed at which these objects can impact the earth range from approximately 12 to 72 kilometers per second or 26,000 to 156,000 miles per hour.12 The area of the earth where it strikes also has a large effect. Is it near a densely populated area of the planet, does it strike the ocean and create a tsunami, at what angle does it impact the earth? All of these are important variables and questions. For simplicity’s sake in this paper many of the variables are averaged and we mainly discriminate between the effects of an object based on the object’s size. The current answer to the question “How big does an impacting object have to be to create major effects?” seems to state that an object with a diameter of tens of meters or greater that survives entry into the atmosphere would be capable of major damage and releasing enough energy to approximate two to three times the power of the atomic bombs dropped on Nagasaki and Hiroshima.13 When you’re talking about kinetic energy being released that equates to the first nuclear weapons developed, it may sound like a lot, but it pales in comparison to the next size up.14 Real catastrophic effects come into play when the object is in the size range of hundreds of meters, especially as the size of the object approaches one kilometer in diameter.15 These impacts would produce craters multiple kilometers in diameter and cause destruction on at least a regional scale. The blast energies are in the multi-megaton range and start to exceed the destructive capabilities of the largest nuclear weapons ever produced. At the upper bounds of this category, approaching the one kilometer diameter range, some effects could have global significance with regard to weather patterns and atmospheric cooling similar to a “nuclear winter” type effect.16 This is due to dust and debris from the impact blocking the sun’s rays after it is ejected high into the atmosphere.17 The effects from a one kilometer wide asteroid with sufficient speed and kinetic energy could impact almost 25% of the earth’s population with its effects.18 Finally, we approach the range where effects are almost beyond belief, the grand daddy of them all. A NEO in the one to five kilometer diameter range would produce effects that have serious global consequences no matter where on the earth it strikes. Again, a “nuclear winter” type scenario would almost certainly occur where the sun could be blotted out by the dust in the atmosphere for months. Plants, crops and animals would die, the very survival of civilization and the human race would be at stake.19 Massive earthquakes would work their way across the land Tsunamis caused by such an event could be hundred of meters high and wipe out entire coastal areas of continents. Acid rain would be created from all the burning pollutants in the blast and freshwater lakes and rivers could be acidified. Even after the dust settled, follow-on effects of increased green house effects could raise global temperatures on an average of ten degrees Celsius for years or decades following the event.20 Such an impact would have lasting effects on the future of humanity and all the plants and animals on the earth that survived the initial impact.

### Its empirically proven that an asteroid impact could cause extinction

Stone, 4

[Stone, Michael P. , 59 U. Miami L. Rev. 435 (2004-2005), Anti-Prognostication, Hein Online]

Among the natural catastrophes, Posner claims that the catastrophic risk with the greatest potential for harm is that of an asteroid collision.55 It is believed that roughly 250 million years ago, an asteroid collision resulted in the extinction of ninety percent of the earth's species (p. 25). Likewise, some sixty-five million years ago, it is believed that an asteroid collision may have resulted in the extinction of the dinosaurs, although paleontologists disagree over the actual cause of extinction (p. 25). The dominant view is that the dust emitted from the asteroid strike impeded photosynthesis and consequently caused the dinosaurs to starve to death (p. 25). An alternative view supposes that the synergy of dust, forest fires, and sulfuric acid emitted from the vaporizing of sulfate rock caused the extinction of the dinosaurs (p. 25). Regardless of which story is correct, the "real world" effect of asteroid impact is clear. Were a large enough asteroid to strike the earth, the extinction or near extinction of the human race could result from a "combination of fire, concussion, enormous tidal waves, and the blocking for several years of the sunlight required for crops and other plant life" (p. 25).

### Collisions lead to extinction

Institute for Astronomy, University of Hawaii 5

(Pan Starrs (Panoramic Survey Telescope and Rapid) , “The Threat to Earth from Asteroids & Comets” , http://pan-starrs.ifa.hawaii.edu/public/asteroid-threat/asteroid\_threat.html)

Since it formed over 4.5 billion years ago, Earth has been hit many times by asteroids and comets whose orbits bring them into the inner solar system. These objects, collectively known as Near Earth Objects or NEOs, still pose a danger to Earth today. Depending on the size of the impacting object, such a collision can cause massive damage on local to global scales. There is no doubt that sometime in the future Earth wil suffer another cosmic impact; the only question is "when?". There is strong scientific evidence that cosmic collisions have played a major role in the mass extinctions documented in Earth's fossil record. That such cosmic collisions can still occur today was demonstrated graphically in 1994 when Comet Shoemaker-Levy 9 broke apart and 21 fragments, some as large as 2 km in diameter, crashed into the atmosphere of Jupiter. If these fragments had hit Earth instead, we would have suffered global catastrophes of the kind that inspire science fiction movies

## Asteroids Bad – Nuclear War

### Asteroids entering the earth’s atmosphere turn tensions between nations into nuclear conflicts

BBC 2

[BBC, “Asteroids 'could trigger nuclear war',” Monday, 15 July, 2002, <http://news.bbc.co.uk/2/hi/science/nature/2128488.stm>]

A small asteroid could accidentally trigger a nuclear war if mistaken for a missile strike, experts have warned. Scientists and military chiefs studying the threat are calling for a global warning centre to be set up to inform governments immediately of asteroid impacts. The risk is seen as particularly grave if an asteroid blast were to happen in areas of military tension, such as over nuclear-armed neighbours India and Pakistan Each year about 30 asteroids several metres in length pierce the atmosphere and explode, with even the smaller sized ones unleashing as much energy as the nuclear bomb dropped on Hiroshima in Japan. 'Panic' reaction Earlier this month, an Israeli pilot flying an airliner over the Ukraine reported seeing a blue flash in the sky similar to the type of blast caused by a surface-to-air missile, despite Ukrainian authorities saying no such missile had been fired. Experts now believe the pilot saw an explosion caused by an asteroid entering the Earth's atmosphere at high speed. Experts met last week in the US capital Washington DC to discuss what might have happened had such an explosion occurred over a volatile area such as the India-Pakistan region. "Neither of those nations has the sophisticated sensors we do that can determine the difference between a natural Neo (near-Earth object) impact and a nuclear detonation," Air Force Brigadier General Simon Worden from the US Space Command told the Aerospace Daily newspaper. "The resulting panic in the nuclear-armed and hair-trigger militaries there could have been the spark for a nuclear war." Warning centre call The incident over Ukraine was also extremely politically sensitive.

### Asteroid collisions risk starting accidental nuclear wars due to misperception

Bosker 2

[Staff Sgt. A.J., “Near-Earth Objects Pose Threat, General Says,” SpaceDaily, Sep 17, 2002, http://www.spacedaily.com/news/deepimpact-02s.html]

This summer, much of the world watched as India and Pakistan faced-off over the disputed Kashmir region, worried that the showdown could escalate into a nuclear war. Coincidentally, U.S. early warning satellites detected an explosion in the Earth's atmosphere June 6, at the height of the tension, with an energy release estimated to be 12 kilotons. Fortunately the detonation, equivalent to the blast that destroyed Hiroshima, occurred over the Mediterranean Sea. However, if it had occurred at the same latitude a few hours earlier, the result on human affairs might have been much worse, said Brig. Gen. Simon P. Worden, U.S. Space Command's deputy director for operations at Peterson Air Force Base, Colo. Had the bright flash, accompanied by a damaging shock wave, occurred over India or Pakistan, the resulting panic could have sparked a nuclear war, Worden recently told members of the congressionally mandated Commission on the Future of the U. S. Aerospace Industry in testimony here. Although U.S. officials quickly determined that a meteor caused the explosion, neither India nor Pakistan have the sophisticated sensors that can determine the difference between a natural near-Earth object impact and a nuclear detonation, Worden said in written testimony. This is one of many threats posed by NEOs, especially as more and more nations acquire nuclear weapons, said Worden, who appeared before the commission as a scientist who has studied NEOs and as a space expert familiar with the technologies that can be used to address the NEO threat. n recent years, the Department of Defense has been working to provide data about asteroid strikes to nations potentially under missile attack and to the scientific community; however, it takes several weeks for the data to be released since much of it is gathered from classified systems.

## Asteroids Bad – Outweighs Nuclear War

### Even a small asteroid collision with earth outweighs nuclear war

Schweickart ‘4

[Russell, Chair of the B612 Foundation, “Near-Earth Objects,” testimony before the Committee on Senate Commerce, Science and Transportation Subcommittee on Science, Technology, and Space, Apr.7 CQ, http://www.spaceref.com/news/viewsr.html?pid=12482]

First I'd like to thank you for the invitation to speak with you today about this emerging public policy issue of near Earth objects (NEOs) threatening life on Earth. One might have thought, just a few years ago, that the subject of asteroids was one for space wonks and wanna-be astronauts and astronomers. But today the realization is rapidly dawning on the media and the general public that asteroids are a subject of more than passing interest! More and more people are coming to know that some few of these asteroids do not silently pass the Earth, but indeed crash in, largely unannounced. On the rare occasions when this happens they can wreak havoc of a magnitude unprecedented in human history. At the upper limit impacts by large asteroids have caused global destruction leading to the virtually instantaneous extinction of life for most of the species living at the time. The dinosaurs were momentary witnesses to a billion megaton event of this kind 65 million years ago. At the lower limit of concern, but occurring much more frequently, we are dealing with events with an explosive force of 10-15 megatons. It is worth pointing out, however, that these small, most frequent events are more powerful than the blast from the most powerful nuclear weapon in the current U.S. nuclear arsenal.

## Asteroids Bad – Laundry List

### We must establish a PDS system to avoid an inevitable asteroid collision that will wreck agriculture, the environment, and government stability across the globe

Urias et al 96

[COL (Sel) John M. Urias Et. Al., Planetary Defense: Catastrophic Health Insurance for Planet Earth,” A Research Paper Presented To Air Force 2025,October 1996, http://csat.au.af.mil/2025/volume3/vol3ch16.pdf]

Regardless of the tendency to downplay the ECO threat, the probability of an eventual impact is finite. When it happens, the resulting disaster is expected to be devastatingly catastrophic. Scientists estimate the 8 impact by an asteroid even as small as 0.5 kilometers could cause climate shifts sufficient to drastically reduce crop yields for one or several years due to atmospheric debris restricting sunlight. Impacts by objects one to two kilometers in size could therefore result in significant loss of life due to mass starvation. Few countries store as much as even one year's supply of food. The death toll from direct impact effects (blast and firestorm, as well as the climatic changes) could reach 25 percent of the world's population.8 Although it may be a rare event, occurring only every few hundred thousand years, the average yearly fatalities from such an event could still exceed many natural disasters more common to the global population. Because the risk is small for such an impact happening in the near future, the nature of the ECO impact hazard is beyond our experience. With the exception of the asteroid strike in Shansi, China, which reportedly killed more than 10,000 people in 1490, ECO impacts killing more than 100 people have not been reported within all of human history.9 Natural disasters, including earthquakes, tornadoes, cyclones, tsunamis, volcanic eruptions, firestorms, and floods often kill thousands of people, and occasionally several million. In contrast to more familiar disasters, the postulated asteroid impact would result in massive devastation. For example, had the 1908 Tunguska event happened three hours later, Moscow would have been leveled. In another event occurring approximately 800 years ago on New Zealand's South Island, an ECO exploded in the sky, igniting fires and destroying thousands of acres of forests.10 If such an event were to occur over an urban area, hundreds of thousands of people could be killed, and damage could be measured in hundreds of billions of dollars.11 A civilization-destroying impact overshadows all other disasters, since billions of people could be killed (as large a percentage loss of life worldwide as that experienced by Europe from the Black Death in the 14th century).12 As the global population continues to increase, the probability of an ECO impact in a large urban center also increases proportionally. Work over the last several years by the astronomical community supports that more impacts will inevitably occur in the future. Such impacts could result in widespread devastation or even catastrophic alteration of the global ecosystem. During the last 15 years, research on ECOs has increased substantially. Fueled by the now widely accepted theory that a large asteroid impact caused the extinction of the dinosaurs, astronomy and geophysics communities have focused more effort on this area. Astronomers, with more capable detection equipment, 9 have been discovering potentially globally catastrophic 1 km and larger ECOs at an average rate of 25 each year.13 The combined results of these efforts help us to realize that there is a potentially devastating but still largely uncharacterized natural threat to earth's inhabitants. A disaster of this magnitude could put enormous pressure on the nations involved, destabilizing their economic and social fabrics. Certainly, such a disaster could affect the entire global community. Historically, governments have crumbled to lesser disasters because of a lack of resources and the inability to meet the needs of their people. Often only the infusion of external assistance has prevented more severe outcomes. What will happen when a significant portion--such as one-quarter--of the world's population is in need of aid, especially when it is not known how long the effects may last? Thus, the time has come to investigate development of the necessary technologies and strategies for planetary defense. While living in day-to-day fear is not the answer, there is a sizable danger to our planet from an ECO impact. Numerous other species may now be extinct because they could not take preventive steps. We must avoid delusions of invincibility. Humans must acknowledge that, as a species, we may not have existed long enough to consciously experience such a catastrophic event. But we currently have the technological means for detecting and possibly mitigating the ECO threat. We would be remiss if we did not use it.

### Asteroid strikes trigger simultaneous overlapping natural disasters

Marusek 7

(James Marusek, Nuclear Physicist and Engineer @ Impact “Comet and Asteroid Threat Impact Analysis,” Paper presented at the 2007 AIAA Planetary Defense Conference, 5-9 March 2007 (Washington, D.C.). [Online] http://www.aero.org/conferences/planetarydefense/2007papers/P4-3--Marusek-Paper.pdf)

Within human history many natural disasters have occurred. But we have yet to experience the depth and breathe of simultaneous disaster events that can be triggered by a large impact. Compounding multiple disasters will likely generate greater devastation, which will further complicate recovery efforts. An impact can trigger very intense earthquakes. In a large earthquake, the land will take on the appearance of the ocean during a storm with large rolling waves. A deafening roar will precede by a few seconds each quake. Large areas of land will be uplifted or sunk. Landslides will occur. Deep fissures will open up in the earth. Sand blows or eruptions will cover some areas with sand and mud. Above ground and underground rivers will be rerouted. Some new ponds and lakes will form while others disappear. Just as a massive earthquake will produce aftershocks, an impact from a large comet or asteroid can produce a sizeable increase in earthquake and volcanic activity. The core of the Earth may develop an oscillation or ring and as a result the pattern of earthquake/volcanic activity could develop a repetitious burst cycle of ~ 33-70 minutes. Some of this activity will occur in or near the oceans. An impact can also induce underwater landslides. These events can produce secondary tsunamis. These secondary tsunamis may also be very destructive when compared to the primary asteroid/comet "impact tsunami" because they will possess longer wavelengths. Because these secondary tsunamis will occur in many parts of the globe, they represent a considerable threat to all coastal regions around the world for several months. In my analysis ground shock is the major component of the primary threat from a deep impact, an impact that can physically penetrate through the Earth’s crust. This type of very large impact can result in global extinction events.4,5 The thickness of the Earth’s crust is ~ 3 miles (5 km) under the ocean and ~ 20-35 miles (30-50 km) on the continents.22 The ocean impact of a large comet or asteroid could puncture a hole through the Earth’s crust penetrating into the molten mantel beneath. This type of impact will produce two areas of devastation. The first is at the site of the impact. The second is at the exit vector on the opposite side of the planet, where the Earth will be turned into a jumbled debris field which will trigger mantle plume volcanism. The resulting massive lava flows at the exit vector represent the major cause of extinctions from an asteroid or comet impact because they result in a long-term global ecological damage. (There was a massive episode of lava flows in what is now India, producing huge sheets of volcanic material known as the Deccan Traps at the end of the Cretaceous Period. There was also a very massive episode of lava flows called the Siberian Traps at the end of the Permian Period.) This phenomenon is observed on other planets. On Mercury, a very large comet or meteorite impact formed the Caloris Basin. The shock wave from this impact traveled through the planet and produced a jumbled terrain on the opposite side of the planet.19 This theory is supported by recent research findings that uncovered a strong correlation between major impact events and secondary volcanic activity. During the last 4 billion years on Earth, scientists have identified 10 major impact events caused by collision with comets/meteors. Nine out of ten of these large Earth impacts also correlate with intense periods of mantle plume volcanism.23

### Results from collision are catastrophic – they can destroy agriculture and cause tsunamis

Schweickart et al, ’08

(L. Schweickart, Russell; D. Jones, Thomas; von der Dunk, Frans; Camacho-Lara, Sergio; Association of Space Explorers Near-Earth Object Committee2008, Asteroid Threats: A Call For a Global Response, “Executive Summary”, p.3, http://www.nss.org/resources/library/planetarydefense/2008-AsteroidThreatsACallForGlobalResponse.pdf)

Earth's geological and biological history is punctuated by evidence of repeated and devastating impacts from space. Sixty-five million years ago, an asteroid impact caused the extinction of the dinosaurs along with some 70% of Earth's living species. A more typical recent impact was the 1908 Tunguska Event, a 3-5 megaton explosion which destroyed 2,000 square kilometers of Siberian forest. A future asteroid collision could have disastrous effects on our interconnected human society. The blast, fires, and atmospheric dust produced could cause the collapse of regional agriculture, leading to widespread famine. Ocean impacts like the Eltanin event (2.5 million years ago) produce tsunamis which devastate continental coastlines. Asteroid 99942 Apophis, which has a 1-in-45,000 chance of striking Earth in 2036, would generate a 500-megaton (MT) blast and inflict enormous damage. Devastating impacts are clearly infrequent events compared to a human lifetime: Tunguska, thought to be caused by the impact of a 45-meter-wide asteroid, is an event that occurs on average two or three times every thousand years. However, when Near Earth Object (NEO) impacts occur they can cause terrible destruction, dwarfing that caused by more familiar natural disasters. Advances in observing technology will lead to the detection of over 500,000 NEOs over the next 15 years. Of those several dozen will pose an uncomfortably high risk of striking Earth and inflicting local or regional devastation.

### An impact from an asteroid whether big or small will destroy life as we know it

Vittorio 5

[Salvatore A. Vittorio. November 2005. Planetary Defense: Preventing a World of Trouble. Planetary Defense, http://mail.sott.net/articles/show/149793-Planetary-Defense-Preventing-a-World-of-Trouble]

Planetary defense encompasses protecting the Earth from potential destruction due to impact by a large piece of space debris. Astronomical telescopes and deep space radar systems have verified the existence of a large number of near Earth objects (NEOs), such as asteroids, meteoroids, and comets that potentially could destroy most life on Earth. Where NEOs intersect Earth's orbit, there exists a risk of a collision. An asteroid with a diameter of 1-10 km would strike the Earth with a power rivaling the strength of a multiple warhead attack with the most powerful thermonuclear explosives known to man. Computational fluid dynamics studies have indicated that an ocean strike by such an asteroid may create a gigantic [tsunami](http://www.csa.com/discoveryguides/planetary/gloss.php#tsu) that would flood and obliterate coastal regions. Perhaps even more significantly, a land strike may eject a massive dust cloud, rivaling that from the most powerful volcanic explosion, which could seriously affect climate on the scale of two to three years. It could alter our [biosphere](http://www.csa.com/discoveryguides/planetary/gloss.php#bio) to the point that life as we know it would cease to exist. As recently as 1998, the astronomical and astrophysics community thought that most of the own NEOs do not pose a near-term threat, and therefore do not present any danger to the Earth and its biosphere. However, the relatively recent collision of the comet Shoemaker-Levy 9 with the planet Jupiter on July 16, 1994, and continuing discoveries of non-cataloged asteroids passing near Earth without any advanced warning, have increased concerns. It is worthwhile to note that one striking feature of practically every celestial body in our solar system is the abundance of impact craters.

## Asteroids Bad – Agriculture/Climate

### Asteroid impact would devastate global agriculture and cause climactic shifts

Urias et al 96

[COL (Sel) John M. Urias Et. Al., Planetary Defense: Catastrophic Health Insurance for Planet Earth,” A Research Paper Presented To Air Force 2025,October 1996, http://csat.au.af.mil/2025/volume3/vol3ch16.pdf]

Regardless of the tendency to downplay the ECO threat, the probability of an eventual impact is finite. When it happens, the resulting disaster is expected to be devastatingly catastrophic. Scientists estimate the 8 impact by an asteroid even as small as 0.5 kilometers could cause climate shifts sufficient to drastically reduce crop yields for one or several years due to atmospheric debris restricting sunlight. Impacts by objects one to two kilometers in size could therefore result in significant loss of life due to mass starvation. Few countries store as much as even one year's supply of food. The death toll from direct impact effects (blast and firestorm, as well as the climatic changes) could reach 25 percent of the world's population.8 Although it may be a rare event, occurring only every few hundred thousand years, the average yearly fatalities from such an event could still exceed many natural disasters more common to the global population.

## Asteroids Bad – Environment

### Empirically, modest sized NEO’s cause serious environmental destruction

NATIONAL ACADEMY OF SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council NATIONAL ACADEMY OF ENGINEERING INSTITUTE OF MEDICINE NATIONAL RESEARCH COUNCIL http://www.nap.edu/catalog.php?record\_id=12842)

Over the past several decades, research has clearly demonstrated that major impact events have occurred throughout Earth’s history, often with catastrophic consequences. The Chicxulub impact apparently caused a mass extinction of species, possibly resulting from a global firestorm due to debris from the impact raining down around the planet. It may also have caused dramatic cooling for a year or more and global climatic effects that may have lasted a long time (e.g., O’Keefe and Ahrens, 1989). Many species became extinct at this time (includ- ing perhaps 30 percent of marine animal genera), but many survived and ultimately thrived in the post-dinosaur world. It may be that impacts throughout the history of this planet have strongly helped shape the development and evolution of life forms. Several recent events and new analyses have highlighted the impact threat to Earth: 1. As Comet Shoemaker-Levy 9 came close to Jupiter in 1992, tidal forces caused it to separate into many smaller fragments that then may have regrouped by means of self-gravity into at least 21 distinct pieces (e.g., Asphaug and Benz, 1994). These pieces impacted Jupiter in July 1994, creating a sequence of visible impacts into the gaseous Jovian atmosphere. The resultant scars in Jupiter’s atmosphere could be readily seen through Earth- based telescopes for several months. In July 2009, a second object, though much smaller than Shoemaker-Levy 9, impacted Jupiter, also causing a visible dark scar in the Jovian atmosphere. Such clear evidence of major collisions in the contemporary solar system does raise concern about the risk to humanity. 2. In December 2004, astronomers determined that there was a non-negligible probability that near-Earth asteroid Apophis (see Chapter 4 for more details) would strike Earth in 2029. As Apophis is an almost 300-meter- diameter object, a collision anywhere on Earth would have serious regional consequences and possibly produce transient global climate effects. Subsequent observations of Apophis ruled out an impact in 2029 and also deter- mined that it is quite unlikely that this object could strike during its next close approach to Earth in 2036. However, there likely remain many Apophis-sized NEOs that have yet to be detected. The threat from Apophis was discovered only in 2004, raising concerns about whether the threat of such an object could be mitigated should a collision with Earth be determined to have a high probability of occurrence in the relatively near future. 3. In June 1908, a powerful explosion blew down trees over an area spanning at least 2,000 square kilometers of forest near the Podkamennaya Tunguska River in Central Siberia. As no crater associated with this explosion was located, scientists initially argued against an asteroid or comet origin. However, subsequent analysis and more recent modeling (see, e.g., Chyba, 1993; Boslough and Crawford, 1997, 2008) have indicated that modest-sized objects (the Tunguska object may have been only 30 to 50 meters in diameter) moving at high supersonic speeds through the atmosphere can disintegrate spontaneously, creating an airburst that causes substantial damage without cratering. Such airbursts are potentially more destructive than are ground impacts of similar-size objects. 4. A stony meteorite 1 to 2 meters in diameter traveling at high supersonic speeds created an impact crater in Peru in September 2007. According to current models with standard assumptions, such a small object should not have impacted the surface at such a high velocity. This case demonstrates that specific instances can vary widely from the norm and is a reminder that small NEOs can also be dangerous. 5. On October 6, 2008, asteroid 2008 TC3 was observed by the Catalina Sky Survey (see Chapter 3) on a collision course with Earth. Although the object was deemed too small to pose much of a threat, the Spaceguard Survey1 and the Minor Planet Center (see Chapter 3) acted rapidly to coordinate an observation campaign over the following 19 hours, with both professionals and amateurs to observe the object and determine its trajectory. The 2- to 5-meter-diameter object entered the atmosphere on October 7, 2008, and the consequent fireball was observed over northern Sudan (Figure 2.2) (Jenniskens et al., 2009). Subsequent ground searches in the Nubian Desert in Sudan located 3.9 kilograms (in 280 fragments) of material from the meteorite. These recent events, as well as the current understanding of impact processes and the population of small bodies across the solar system but especially in the near-Earth environment, raise significant concerns about the current state of knowledge of potentially hazardous objects and the ability to respond to the threats that they might pose to humanity.

## Asteroids Bad – Moral

### There is a moral responsibility to mitigate the risks from asteroids

Urias et al 96

[COL (Sel) John M. Urias Et. Al., Planetary Defense: Catastrophic Health Insurance for Planet Earth,” A Research Paper Presented To Air Force 2025,October 1996, http://csat.au.af.mil/2025/volume3/vol3ch16.pdf]

The fact that it may only happen once in several lifetimes does not absolve the current defense team of at least a moral responsibility if it does happen, particularly if it had the means to prevent or at least mitigate it. Perhaps for the first time in not only human history but the entire history of the planet, the inhabitants of earth are on the verge of having such capability. Currently, the chemical and nuclear propulsion systems now in development offer the best options for planetary defense. Employment of nuclear devices in a standoff mode represents the gentle nudge of all the options available. Though technically much more difficult, nuclear devices exploded on or beneath the object's surface impart 10 or more times the impulse of a standoff explosion.45

### Humanity has a moral obligation to protect itself against asteroids

Urias et al 96

[COL (Sel) John M. Urias Et. Al., Planetary Defense: Catastrophic Health Insurance for Planet Earth,” A Research Paper Presented To Air Force 2025,October 1996, http://csat.au.af.mil/2025/volume3/vol3ch16.pdf]

Although promising signs exist in terms of more frequent workshops, technical discussions, and increased international cooperation, we must address several issues to resolve the planetary defense problem by 2025. First and foremost, does the global community believe that an unacceptable risk to the EMS exists, and, if so, is it committed to developing a solution? Obviously, the concepts presented in this paper require many new technologies that will take much time, talent, and resources to develop. Commitment does not 62 equate to paper studies alone—it must be supported by substantial research and funding for these studies to be followed up with action. In an era of declining budgets, this issue presents a significant dilemma for leaders across the world. It should be remembered, however, that the threat of nuclear war was uncertain and even improbable during the cold war period; yet, the US spent more than $3 trillion over this 50-year time frame to maintain its strength against this uncertainty. These authors suggest that one needs only to consider the potential catastrophic effects from a large (>1 km diameter) ECO impact to conclude that humanity has a moral obligation to protect humanity.

## Asteroids Bad – Tsunamis

### Although speculative, recent studies indicate that NEO airbursts create chains of shock waves likely to create disastrous tsunamis

NATIONAL ACADEMY OF SCIENCES 2009 (Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council NATIONAL ACADEMY OF ENGINEERING INSTITUTE OF MEDICINE NATIONAL RESEARCH COUNCIL <http://www.nap.edu/catalog.php?record_id=12842>)

One of the least understood aspects of the airburst phenomenon is whether and how these events play a role in the formation of tsunamis. There has been significant debate on the effects of ocean impacts, both by direct impact into and by airbursts above the water. Some investigators suspect that an airburst over an ocean may be much more devastating than a similar-sized impact event directly into the water. The modeling of direct oceanic impacts suggests that the impact splash is significant and will be detrimental to those nearby, but that the wavelength of the resultant waves generated is not of sufficient length to cause a tsunami. Other studies suggest on the contrary that even this type of impact may be enough to generate a tsunami-like phenomenon depending on the terrain that such impact-generated waves may encounter. Still others have found that, based on numerical simulations and on data from nuclear oceanic tests, tsunamis are not generated by impact events. More recent work on airburst events over the ocean suggests that this too is an area of uncertainty. Previous investigations have treated these types of airbursts in a fashion similar to nuclear explosions that deliver their energy from a single point. If this treatment were correct, then the resultant blast waves would not produce a tsunami-type of event. However, a recent study suggests that NEOs entering the upper atmosphere and exploding there act more like a linear series of nearly simultaneous explosions (Boslough and Crawford, 2008). These blast effects are not as localized as those from the single source models, in which the momentum of the object is carried downward into the atmosphere and produces a shock wave. If the shock wave were sufficiently strong to depress a wide area of the ocean’s surface, the resultant rebound effect of the ocean would create a classic tsunami. Hence the threat from small NEO airbursts over the ocean might present their most significant hazard to humanity given that most of the world’s population is concentrated on or near oceanic coastlines. Finding: U.S. Department of Defense satellites have detected and continue to detect high-altitude airburst events from NEOs entering Earth’s atmosphere. Such data are valuable to the NEO community for assessing NEO hazards. Recommendation: Data from NEO airburst events observed by the U.S. Department of Defense satellites should be made available to the scientific community to allow it to improve understanding of the NEO hazards to Earth. Finding: Preliminary theoretical studies on low-altitude atmospheric Tunguska-like airbursts from asteroids as small as 30 meters in diameter suggest that significant risk exists from these NEOs. Finding: Current models for the generation of tsunamis by impacts into or airbursts above the ocean are not yet sufficiently reliable to establish threat levels to coastal communities. Recommendation: Additional observations and modeling should be performed to establish the risk associated with airbursts and with potential tsunami generation.

## Asteroid Mining Good

### Asteroid mining is key to human survival

Honan 11

[Daniel Honan, “The First Trillionaires Will Make Their Fortunes in Space ,” Big Think, May 5, 2011, <http://bigthink.com/ideas/38186>]

Asteroids represent a dual threat and opportunity for humanity. In the starkest terms, an asteroid collision could lead to the extinction of the human race, as presented in this terrifying computer-simulated video. And yet, asteroids also represent an opportunity for the salvation of the human race. Asteroids contain a wide range of resources, including nickel-iron metal, silicate minerals, trapped or frozen gasses, and water, which could be utilized by a spacecraft's steam propulsion rocket for a return trip to Earth. Asteroids have also been thought of as a possible site for the colonization of space. After all, it was the impact of asteroids that transformed life on Earth and may have made human life possible in the first place. As Peter Diamandis has noted, there are many motivations for going to space. It was curiosity that drove NASA's budgets for fifty years. Another fundamental motivator to go to space is to back up the biosphere. Diamandis suggests that we "record all of the genomes on this planet, all the works of art, and back it up off earth." Twenty trillion dollars isn't bad motivation either, and the drive to create wealth from space may very well prove the key to human survival and our future prosperity.

# Solvency Extensions

## US Key

### Unambiguous U.S. leadership is key to planetary defense

Dinerman ‘9

(Taylor, journalist for the Space Review “The new politics of planetary defense,” The Space Review, 7-20, <http://www.thespacereview.com/article/1418/1>)

While the US is obviously going to have to take the lead in any effort to detect and possibly deflect any celestial object that might do our planet harm, it will have to consult with others, both to keep other nations informed and to help make the choices needed to deal with the threat. Yet in the end, it is likely that the decision, if there is one, will rest with the President of the United States. He or she is the only world leader today with the wherewithal to deal with such a threat. If the US is have any claim to global leadership in the 21st century it will have to unambiguously take the lead in planetary defense. This is why any planning effort that leans to heavily on international institutions may endanger the whole planet. The process inside an organization like the UN would simply get bogged down in procedural and political questions. US leaders may find that the system would be paralyzed while, for example, nations argued over deflection or destructions methods or who would control and pay for them. Precious time would be lost while nations would consider their own best interests in supporting one approach or another. If the US is have any claim to global leadership in the 21st century it will have to unambiguously take the lead in planetary defense. It should do so in an open way and be ready to listen to everyone’s concerns and ideas. But if the Earth is to be effectively protected, the ultimate decisions will have to be American. In this case “global governance” could end up setting the stage for a disaster.

### Everyone is waiting for U.S. leadership on planetary defense

France ‘2k

(Martin, Lt. Colonel, USAF, “Planetary Defense: Eliminating the Giggle Factor, [Air & Space Power Journal](http://www.airpower.maxwell.af.mil/airchronicles/apje.html),

<http://www.airpower.maxwell.af.mil/airchronicles/cc/france2.html>)

A key component of the Shoemaker Report, as in the earlier Spaceguard Survey, was its international character. However, it seems that most nations interested in the NEO threat are still awaiting America’s lead. Russia, for example, has the technology and interest (Tunguska) among its astronomy and military communities to play a significant role in the Spaceguard Survey, but economic circumstances have precluded them from taking the initiative. Australia has recently backed away from its fledgling telescope program, which played a critical role in confirming NEOs first seen by other telescopes from its unique location in the southern hemisphere, and international attempts to encourage the Australian government to bring its program back into operation have failed.23 The United Kingdom, home of some of the most enthusiastic NEO watchers, formed a "Task Force on NEOs" led by Dr. Harry Atkinson. This group of four scientists has limited funding and is only tasked with making recommendation to Her Majesty’s Government by mid-2000 on how the UK should best contribute to the international effort on NEOs.24 Additionally, Spaceguard is a loose, voluntary consortium of international observatories and interested parties that serves to relay NEO identification to concerned groups and fellow participants.

### Unilateral U.S. initiation of the program is key to global coalition building

Barrett ‘6

[Scott, Professor and Director of International Policy, School of Advanced International Studies, Johns Hopkins University and Distinguished Visiting Fellow, Center for the Study of Globalization, Yale University, 6 Chi. J. Int'l L. 527, http://www.allbusiness.com/legal/4069484-1.html]

But can we expect that this public good will be provided? Or will free riding undermine global provision of asteroid protection? The US would likely have the greatest incentive to provide this public good since it would, in absolute terms, bear the greatest loss from an asteroid collision. Indeed, it is easy to demonstrate that the economics of asteroid protection are so attractive that it would be beneficial for the US to finance the entire protection program.40 Since it pays the US to supply the public good unilaterally, theory suggests that the good will be supplied. As it happens, behavior is consistent with this prediction. The US is already "doing more about Near Earth Objects than the rest of the world put together."41 For example, the US has already funded a program to track large objects in space, a prerequisite for further action. (Fortunately, the nature of asteroid travel means that we should have decades, if not centuries, to prepare for a possible collision; however, comets with long-period orbits cannot be observed as easily, and these are thus particularly dangerous.) What theory cannot predict is how the public good of asteroid defense will be financed. It could be financed entirely by the US, but it could also be financed via any number of other burden-sharing arrangements.42 To illustrate this point, consider the financing of the 1991 Persian Gulf War. Removing Iraqi forces from Kuwait was also a best shot, global public good. It enforced the norm safeguarding a state's territorial sovereignty, stabilized the global oil market, and invigorated the United Nations by carrying out the threat expressed in Security Council Resolution 678, which authorized the use of "all necessary means" to free Kuwait.43 The US would have gained substantially from restoring Kuwait's sovereignty, but so would all other countries. Thus, while the US led the coalition against Iraq, many countries contributed, both financially and in kind. According to a Department of Defense study, foreign governments funded almost 90 percent of the military effort.44 Bennett, Lepgold, and Unger claim that other countries paid because the US would not have intervened without allied contributions.45 However, assuming that was not the case-meaning that the US was willing to intervene unilaterally-other countries would likely have contributed anyway. The US would have wanted to share the burden and other countries would have recognized their obligation to pay their fair share.

### U.S. needs to take the lead in international efforts; could use current structures to implement

NATIONAL ACADEMY OF SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council <http://www.nap.edu/catalog.php?record_id=12842>)

A formal integration of these elements, with agreed-to plans, roles, and responsibilities, is needed well in advance of the identification of any specific threat. The United States is in a unique position to lead the sustained effort required to marshal the international community to ensure preparedness. Given this international community of interested and knowledgeable scientists and (at least some) concerned governments, how should the world develop a coherent program to meet this threat, in all of its aspects? One approach is to work through the United Nations, perhaps through an enhancement of the existing Committee on the Peaceful Uses of Outer Space␣a committee that has already received an extensive report from a nongovernmental agency of experts on the various aspects of NEO hazards (Schweickart et al., 2008). Another approach, mentioned above, is to organize the various national, and for Europe, international, space agencies. A third approach is to organize a new group␣a standing committee␣composed of representatives of nations concerned with this problem and willing to invest in preparedness for a damaging collision. A minimum for annual contributions or national expenditures on this problem could be set and monitored, say, by the standing committee. The level of contributions could be fixed so that even the minimum would allow “useful” accomplishments. This international standing committee would be open to membership by representatives of all nations that wished to contribute to addressing this problem at the minimum or a greater level. Since no nation would likely give up much, if any, of its sovereignty, even in the face of this supranational issue, the standing committee would develop a program and submit it for approval to the individual member countries. In the absence of a specific future-impact event of concern, however, it might be hard to reach agreement (it would probably be hard enough, even in the face of imminent danger). International collaborations perforce spawn legal issues, and organizing a hazard response would be far from immune to them. Suppose, for example, that two or more nations in the consortium wish to alter the orbit of a potential impactor. In a case of seemingly irreconcilable differences, to whom could they appeal for adjudication of the dispute, and what precedent(s) would inform such adjudication? As a second example, consider nations A and B that, in collaboration, succeeded in altering the orbit of an imminent impactor, but, through circumstances beyond their control, changed the impact site from nation C to nation D (instead of causing the object to miss Earth entirely). Who decides who is responsible for the damage inflicted on nation D and to what degree? As a last example, consider nations A through E collaborating on a mission to change the orbit of an imminent impactor by using nuclear explosives. Suppose that one of the armada of spacecraft dispatched for this mission failed to gain orbit and crashed onto nation F, releasing damaging radioactive material. How are the damages to be assessed and by whom, and how are the responsibilities for payment to be determined and the judgment enforced? The existing legal entity that appears most appropriate to handle such issues is the World Court. It could also deal with contract disputes involving bi- and multinational agreements involving these issues. The nations of the world would need to agree in advance, through some type of treaty, to give jurisdiction to the World Court and to abide by its findings and penalty assessments. Other alternatives could be investigated, such as a new judicial entity that could be created solely to deal with these hazard issues and which might better safeguard national sovereignty. This legal component of the hazards issue suggests that the Department of State and perhaps the Department of Justice may need to play a strong role in dealing with the international aspects of the hazards issue. One major concern with a standing committee and its affiliates, especially in the area of preparation for disasters, is the maintenance of attention and morale, given the expected exceptionally long intervals between harmful events. Countering the tendency to complacency will be a continuing challenge. This problem would be lessened were, for example, the civil-defense aspects combined with those for other natural hazards. Recommendation: The United States should establish a standing committee, with membership from each of the relevant agencies and departments, to develop a detailed plan for treating all aspects of the threat posed to Earth by near-Earth objects, and apportioning among these agencies and departments the authority and responsibility for carrying out this plan, in coordination and collaboration with other nations. The standing committee would be further charged with overseeing on a continuing basis the carrying out of each agency’s and department’s activities under this plan. The administration should designate one agency or department as the lead; the chair of the committee should be the representative from this agency or department. Recommendation: The United States should take the lead in organizing and empowering a suitable inter- national entity to participate in developing a detailed plan for dealing with the NEO hazard. The lead U.S. representative to this group could be the chair of the standing committee, or the chair’s designee.

### Other countries working on NEO detection; danger of impact requires insurance of effective NEO detection and prevention program

NATIONAL  ACADEMY  OF  SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council NATIONAL ACADEMY OF ENGINEERING INSTITUTE OF MEDICINE NATIONAL RESEARCH COUNCIL http://www.nap.edu/catalog.php?record\_id=12842)

RECENT NEAR-EARTH-OBJECT-RELATED EVENTS The U.S. Department of Defense, which operates sensors in Earth orbit capable of detecting the high-altitude explosion of small NEOs, has in the past shared this information with the NEO science community. The committee concluded that this data sharing is important for understanding issues such as the population size of small NEOs and the hazard that they pose. This sharing is also important for validating airburst simulations, characterizing the physical properties of small NEOs (such as their strength), and assisting in the recovery of meteorites. Recommendation: Data from NEO airburst events observed by the U.S. Department of Defense satellites should be made available to the scientific community to allow it to improve understanding of the NEO hazards to Earth. In 2008, Congress passed the Consolidated Appropriations Act3 calling for the Office of Science and Technology Policy to determine by October 2010 which agency should be responsible for conducting the NEO survey and detection and mitigation program. Several agencies are possible candidates for such a role. During its deliberations the committee learned of several efforts outside the United States to develop spacecraft to search for categories of NEOs. In particular, Canada’s Near-Earth-Object Surveillance Satellite, or NEOSSat, and Germany’s AsteroidFinder are interesting and capable small-scale missions that will detect a small percentage of specific types of NEOs, those primarily inside Earth’s orbit. These spacecraft will not accomplish the goals of the George E. Brown, Jr. Near-Earth Object Survey Act of 2005. However, they highlight the fact that other countries are beginning to consider the NEO issue seriously. Such efforts also represent an opportunity for future international cooperation and coordination in the search for potentially hazardous NEOs. In addition, the committee was impressed with the European Space Agency’s early development of the Don Quijote spacecraft mission, which would consist of an observing spacecraft and a kinetic impactor. This mission, though not funded, would have value for testing a mitigation technique and could still be an opportunity for international cooperation in this area. Finally, the committee points out a current estimate of the long-term average annual human fatality rate from impactors: slightly under 100 (Harris, 2009). At first blush, one is inclined to dismiss this rate as trivial in the general scheme of things. However, one must also consider the extreme damage that could be inflicted by a single impact; this presents the classic problem of the conflict between “extremely important” and “extremely rare.” The committee considers work on this problem as insurance, with the premiums devoted wholly toward preventing the tragedy. The question then is: What is a reasonable expenditure on annual premiums? The committee offers a few possibilities for what could perhaps be accomplished at three different levels of funding (see Chapter 8); it is, however, the political leadership of the country that determines the amount to be spent on scanning the skies for potential hazards and preparing our defenses.

## US Space Leadership Uniqueness – No

### No US leadership in space now

Armstrong, Lovell, and Cernan 11

(Neil Armstrong, Jim Lovell, Gene Cernan, May 27,2011, Statesman Journal, “Is Obama Grounding JFK’s Space Legacy?”, <http://www.statesmanjournal.com/article/20110528/OPINION/105280308/Is-Obama-grounding-JFK-s-space-legacy->)

The response to Kennedy's bold challenge a half-century ago has led to America's unchallenged leadership in space. We take enormous pride in all that has been accomplished in the past 50 years. And we have the people, the skills and the wherewithal to continue to excel and reach challenging goals in space exploration. But today, America's leadership in space is slipping. NASA's human spaceflight program is in substantial disarray with no clear-cut mission in the offing. We will have no rockets to carry humans to low-Earth orbit and beyond for an indeterminate number of years. Congress has mandated the development of rocket launchers and spacecraft to explore the near-solar system beyond Earth orbit. But NASA has not yet announced a convincing strategy for their use. After a half-century of remarkable progress, a coherent plan for maintaining America's leadership in space exploration is no longer apparent. "We have a long way to go in this space race. But this is the new ocean, and I believe that the United States must sail on it and be in a position second to none." — President Kennedy. Kennedy launched America on that new ocean. For 50 years we explored the waters to become the leader in space exploration. Today, under the announced objectives, the voyage is over. John F. Kennedy would have been sorely disappointed.

### The US is losing its lead in the space race

Leonard ’08

(Leonard, Tom Journalist in New York 6/10/08, The Telegraph, “America losing its lead in the space race, http://www.telegraph.co.uk/earth/earthnews/3346930/America-losing-its-lead-in-the-space-race.html)

America is losing its lead in the space race as other countries challenge its dominance on the "final frontier", the head of Nasa has warned. A recent report on international space competitiveness by Futron, an American technology consultancy, concluded that "systemic and competitive forces threaten US space leadership". America had failed to keep track of how quickly the "globalisation" of space was occurring, the study said. Meanwhile, as Asians and Europeans became increasingly enthusiastic about manned space exploration, public interest in the US was "limited", said the study. In 1998, the US launched 121 new satellites but that number had fallen to 53 - about 50 per cent of the total - by 2007. Michael Griffin, Nasa's administrator, acknowledged that the US space agency's budget had fallen by 20 per cent in real terms since 1992. He told the Washington Post: "We spent many tens of billions of dollars during the Apolla era to purchase a commanding lead in space over all nations on Earth." "We've been living off the fruit of that purchase for 40 years and have not... chosen to invest at a level that would preserve that commanding lead." Mr Griffin has lobbied the US Congress for an increase in its $17 billion annual budget after it was turned down by the Senate. US space experts note how, in so many areas in which it has made gradual progress over the years, other countries are now catching up by leaps and bounds. India has followed China in announcing a manned space programme, while the European Union is expected to approve a plan in November to collaborate with Russia on a similar project. Japanese and Chinese satellites are circling the moon and will eventually be joined by ones from India and Russia. When men next returns to the moon, experts believe they will be Chinese. The country has sent men into space twice in the past five years, with another mission scheduled for October. Mr Griffin said the Chinese had a "carefully thought-out human space flight programme" that would make them space equals with the US and Russia. "They've investing to make China a strategic power second to none - not so much to become a grand military power, but because deals and advantage flow to world leaders", he said. South Korea, Taiwan and Brazil are all planning to develop their own national programmes, which may involve launching cheap satellites and even home-grown rockets. Israel has announced plans to set itself up as a launchpad for tiny "nano-satellites". While the US is no longer involved in launching satellites for other countries, competitors such as Russia, India and the Europe's Arianespace has stepped into the breach for clients including Israel, Nigeria and Singapore. Even the areas in which the Americans continue to dominate heavily - the private space industry and military satellites - are being challenged. Russia has dramatically increased its military space spending since the fall of the Soviet Union. Japan and China are also investing in this field. Last year, China attracted controversy when it tested a ground-based anti-satellite system by destroying an orbiting weather satellite. Analysts point out that America's ability to co-operate on space projects with other countries – as is happening widely elsewhere – has been hampered by its determination to withhold technology from potential enemies.

### U.S. space leadership stands at a crossroads

Wolf 10

(Frank Wolf, April 25, 2010, ranking member of the U.S. House Appropritations commerse, justice, science subcommittee, Space News “Don’t Forsake U.S. Leadership in Space” http://spacenews.com/commentaries/100425-dont-forsake-leadership-space.html)

Space exploration has been the guiding star of American innovation. The Mercury, Gemini, Apollo and shuttle programs have rallied generations of Americans to devote their careers to science and engineering, and NASA’s achievements in exploration and manned spaceflight have rallied our nation in a way that no other federal program — aside from our armed services — can. Yet today our country stands at a crossroad in the future of U.S. leadership in space. President Barack Obama’s 2011 budget proposal not only scraps the Constellation program but radically scales back U.S. ambition, access, control and exploration in space. Once we forsake these opportunities, it will be very hard to win them back. As Apollo astronauts Neil Armstrong, Jim Lovell and Gene Cernan noted on the eve of the president’s recent speech at Kennedy Space Center, Fla.: “For The United States, the leading space faring nation for nearly half a century, to be without carriage to low Earth orbit and with no human exploration capability to go beyond Earth orbit for an indeterminate time into the future, destines our nation to become one of second or even third rate stature.” In terms of national security and global leadership, the White House’s budget plan all but abdicates U.S. leadership in exploration and manned spaceflight at a time when other countries, such as China and Russia, are turning to space programs to drive innovation and promote economic growth. Last month, China Daily reported that China is accelerating its manned spaceflight development while the U.S. cuts back. According to Bao Weimin with the Chinese Academy of Sciences, “A moon landing program is very necessary, because it could drive the country’s scientific and technological development.” In a recent special advertising section in The Washington Post, the Russian government boasted of its renewed commitment to human spaceflight and exploration. Noting the White House’s recent budget proposal, the piece said, “NASA has long spent more money on more programs than Russia’s space agency. But President Barack Obama has slashed NASA’s dreams of going to the moon again. At the same time, the Russian space industry is feeling the warm glow of state backing once again. There has been concerted investment in recent years, an investment that fits in well with the [Vladimir] Putin doctrine of trying to restore Russian pride through capacity.” Manned spaceflight and exploration are one of the last remaining fields in which the United States maintains an undeniable competitive advantage over other nations.

## US Space Leadership Good

### US needs to maintain is leadership in space

Stone 11

(Christopher Stone, March 14 2011, The Space Review “American leadership in space: leadership through capability”, Space policy analyst and strategist, <http://www.thespacereview.com/article/1797/1>) PS

Finally, one other issue that concerns me is the view of the world “hegemony” or “superiority” as dirty words. Some seem to view these words used in policy statements or speeches as a direct threat. In my view, each nation (should they desire) should have freedom of access to space for the purpose of advancing their “security, prestige and wealth” through exploration like we do. However, to maintain leadership in the space environment, space superiority is a worthy and necessary byproduct of the traditional leadership model. If your nation is the leader in space, it would pursue and maintain superiority in their mission sets and capabilities. In my opinion, space superiority does not imply a wall of orbital weapons preventing other nations from access to space, nor does it preclude international cooperation among friendly nations. Rather, it indicates a desire as a country to achieve its goals for national security, prestige, and economic prosperity for its people, and to be known as the best in the world with regards to space technology and astronautics. I can assure you that many other nations with aggressive space programs, like ours traditionally has been, desire the same prestige of being the best at some, if not all, parts of the space pie. Space has been characterized recently as “congested, contested, and competitive”; the quest for excellence is just one part of international space competition that, in my view, is a good and healthy thing. As other nations pursue excellence in space, we should take our responsibilities seriously, both from a national capability standpoint, and as country who desires expanded international engagement in space. If America wants to retain its true leadership in space, it must approach its space programs as the advancement of its national “security, prestige and wealth” by maintaining its edge in spaceflight capabilities and use those demonstrated talents to advance international prestige and influence in the space community. These energies and influence can be channeled to create the international space coalitions of the future that many desire and benefit mankind as well as America. Leadership will require sound, long-range exploration strategies with national and international political will behind it. American leadership in space is not a choice. It is a requirement if we are to truly lead the world into space with programs and objectives “worthy of a great nation”.

## Cooperation Key

### NEO strategies require the national and international cooperation

Schweickart et al 2010

(Russell L. Chairman, B612 Foundation (Task Force Co-Chair)Report of the NASA Advisory Council Ad Hoc Task Force on Planetary Defense October 6, T http://www.nasa.gov/pdf/490945main\_10-10\_TFPD.pdf)

1.4. Interfaces. A comprehensive PD plan must include development of important interfaces internal and external to the U.S. government. The PDCO should take immediate action to develop short-term impact warning procedures in conjunction with the DHS and other emergency response and consequence management agencies. This quick-response information interface should be designed in close coordination with the established disaster response community. The PDCO should seek bilateral and/or multilateral international cooperative opportunities for NASA to initiate joint NEO deflection development/demonstration missions. An actual impact threat response will require international coordination, and deflection development can explore the capabilities, limitations, and trust necessary for such cooperation. Given the global nature of the hazard and the need for a coordinated response from the space-faring nations, it is both desirable and cost-effective for the US to seek international partners in demonstrating deflection capability. The PDCO should lead NASA efforts, in cooperation with Department of State and other agencies as appropriate, to proactively challenge the international community to join in the analytical, operational, and decision-making aspects of Planetary Defense. Substantial efforts have been underway for over five years in the U.N. Committee on the Peaceful Uses of Outer Space (COPUOS) and other space-related forums, to encourage international participation in NEO detection efforts. Current efforts to develop a standing NEO threat decision-making process--enabling the international community to effectively respond to an impact threat--could benefit substantially from U.S. and NASA leadership.

## International Cooperation Key

### Procedures and protocol must be established for international cooperation even though agencies like NASA may be ones to complete the mitigation attempts

Foust 2007

(Jeff, editor and publisher of The Space Review The three D’s of planetary defense March 19, http://www.thespacereview.com/article/835/1)

Decisionmaking Between detection and deflection, though, lies an oft-forgotten step: deciding the course of action to be taken to mitigate the threat posed by the NEO. Who should be responsible for making a decision whose effects impact—figuratively and potentially literally—people around the world? Rusty Schweickart, the Apollo-era astronaut who serves as chairman of the board of the B612 Foundation as well as chairman of the NEO committee of the Association of Space Explorers (ASE), believes that any decisionmaking process must be international in nature. He notes that, in the process of deflecting an asteroid initially on a course to hit one country, the risk of an impact might temporarily shift to another country during the course of the deflection. Moreover, such decisions might have to be made long before the probability of an impact becomes one in order to have enough time to deflect the object. That means all the countries involved need to have a say in the decisionmaking process, even if they are not involved with the deflection itself, and with more potentially hazardous NEOs to be discovered in the years to come, more and more countries will face the risks of an impact. “Inherently every nation is going to be involved in making this decision,” said Schweickart at the AAAS conference. “There is one agency, namely the United Nations, which therefore has got get involved in this decisionmaking process.” Schweickart said he doesn’t know what that decisionmaking process should be, but he is embarking on an effort to help develop one. His ASE NEO committee is planning a series of four workshops, starting in May in Strasbourg, France, to bring together experts to determine what the best approach might be. The goal of this effort is to present to the United Nations in 2009 a proposed treaty that would serve as a protocol should the need arise. Although Schweickart was clear to state in his AAAS presentation that the UN should be the forum for the decisionmaking process, not the body actually charged with carrying out any deflection, some interpreted his comments to suggest that he believed the UN—an organization not known for its decisive and efficient processes—should be given complete responsibility for planetary defense. “We are not in any way proposing that the United Nations create a bureaucracy or that the United Nations be responsible for taking action,” he said during a public forum that was part of the Planetary Defense Conference in Washington earlier this month. The UN, though, “has to be in a position to make a timely decision” and then contract the actual task out to NASA or another organization or consortium. This effort was prompted in large part by Apophis, even though this asteroid has only a very slim chance of posing a threat to the Earth in 2036 or beyond. New search programs, even without the dedicated telescopes that are too expensive for NASA, will in the years to come discover more and more objects that might pose a threat to the Earth years or decades from now. “Apophis is an unusual case and we may not see another one for a long time like it,” said Schweickart. “But it’s been a terrific learning experience for all of us, because it has tickled every possibility that there is in this business.”

### International cooperation key to developing NEO mitigation strategies

NATIONAL ACADEMY OF SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council <http://www.nap.edu/catalog.php?record_id=12842>)

INTERNATIONAL COOPERATION The probability of a devastating NEO impact in the United States is small compared to the likelihood of an impact in other nations, most with far fewer resources to detect, track, and defend against an incoming NEO. The NEO hazard, however, is such that a single country, acting unilaterally, could potentially solve the problem. Although the United States has a responsibility to identify and defend against threats with global consequences, this nation does not have to bear the full burden for such programs. There have been several international efforts to characterize objects in the near-Earth environment, but these studies have generally been driven by scientific curiosity and were not designed to address the risk of NEOs. As NEO survey requirements evolve to fainter objects and as mitigation strategies are refined, additional resources will be necessary, and these could be provided by other developed countries. International partnerships can be sought with other science organizations, notably but not exclusively space agencies, in the areas of surveys, characterization, and mitigation technologies. NEO discovery rates and survey completeness could be significantly enhanced through the coordinated use of telescopes owned and operated by other nations. Future NEO space missions, carried out by the United States, by other nations, or through the cooperation of various countries, could be optimized for characterization that enables the development and refinement of mitigation strategies. Space missions to test such strategies could also be developed on a cooperative basis with other nations, making use of the resulting complementary capability. While a coordinated intergovernmental program would be needed to address the full spectrum of activities associated with NEO surveys, characterization, and mitigation, an important first step in this direction would be to establish an international partnership, perhaps of space agencies, to develop a comprehensive strategy for dealing with NEO hazards. Many scientists, especially among the world’s planetary scientists, have been concerned for well over a decade with the danger posed to Earth from the impact of an asteroid or a comet. Officials from various nations have echoed these concerns. Thus a substantial and important component of the existing international cooperation is the informal contact among professional scientists and engineers, mainly of space-faring nations, but also including some other countries. International conferences and small meetings, as well as the Internet, have allowed experts in different aspects of space science and technology, including asteroid detection and mitigation, to know their counterparts in other nations personally. Such connections often lead to offers of or requests for aid in the solution of common problems arising in the course of these experts’ work. Veterans of the U.S. or Russian space programs often participate either openly or behind the scenes in the European Space Agency and the Japanese Space Agency and in Indian and Chinese space activities. Nuclear-weapons designers in both Russia and the United States have often met to discuss the use of nuclear explosives to effect asteroid orbit changes. In the event of a sudden emergency due to the discovery of a threatening NEO, it is likely that people forming this international network would be the first to communicate with one another and to consider responses to the threat. For instance, when an observatory in Arizona discovered NEO 2008 TC3 only 19 hours before its impact in Sudan, the informal network of amateur and professional astronomers in many countries responded in time for thousands of observations of the object to be made and communicated to the MPC, thus allowing an extremely accurate prediction of the time (<1 minute error) and location (<1 kilometer error) of impact.

### The cost and development of planetary defense system will require national and international cooperation; must plan now and begin with detection program before development of mitigation strategies

Borchers 2009

(Brent W., Major, USAF Should the USAF be Involved in Planetary Defense?AIR COMMAND AND STAFF COLLEGE AIR UNIVERSITY <http://www.dtic.mil/cgi> bin/GetTRDoc?AD=ADA539693&Location=U2&doc=GetTRDoc.pdf)

CHAPTER FOUR The previous chapters list a few of the problems that need to be worked out for a planetary defense system. Such a system is so complex and will end up being so large and cost prohibitive that it must be a government funded and run organization. In fact, since it benefits the whole world and many countries, it will probably end up being an international consortium of nations who all share in the common fate of our earth or the particular region where the object is predicted to strike. This would allow for a larger funding base and multiple nations of engineers and scientists tackling the largest and most serious problem humankind has seen to date. In 1992 a NEO interception working group meeting at Los Alamos National Laboratory in New Mexico came up with some cost calculations to develop and implement a planetary defense system for three different sizes of NEO’s. For small NEOs less than 50 meters in diameter the cost benefit analysis yielded results of one million dollars per year. This is based on the formula for a cost/risk analysis of the damage caused by a NEO impact divided by the number of years between impacts on the average. For a larger NEO around two kilometers in diameter, the cost per year rises to two hundred million dollars and it increased at a geometric rate onward for larger NEOs.48 These average cost answers still don’t tell us the total cost of a defense system. Estimates show that around 120 million dollars a year over 20 years would maintain a planetary defense system.49 This does not include the estimated billions to develop the initial system and the development cost depends on which method of destruction or deflection is chosen. Cheaper options include the already existing technologies of nuclear weapons with modified ICBMs launch systems. It would cost substantially more to develop a new technology like a solar sail solution or some type of gravity drive system.50 It is also estimated that spending this much on a system would only give the earth a limited mitigation system. If we are to develop a system to destroy and deflect those giant five kilometer diameter asteroids that exist those costs could run into the hundreds of billions or even trillions and be the most expensive project in the history of the human race. As noted by some researchers though, initiating a defense system now before we fully understand the problem would end up wasting more effort, money and time and jeopardize further funding. They theorize that the best approach at this time would be to spend more money studying the best way to track and defend against these NEOs before enacting an actual plan and developing and building new technologies and physical capabilities. With that said, a partial effort to develop some of the new technologies that will be required couldn’t hurt the cause at this stage of the problem and solution development. The lead time for developing some technologies could be many years or even decades and starting earlier can only help us in the endeavor.

### Must make good choices when determining the extent of international cooperation

Borchers 2009

(Brent W., Major, USAF Should the USAF be Involved in Planetary Defense?AIR COMMAND AND STAFF COLLEGE AIR UNIVERSITY <http://www.dtic.mil/cgi> bin/GetTRDoc?AD=ADA539693&Location=U2&doc=GetTRDoc.pdf)

Once our chosen organization begins working on the project, who do we want to partner with in the world arena? Certainly many countries would like to help either because they see the true need for a planetary defense system or they see it as a public relations and media bonanza. What developing nation wouldn’t want to be seen as contributing to the defense of all human kind and carrying that banner forward in front of their people and regional or neighboring nations? Who would we let in on the project? Allies only who possess the technology and funding to actually help, or anyone who is willing to join with us in this endeavor? Does this include our sworn enemies who might use this opportunity to gain some technological knowledge or advantage over us? What a perfect opportunity for industrial espionage or stealing proprietary information from top U.S. defense contractors. Or could it follow the model of international cooperation that we’ve seen on the International Space Station? One of the nations that we’re currently not on the best of terms with possesses the most powerful launch and booster systems on the planet. Russia’s Energia launch system was capable of boosting a payload of over 40,000 pounds into low earth orbit. This is approximately three times the payload that the U.S. Space Shuttle can boost into orbit, and the Space Shuttle is the second most powerful launch vehicle on the planet. Some of our fellow countries also possess or have access to some of the best launch sites on the planet, Kourou, French Guiana; Alcantara, Brazil or movable Sea Launch facilities as part of an international consortium. Many of these sites would be advantageous because their close proximity to the equator means an energy savings on launch and would allow a vehicle to carry heavier payloads. Clearly many political considerations outside of the realms of technology and science need to be taken into consideration. The scientists and engineers will have to work within the boundaries created for them in this project by the politicians. However this is nothing unique, science and technology in the modern age has always been held prostrate to the needs and wishes of the state or politicians.

### International cooperation, not technology, is the greatest challenge for PDS

UPI 10

[UPI, “Nuclear asteroid defense revisited,” Dec. 15, 2010, UPI Science News, http://www.upi.com/Science\_News/2010/12/15/Nuclear-asteroid-defense-revisited/UPI-17811292458900/]

While humanity probably has the technological capability to pull off an asteroid-destroying mission right now, Weaver said, an obstacle might be getting the international community to cooperate enough to organize such a strike. With nuclear missiles involved, working together might be difficult, he said. "The social and political implications of how to carry out this mission are actually much tougher than the science," Weaver said.

## Coordination Key

### Current efforts to study and mitigate NEO’s are ad hoc; must have better organization to deal more effectively with them

NATIONAL ACADEMY OF SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council <http://www.nap.edu/catalog.php?record_id=12842>)

7 National and International Coordination and Collaboration Responding effectively to hazards posed by near-Earth objects (NEOs) requires the joint efforts of diverse institutions and individuals. Thus organization plays a key role that is just as important as the technical options. Because NEOs are a global threat, efforts to deal with them may involve international cooperation from the outset. This chapter discusses possible means to organize responses to those hazards at both the national and the inter- national level. Arrangements at present are largely ad hoc and informal in the United States and abroad, and they involve both government and private entities. However, the Office of Science and Technology Policy (OSTP) has been directed by Congress to “recommend a federal agency or agencies to be responsible for protecting the United States from a near-Earth object . . . expected to collide with Earth” (NASA Authorization Act of 2008, P.L. 110-422). The OSTP is directed to produce such a recommendation by October 2010. EXISTING ORGANIZATIONS At the national level in the United States, the Minor Planet Center (MPC) at the Harvard-Smithsonian Center for Astrophysics, sponsored by the International Astronomical Union but funded about 90 percent by NASA, collects observations of all asteroids and comets made around the world. The MPC archives these observations, makes them publicly available, and computes orbits for all individual, identified objects. For any object that seems to pose a threat to Earth, the MPC director or designee has a reporting system to alert a NASA official and thence through specified government channels to alert the country at large. Also in the United States, individual observers and observatories are dedicated in whole or in part to discovering and observing NEOs. Further, NASA supports a group of researchers at the Jet Propulsion Laboratory (JPL) that carries out accurate, long-term predictions of asteroid orbits, quantifies threats, and notifies NASA, as does the MPC, if a “threshold” is exceeded. The National Response Framework of the Department of Homeland Security (DHS) seeks to coordinate the identification of threats and disaster response with communication and recovery challenges similar to that needed for NEO threats. However, at present, NEOs are not included in the framework. At the international level, there is one organization, the Near-Earth Object Dynamic Site (NEODyS) system in Pisa, Italy (with a mirror site in Spain), that monitors and publicizes all potentially hazardous objects. The explosion of the 2008 TC3 asteroid in an airburst over Sudan demonstrated that even in the absence of formal international organization, effective international communications may occur, despite limited advance warning. Formal integration of these elements, with agreed-to plans, roles, and responsibilities is needed well in advance of the identification of any specific threat.

## Detection Key

### Numerous NEO’s exist which could impact the Earth; must continue monitoring to avoid having to take mitigation steps

Foust 2007

(Jeff, editor and publisher of The Space Review The three D’s of planetary defense March 19, http://www.thespacereview.com/article/835/1)

Detection The one facet of planetary defense where there are ongoing official efforts is in the detection of NEOs. For a number of years there have been several efforts underway to search for NEOs, and these efforts have been yielding an increasing bounty of objects thanks to improved techniques and technologies. As a result, about 4,000 NEOs have been discovered to date, according to Don Yeomans, head of the NEO program office at JPL, including some 700 “large” ones with diameters of one kilometer or more. Those search efforts have, so far, failed to turn up any objects that have the Earth definitively in its crosshairs. The biggest alarm in recent years came in late 2004, when asteroid 2004 MN4 (since renamed (99942) Apophis) had, based on the orbital information available, about a 2.7-percent probability of colliding with the Earth on April 13, 2029. It failed to make headlines because of the timing (around Christmas and the Asian tsunami that took place soon thereafter); by the time people would have paid attention other observations had reduced the odds of a 2029 impact to zero. (See [“Sounding an alarm, cautiously”](http://www.thespacereview.com/article/384/1), The Space Review, May 31, 2005) Still, Apophis does have about a 1-in-45,000 chance of colliding with the Earth in 2036, depending on if it passes through a narrow “keyhole” during its 2029 close approach to the Earth; [JPL’s impact risks page](http://neo.jpl.nasa.gov/risk/) lists, as of March 18th, 137 NEOs, including Apophis, that have a non-zero (albeit extremely small) chance of colliding with the Earth at some point in the next 100 years. That makes the detection and tracking of NEOs critical. “If it’s part of your job to keep the Earth safe from asteroid attacks, there are three important things you always have to remember,” quipped Steve Chesley, a planetary astronomer at JPL, during a press conference at the annual conference of the American Association for the Advancement of Science (AAAS) last month in San Francisco. “First is, you have to find them as early as possible. And the other ones I can never remember. The point is that discovery surveys are job one for protecting Earth from asteroid impacts.” In a talk during a later session of the AAAS conference, Chesley noted that, in general, impact probabilities will increase as new observations are added, then quickly drop to zero once enough observations are made—assuming that the object is not, in fact, actually on a collision course. Because of that, Chesley said, “you want to delay your efforts [to deflect an asteroid] as long as possible in the hope that the observations move the asteroid off the Earth, in a sense, rather than having to send a spacecraft to do the work.”

### Detection is the most important part of the PDS equation

Barbee and Fowler et al 6

(Brent William Barbee, Aerospace Engineer @ Emergent Space Technologies, Wallace T. Fowler, Professor of Aerospace Engineering @ UT-Austin, with George W. Davis and David E. Gaylor, “Optimal Deflection of Hazardous Near-Earth Objects by Standoff Nuclear Detonation and NEO Mitigation Mission Design,” Paper presented at NASA Workshop on Near-Earth Object Detection, Characterization, and Threat Mitigation, 26 June 2006 (Vail, CO http://www.aero.org/conferences/planetarydefense/resources.html)

Improved techniques and equipment for accurate processing of orbital observation data and orbit propagation are constantly under development, and this development should be continued. In addition, systems for detecting and tracking NEOs should be continually upgraded and expanded to minimize the time required to both detect a NEO and determine whether it is a threat. Early warning is the most important ingredient in successful mitigation of a hazardous NEO.

### Key to controlling costs is early detection and prediction; must have that to make any mitigation strategies more effective

Schweickart et al 2010

(Russell L. Chairman, B612 Foundation (Task Force Co-Chair)Report of the NASA Advisory Council Ad Hoc Task Force on Planetary Defense October 6, T http://www.nasa.gov/pdf/490945main\_10-10\_TFPD.pdf)

Recommendation 2: Acquire Essential Search, Track, and Warning Capabilities. NASA should significantly improve the nation’s discovery and tracking capabilities for early detection of potential NEO impactors, and for tracking them with the precision required for high confidence in potential impact assessments. Our ability to project a NEO’s orbit years into the future is accompanied by considerable uncertainty. The object’s orbital plane will generally be known to good accuracy, such that the intersection of that plane with the orbit of the Earth can be predicted to within a relatively few kilometers. However, except in the case of a NEO observed on its terminal impact trajectory, a threatening NEO’s exact orbital period will generally not be known accurately enough to predict whether an impact many years in the future will actually occur. Decision-makers will thus frequently face the question of how to react to a NEO with a worrisome (but uncertain) probability of impact. For example, a particular NEO may have a 2 percent chance of impacting Earth on a particular day decades in the future. Waiting until ground-based observations improve the impact prediction to, say, 50 percent confidence will make an attempted deflection far more costly, if not physically impossible. Even the prompt launch of a robotic transponder mission to improve our knowledge of the NEO’s orbit will cost several hundred million dollars for each potential impact threat. Decisions of this sort will be very unpleasant for policy-makers. The Task Force recommendations seek to minimize these situations through development and deployment of search and tracking assets that reduce the uncertainty in a NEO’s position, and thus the uncertainty in its impact probability. Reducing the number of such “worrisome probability of impact” situations via better NEO search and track technologies (producing observations that prove the more likely case that the asteroid will miss Earth) will be far less expensive than launching transponder missions or an actual deflection campaign. Parallel efforts to demonstrate cost-effective deflection technologies would help deal with those few objects with impact probabilities that remain too worrisome to ignore. The Task Force recommends that NASA choose search and deflection capabilities that minimize the total combined cost of confronting future impact threats. 2.1. NEO Search: To implement this recommendation, the Task Force recommends that NASA immediately initiate a space-based infrared telescopic NEO search project as the primary means of meeting the congressionally mandated George E. Brown NEO Survey goal. NASA was tasked to discover 90 percent of the NEOs larger than 140 meters by the end of 2020 as part of the NASA Authorization Act of 2005 (Public Law No. 109-155). Both ground- and space-based options for meeting the George E. Brown, Jr. NEO Survey goals have been investigated. Although NASA should continue to assist state-of -the-art ground-based optical surveys, including those coming on line or planned by other agencies (e.g., PanSTARRS, LSST), one or more space-based infrared (IR) telescopes in an orbit interior to Earth’s (e.g., a Venus-like orbit) offers several search efficiency advantages. Compared with ground-based optical systems, such space-based systems possess greater discovery efficiency and can more accurately determine the sizes and orbits of potentially threatening objects. The cost of such a survey asset is comparable to the multiple dedicated ground-based alternatives required, and will rapidly meet the legislated completion goal (probably within seven years). Additionally, a space-based survey, with its advantageous observing geometry and frequency, will enable prompt and precise orbit determination of newly discovered NEOs in collaboration with ground-based optical and radar systems, reducing the need for actual deflection campaigns. NASA should also examine the additional costs and observing advantages of a pair of such Venus-orbit survey telescopes, both to complete the overall survey more rapidly and aid in collapsing the error ellipse of worrisome NEOs. These enhanced capabilities may further reduce unnecessary launches of *in situ* tracking or deflection spacecraft. Although some NEOs are potentially hazardous, their periodic close approaches to Earth also make them among the most accessible objects in the solar system for robotic and human exploration. A space-based IR survey telescope would efficiently find both exploration targets and threatening NEOs currently inaccessible to observation by ground-based systems.

## Research/Testing Key

### Research programs for NEO’s are like those for earthquakes; we must prepare even though we don’t know when they might be occurring

NATIONAL ACADEMY OF SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council <http://www.nap.edu/catalog.php?record_id=12842>)

Dealing with the hazards of near-Earth object (NEO) impact is complicated because it involves balancing the imprecisely known risks of this hazard against the costs, risks, and benefits of proposed responses. Since the NEO impact risk is partly probabilistic in nature, it is difficult to grasp and difficult to communicate unless and until an object is discovered that will hit Earth at some definite date not too far in the future. However, the probabilistic risk is similar to that for other types of natural disasters like earthquakes. Scientists have an idea of the likelihood that an earthquake of a given magnitude will strike a given region within a given time. The fundamental reasons why earthquakes occur are known (they are associated with plate tectonics), and it is known that the risks from earthquakes are particularly high in certain specific regions (e.g., near plate boundaries, in certain types of soil). However, no one can predict with confidence the date of the next great earthquake of magnitude 7 or larger that will strike San Francisco or Tokyo. Nevertheless, it is known from experience that such disasters will occur, and moreover experts can assess the likely damage. The United States and other countries around the world have responded to the risk of earthquakes by committing to various civil-defense and mitigation programs, including research programs. The U.S. federal and state governments dedicate resources to earthquake research in order to improve the understanding of the causes of the hazard, to better quantify risks and to improve the capabilities for prediction, and to increase the effectiveness of mitigation measures. Likewise, an appropriate and necessary aspect of mitigation of the NEO impact hazard is a research program.

## Mitigation Key

### Must begin considerations of mitigation approaches now; mitigation will require multiple approaches and international cooperation

NATIONAL ACADEMY OF SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council <http://www.nap.edu/catalog.php?record_id=12842>)

Perhaps the most significant conclusion that can be drawn is the large uncertainty in the effectiveness of the mitigation techniques because of their dependence on the physical properties of NEOs that are not well known, and because of the difficulty of scaling any laboratory experiments to this regime. At this point it is not even possible to determine reliably the boundaries of applicability of the various approaches. In a later chapter the committee addresses organizational aspects of the decision-making process, but it still lacks information to guide that process. Any process must carry out a detailed study of where to draw the boundaries and what additional information would be needed. An applied research program, directed explicitly at the NEO hazard, could significantly reduce the uncertainties. At the lowest meaningful level of investigating the mitigation issues, this program would include both numerical simulations by multiple groups and laboratory experiments. A much-larger-scale effort to address the mitigation of NEO hazards will likely include activities in space. The single most-significant step in this area appears to be a kinetic impact mission on a far larger scale than the Deep Impact mission, employing a much larger impactor on a much smaller target, with another spacecraft that has a rendezvous with the target well prior to impact to characterize the target and its orbit very precisely. This characterizing spacecraft would remain with the target until long after the impact in order to determine accurately the change in its orbit resulting from the impact. The Don Quijote mission that was studied by the ESA but is no longer under active consideration would have addressed most of these goals. Suggestions have been made to use the rendezvous spacecraft as a gravity tractor after the primary mission, but given the different design considerations it is not yet clear whether this is a good approach or not. A demonstration flight of a gravity tractor appears to be the second most significant step, since lesser knowledge of NEO behavior is needed for implementation. Both the kinetic impact and gravity-tractor approaches require significant engineering study, but more basic knowledge is needed for the kinetic impactor. In cases of the late discovery of a hazardous NEO, the change in the NEO’s orbit that must be made for it to miss Earth can be so large that the required impact energy is comparable to or greater than the energy to disrupt the body. Depending on how the body disrupts, the effect on Earth could, in some circumstances, be worse overall than if disruption were not attempted. Alternatively, disruption might lead to less total damage to Earth but more damage to, for example, a particular populated location. With the uncertainty in the present understanding of fragmentation and disruption, the committee does not now endorse disruption as a mitigation strategy, but it suggests that further study of this issue should be an important part of any research program into mitigation of the NEO hazard. (See Chapter 6.) Finding: The mitigation of the threat from NEOs would benefit dramatically from their in situ characterization prior to mitigation if there is time. Finding: Changing the orbit of an NEO given the current level of understanding is sufficiently uncertain that, in most cases, it requires an accompanying verification. This is easy to implement with many slow-push techniques, but it would require considerable additional effort for other techniques. Recommendation: If Congress chooses to fund mitigation research at an appropriately high level, the first priority for a space mission in the mitigation area is an experimental test of a kinetic impactor along with a characterization, monitoring, and verification system, such as the Don Quijote mission that was previously considered, but not funded, by the European Space Agency. This mission would produce the most significant advances in understanding and provide an ideal chance for international collaboration in a realistic mitigation scenario.

### Tag

Barbee (Aerospace Engineer @ Emergent Space Technologies) and Fowler (Professor of Aerospace Engineering @ UT-Austin), et al – 2006

Hazardous NEO mitigation represents a multi-disciplinary engineering design problem and is best treated with a systems engineering approach. Finding solutions to this problem will enhance our scientific knowledge of asteroids, comets, and our solar system. It will also enhance our spacecraft technology. Since Congress has passed legislation requiring NASA to assume responsibility for NEO mitigation, we recommend that mitigation system testing begin as soon as possible, starting with standoff nuclear detonation. It is both an honor and challenge for NASA to be tasked with developing such systems. We hope that they will never be needed, but proving our ability to mitigate the threat posed by hazardous NEOs is necessary to ensure the survival of humankind.

## Laser Mitigation Good

### NEO’s present disastrous consequences; best way to engage them is with a laser; we will have only 100 days to detect and engage

Phipps 2010

(Claude Photonic Associates Can Lasers Play a Rôle in Planetary Defense? AIP Conf. Proc. 1278, 502 (2010), DOI:10.1063/1.3507139)

THE PROBLEM OF PLANETARY DEFENSE It is now well-established that a NEO in the 1 to 5-km size range extinguished the dinosaurs. From a risk point of view, these objects are of two types: asteroids in stable orbits which can be tracked and long period comets. Among the latter, comet nuclei which have not yet been detected constitute the main hazard. NEO’s are not an “academic” problem. Direct impact by an Earth-crossing object of order 10km diameter will result in annihilation of most biota by the resulting firestorm and nuclear winter. Such objects have a kinetic energy release of order 30TT (teratons), create 10-km tsunamis[1] and magnitude 12 earthquakes. The last such event occurred 65M years ago. Beginning with the 1991 NASA/Los Alamos Workshop on Near Earth Object Interception [2-3], lasers have been considered a means for deflecting near-Earth objects (NEO’s) discovered to be on a collision course with Earth [4-7]. However, majority opinion in such meetings has been that the most effective response is a standoff nuclear detonation, physically delivered to the NEO. Aside from the lack of enthusiasm many nations might exhibit for the U.S. putting nuclear devices in orbit, the astrodynamics of delivery of the weapon to the NEO require v capabilities of order 100km/s, well beyond current capability. Further, even if delivery is successful, there is only one chance of success per delivery, so that many simultaneous launches would be necessary to give an acceptable probability of defending the planet. There are significant advantages in retargeting, probability of success and even precise target location which are possible with the high-power laser alternative. What makes this possible is discarding earlier assumptions about arbitrary limits on imaging mirror size. With our choice of laser parameters, the laser and imaging mirror would be space-based, because of the size involved, the pointing stability required, and to avoid nonlinear optics effects in the Earth’s atmosphere. In the 1908 Tunguska event, the impactor was probably an iceball about 80m in diameter. It leveled 2150 km2 of Siberian forest (Figure 1.c.) [5]. Events such as this recur every thousand years or so. The event that formed the so-called “Cretaceous- Paleogene boundary,” terminating the Mesozoic era and causing mass extinction of life on Earth was caused by impact of an object in the 10-km size range at the Chicxulub site off the coast of present-day northern Yucatan. These events are infrequent – about one per 100My. Nevertheless, there is now no way to prevent another mass extinction if such an object were detected approaching Earth. The most worrisome aspect of the problem is detection, since “dirty snowball” objects typically have albedo of a few percent, and such objects in the 0.1 to 1 km size range might not be detected before approaching within 3 A.U. of Earth and, since their approach velocity may be 30-60 km/s, that situation leaves on the order of 100 days to respond.

### Laser technology would be simpler and easier to use than nuclear weapons; cost would be worth saving the planet

Phipps 2010

(Claude Photonic Associates Can Lasers Play a Rôle in Planetary Defense? AIP Conf. Proc. 1278, 502 (2010), DOI:10.1063/1.3507139)

LASER NEO DEFLECTION A laser has the crucial advantages of propagating its influence at the speed of light, and of instant retargeting and predictable, calibrated momentum exchange. The momentum is applied slowly, making fracture an impossibility and providing ample time for interaction diagnostics. Our previous studies of this problem assumed side-on deflection. To do this, of course, appropriate illumination geometry requires the laser station to be located to one side of the NEO path, about one AU away from Earth. At least two stations are required, so that the laser station isn’t on the wrong side of Earth when the NEO approaches. These studies were also hampered by limiting consideration to beam director mirror diameters no larger than 10km, which gave a spot size at range much larger than the NEO. Because of the tremendous mass of even a small NEO, time- average laser power required in these studies was of order 10GW for even a 40-m- diameter asteroid [5,7]. In this paper, we will discuss a new approach in which a 10-km-diameter beam director is assumed. We assume a 10-m-aperture WISE-type device which detects the object at 6.3AU, giving *t*o = 3.1E7s (one year) to respond. The concept of operations is illustrated in Figure 3. Instead of sidewise deflection, we address the object head-on. The mirror diameter is chosen sufficient to create a spot size that is smaller than the object size during the entire period. The spot size *d*s=*aM*2*z*/*D* . (2) We use a hypergaussian beam profile, *I* (r)/*I*o = exp [–(*r*/*w*o)*n*] . (3) If *n* = 6, *a* = 1.70 [10], and we take beam quality *M* 2 = 1.75 and =355nm. FIGURE 3. New concept for planetary defense (not to scale) In the new concept, we detect the object as far out as possible, and illuminate it with a spot smaller than the object (100m diameter) using 10ps pulses to enhance plasma formation. The laser station is space-based, to avoid nonlinear optical effects in Earth’s atmosphere and to permit stable deployment and nrad pointing jitter for the 100-km-diameter mirror required to create a 100m focal spot at 6.3AU. The Kepler exoplanet survey spacecraft already approaches this pointing jitter capability [11]. The goal is to slow the object by a few cm/s so that it arrives a few minutes later than it would have, permitting the Earth to get out of its way. Since the Earth’s orbital velocity is *v*E = 29.8km/s, the necessary delay to clear one Earth radius rE is a delay of *t* = *r*E/*v*E = 214 s . (4) We assume the NEO approach velocity is vo = 30km/s, so the net change in velocity we need to apply over time to is *v* = *v*o*t*/*t*o = 20cm/s . (5) In Table 1, we show what laser parameters would be necessary to provide this *v* to ice NEO’s of diameter 200m and 1km. In the Table, we include a 7% correction factor for total energy on target to account for the ratio b/ro *b*/*r*o = *v*max/*v*o = (2*M*E*G*/*r*E + *v*o2)/*v*o = 1.07 (6) of the initial impact parameter *b* at detection to the distance of closest approach *r*o, in order to insure that the object misses the Earth. In Eq. (5), *M*E is Earth’s mass, and *G* is the universal gravitation constant. In this system concept, the mirror would be the dominant cost. From earlier work [13], we estimate total system cost at 30B$, which is not a lot to pay for defense of the planet. However, projected cost to launch the system into space from Earth is 1.1T$, mainly due to mirror mass. The only practical solution for a system this size is mining and manufacturing the mirror structure on the Moon, which would reduce launch cost to 48B$ and total system cost to 78B$.

## Nuclear Mitigation Bad

### Nuclear explosions are destructive and imperfect causing fragmentation making the impact worse

Lu ‘4

(Statement of Dr. Ed Lu President, B612 Foundation, “Near-Earth Objects,” testimony before the Committee on Senate Commerce, Science and Transportation Subcommittee on Science, Technology, and Space, Apr.7 http://www.astrobio.net/index.php?option=com\_retrospection&task=detail&id=972)

Why does the asteroid need to be moved in a "controlled manner"? If the asteroid is not deflected in a controlled manner, we risk simply making the problem worse. Nuclear explosives for example risk breaking up the asteroid into pieces, thus turning a speeding bullet into a shotgun blast of smaller but still possibly deadly fragments. Explosions also have the drawback that we cannot accurately predict the resultant velocity of the asteroid -- not a good situation when trying to avert a catastrophe. Conversely, moving an asteroid in a controlled fashion also opens up the possibility of using the same technology to manipulate other asteroids for the purposes of resource utilization.

### Nuclear weapons fragmentation of the asteroid prevents other forms of deflection

Chapman ‘3

(Clark, scientist at the Southwest Research Institute's Department of Space Studies, Great Impact Debates, Collision Course for Earth 3/03 http://www.astrobio.net/index.php?option=com\_debate&task=detail&id=389)

Clark Chapman: The advantage of using nuclear weapons to destroy asteroids is that they are our most powerful devices by far. But the disadvantages are many. In particular, the more we learn about asteroids and comets, the more we realize that they are incredibly fragile. Most asteroids larger than a few hundred meters across are now thought to be "rubble piles" -- collections of rocks, boulders, and "mountains" simply resting against each other, loosely held together by the tenuous gravitational field of the ensemble. Any sudden force applied to such an object would likely tear it apart into a swarm of objects. The total impacting energy of the swarm would be the same as the original asteroid, but spread out across the Earth's surface. In any case, once you disrupt a comet or asteroid into many different chunks, you've lost all ability to affect what happens next. In short, it is a very bad idea.

### Nuclear mitigation fails – either causes fragmentation or the stand-off blast will be absorbed

Fountain ‘2

(Henry, New York Times correspondent, Armageddon Can Wait: Stopping Killer Asteroids, November 19, http://www.nytimes.com/2002/11/19/science/space/19ASTE.html)

But it is becoming clear that a longtime assumption of many scientists — and of Hollywood filmmakers — that a nuclear weapon is the best way to save the planet from a threatening asteroid is no longer in such favor. Increasingly, those scientists who study asteroid hazards say that a subtler, quieter, slower approach might be called for. These scientists are turning T. S. Eliot on his head: it's not that the world will end with a whimper rather than a bang, they say. It's that it may not end that way. A nuclear detonation, some scientists say, could break the asteroid into several large pieces, increasing, rather than eliminating, the threat. And a blast some distance from an asteroid, designed to shove it into a slightly different orbit, might not work either; the asteroid might soak up the energy like a sponge. "I'd say forget that," said Dr. Keith A. Holsapple, a professor at the University of Washington who studies the effects of simulated nuclear explosions. By contrast, most of the alternative approaches would build up force gradually, gently nudging, rather than shoving, the asteroid. They would rely on the same basic Newtonian principle — that for every action there is an equal and opposite reaction — only written small, with tiny actions creating tiny opposite reactions that, given enough time, could shift an asteroid's orbit enough to change a hit into a close call.

### Nuclear weapons fail to deflect porous NEOs

Fountain ‘2

(Henry, New York Times correspondent, Armageddon Can Wait: Stopping Killer Asteroids, November 19, http://www.nytimes.com/2002/11/19/science/space/19ASTE.html)

What makes some of these alternatives promising is what scientists have come to understand about asteroids. Many of them, the scientists say, are rather loose agglomerations of stony fragments that have stuck together over time in the cosmic rock tumbler that is the solar system. They are not giant solid boulders. "Maybe something like a popcorn ball is a better way to describe it," Dr. Holsapple said. Such porous objects would be hard to obliterate or move with a nuclear blast, even one some distance from the surface, he said. "But pushing a little bit for a long time would work equally well whether an asteroid is porous or not," he added.

### Present nuclear technology is not an option for engaging NEO’s; other options could work in theory

Borchers 2009

(Brent W., Major, USAF Should the USAF be Involved in Planetary Defense?AIR COMMAND AND STAFF COLLEGE AIR UNIVERSITY <http://www.dtic.mil/cgi> bin/GetTRDoc?AD=ADA539693&Location=U2&doc=GetTRDoc.pdf)

Attacking the most obvious answer first, why can’t we just send up a swarm of intercontinental ballistic missiles (ICBMs) with nuclear warheads to intercept it and blow the object apart and completely destroy it? One of the first problems is current ICBM delivery and targeting methods are ground based and current missile configurations wouldn’t allow a warhead to travel far enough into space to impact the object far enough away from earth to make a difference in time.39 The warheads would have to be placed on a modified ICBM body or spacelift vehicle with enough thrust to place the warheads on an intercept path that would be far enough out to make a difference in the objects trajectory. This may not take a great deal of effort when compared to other options but some major modifications in the ICBM guidance and targeting system would be needed. Additionally, the Hollywood movie script of blowing up the object to smaller chunks isn’t an ideal plan as that just would create more impactors with roughly the same center of mass that were on a collision course with earth, and now the earth’s population has multiple impacts and to deal with. Some studies estimate that destroying an object could create a blast area or area of effects up to two times the original objects damage. For example, a ten megaton blast from a single meteorite would affect an area of 750 square miles with moderate damage. However, by spitting that ten megaton meteor into four two and a half megaton sized meteors with impact areas 20 miles apart, the total area of devastation would equal over 1200 square miles or almost twice the area. This is not on the desirable side of the effects if we are to try and limit the damage or avoid it altogether. This situation might not apply however, if the object has a low density and would fracture easily. For example a comet is usually composed of ice and dust and some rock matter loosely held together by its gravitational attraction. If a nuclear blast could break it up into chunks smaller than 20 meters in diameter, this might work. These low density objects smaller than 20 meter in diameter rarely make it through the atmosphere and are usually ablated or explode in the upper reaches of the atmosphere where their effects aren’t felt on earth. In another case using nuclear weapons detonated near the object to affect its orbit rather than trying to completely destroy it could be successful in theory and practice. Scientists have theorized that exploding a nuclear weapon next to an object in space might be the best solution. The radiation and blast would vaporize a small part of the surface area of the asteroid that was exposed directly to the blast. This mass of this vapor would then impart a small nudge or push to the asteroid in the opposite direction of the blast42 This is only a simple description of the operation required to move the object from its orbit. Complex calculations are required to determine the exact distance a weapon would need to be exploded to create the largest effect. Too close of a blast and you might accidentally fracture the object or the blast would be too concentrated in one area and not spread its full pressure over the surface of the asteroid. If the explosion occurred too far away then the energy imparted would be spread too thinly over too large of an area and wouldn’t vaporize enough mass to impart enough momentum on the object to move it. Another problem with any solution that intercepts the object is accuracy. It’s hard enough to get two objects to intercept each other when they’re both moving at 17,500 mph in low earth orbit or in the case of intercepting a missile with an anti ballistic missile battery or something similar. We’ve tackled both of the problems listed above with our anti-ballistic missile system and testing of anti-satellite weapons in the past. However, the problem with intercepting a NEO in bound for the earth is that the object you’re trying to intercept is moving at a speed between twelve to seventy two kilometers per second. This is much faster than any incoming ICBM or a satellite that is moving in low earth orbit. Add to this that the object is not coming in on a straight line and your missile or interceptor is not moving towards that target on a straight line either.44 Both objects are on a slight parabolic arc (when viewed from the macro level) because of the gravitational pull of the sun, earth and any other bodies that are nearby in our solar system. Even though gravity may seem to work against you in some of these situations, in the following deflection operations gravity is the basic force that makes them work. One option of moving the object out of earth’s path involves using a gravity tug to slow or alter the NEOs path. If the object is intercepted far enough away from earth, its orbit may only need to be slowed .1 meter per second. Placing a large satellite or perhaps even a nearby asteroid on the same path as the object and keeping it there will provide a slight but sure tug on the object. The force of gravitational attraction between the two objects will slowly pull the target object off course by fractions of inches. If the object is intercepted in time, these fractions of inches will add up and the object should miss the earth. These are only a few of the options available and the options seem to be only limited by the imagination of the scientists that continue to theorize about them. However, the purpose of this paper isn’t to produce an exhaustive list of options, but to provide a background for the reader to sufficiently understand some of the problems and nature of such a large task. Some of these options are listed to provide insight into the progress we’ve currently made or possible areas we should focus our efforts.

### Nuclear weapon engagement with the NEO is complicated; any one of the steps could lead to failure

Phipps 2010

(Claude Photonic Associates Can Lasers Play a Rôle in Planetary Defense? AIP Conf. Proc. 1278, 502 (2010), DOI:10.1063/1.3507139)

NEO DETECTION Detecting an approaching NEO will be a matter of good fortune, since whole-sky surveys capable of detecting very faint objects are not repeated frequently enough to give good warning. However, we assume a sensitive telescope is looking in the right direction. If the NEO has optical scattering coefficient into 2sterradians, the range to detection ZDET in units of A.U. is given by [3] Figure 2 shows that, for the “dirty snowball” objects, our warning time for an epoch- terminating asteroid collision with Earth could be as little as 100days. NASA’s planned WISE spaceborne infrared survey spacecraft [9] will mitigate this problem to a significant extent, increasing detection distance for large, dark objects by a factor-of- 5 during its 6-month mission. WISE will have a wide 0.7 degree field of view and a 40cm aperture diameter. It detects dark objects at greater range because they are brighter in the infrared. ASTRODYNAMICS OF PHYSICAL NEO DEFLECTION If it is desired to fly a space platform to the NEO and push it aside with a standoff nuclear explosion [3], in the simplest astrodynamic sequence, three sequential maneuvers are necessary. Consider a 30km/s NEO which has been detected at a distance of 100days. Where vo = 30 km/s is the NEO approach velocity, these are: 1) Accelerate through *v* = *v*o 2) Decelerate through *v* 3) Reaccelerate in the reverse direction through *v* to match the NEO’s velocity while carefully arming and placing the nuclear device. The interceptor platform must be capable of a total v = 90km/s, which is beyond present capability. With chemical propellants, the rocket equation gives a launch mass to payload mass ratio *M*/*m* = of 6.6E7 for such a device. If the payload were 100kg, the rocket mass on the ground would be 6.5MT. If the vehicle acceleration is 0.1G (implying a liftoff thrust 200 times larger than has yet been realized), each of these three maneuvers can be completed in about one day. More severe problems are the time required and the chances of error or failure. By the time the interceptor platform has pulled alongside the NEO in the above scenario, only 47 days remain. In addition, the first vehicle may arrive and its nuclear device fail to fire, or fail to impart the necessary momentum to the NEO, or, even if applied correctly in one pulse, could fracture it. This result is particularly likely for a snowball. The effect would be to convert the one target into many, making the problem far worse because of the “hohlraum effect” arising from multiple dispersed impactors converting the whole atmosphere into a glowing oven for several minutes back on Earth. One vehicle is not enough. Finally, multiple vehicles must be launched simultaneously, because failure is intolerable, and the associated cost is much larger than is usually assumed for one vehicle, probably in the multiple T$ range including development costs.

## Space Based Detection Key

### Space based detection systems necessary as they are more accurate than ground based systems only

NATIONAL ACADEMY OF SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council NATIONAL ACADEMY OF ENGINEERING INSTITUTE OF MEDICINE NATIONAL RESEARCH COUNCIL <http://www.nap.edu/catalog.php?record_id=12842>)

No nation has had or currently operates a space-based observatory dedicated to the discovery and/or characterization of NEOs. Space-based observatories are, however, planned for launch that will help to discover and/or characterize NEOs, especially because of the sensitivity of the observatories’ telescopes to infrared light, as explained below. Asteroids in orbits that bring them close to Earth are especially menacing if they are dark and have evaded detection by ground-based surveys in visible light. Also, since the assumed albedo might not be representative of a dark object, the calculated diameter could be misrepresented as smaller than the object’s true diameter. But dark objects are especially detectable in infrared light. The bias against lower-albedo (darker) asteroids is reduced through the use of infrared observations in space: At the temperatures and albedos that dominate the solar system inside the orbit of Mars, the diameters computed from infrared signals are more accurate than those derived from visible-light reflections from asteroids and comets. Thus, the detections of potentially hazardous NEOs by an infrared telescope (one sensitive to infrared light) will result in a more accurate size-frequency distribution for these objects. Additionally, the background from other astronomical sources is about 100 times lower at infrared wavelengths of 10 microns (a micron is one-millionth of a meter) than at visible wavelengths, since most stars emit far less infrared light than visible light. This difference reduces the chance for interference from other strong astronomical sources. Combined with visible-light data, the albedos of NEOs detected in the infrared can also be derived. This derivation of albedos offers insight into composition and surface properties. The Wide-field Infra- red Survey Explorer for Near-Earth Objects (NEOWISE), a U.S. mission (see below), will leverage this infrared advantage. Canada and Germany are both building spacecraft (see below) that could contribute to the discovery of NEOs, especially those whose orbits are partially or fully inside Earth’s orbit. These NEOs are less able to be observed by ground-based telescopes because they are so close to the Sun, as seen from Earth. Searching for NEOs from orbits in which spacecraft can be positioned to observe objects while the spacecraft is not pointed toward the Sun is an advantage for observing NEOs with orbits largely inside Earth’s orbit. Neither mission, however, will detect fainter or smaller objects than those detected by ground-based telescopes.

### Must have space missions to accurately assess and engage in prevention of NEO strikes

NATIONAL ACADEMY OF SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council <http://www.nap.edu/catalog.php?record_id=12842>)

IN SITU CHARACTERIZATION RELEVANT FOR MITIGATION Detailed knowledge of the physical characteristics of several representative NEOs would improve understanding of the overall NEO population and help the design and implementation of the mitigation techniques that may be employed should an NEO threaten Earth (but that understanding may well not improve the knowledge of a specific object on an impact trajectory Although the physical characteristics of an individual NEO that might strike Earth cannot be accurately predicted in advance, the knowledge of the range of possible characteristics will greatly aid in advance planning and might be essential if there is no opportunity to perform detailed characterization studies of the incoming NEO.). Dedicated space missions such as Near Earth Asteroid Rendezvous (NEAR) Shoemaker and Hayabusa have provided detailed information on two vastly dissimilar NEOs. NASA’s NEAR Shoemaker spacecraft visited one of the largest NEOs, Eros, in February 2000; the Japan Aerospace Exploration Agency’s Hayabusa probe rendezvoused with the subkilometer-sized asteroid Itokawa in September 2005. Both of these robotic missions generated much scientific interest in NEOs and revealed many intriguing surprises and new paradigms for asteroid scientists to consider. It is now apparent from just these two missions, and the suite of ground-based optical and radar observations of NEOs, that NEOs have a much wider range of internal structures, more diverse physical conditions, and more complex surfaces than had previously been realized. Essential physical properties relevant for the mitigation of NEOs are best determined from dedicated spacecraft missions. Although ground-based observations can provide significant information about the physical properties of NEOs (e.g., rotation rates, size estimates, and composition), dedicated spacecraft missions to NEOs providing extended periods for observations and investigation close to NEOs obtain detailed characterizations of their rotational motions, masses, sizes, shapes, surface morphology, internal structure, mineral composition, and collisional history. The data collected from NEO characterization missions would also help to calibrate the ground- and space-based remote sensing data and may permit increased confidence in the remote classification of NEOs and their associated physical characteristics, which could inform future mitigation decisions. Flyby missions are not well suited for these detailed types of investigations because of the limited time for performing observations during the spacecraft encounter. To attain the required details of an NEO’s physical characteristics for hazard mitigation, much more time must be spent near the NEO than is possible in a flyby in order to operate instruments making gamma-ray, x-ray, and other compositional measurements. Constraints on some surface characteristics and on the object’s mass can be obtained, but the uncertainties on the NEO’s physical properties obtained from a flyby encounter are far too large to be useful for hazard mitigation purposes. Such missions may be suitable for basic reconnaissance of the NEO population, but overall the data return relevant to mitigation is low relative to cost. Continued efforts to obtain characterization data from ground-based studies are desirable, and spacecraft observations of representative NEOs are very important. Spacecraft characterization of any NEO for which orbit change is to be attempted is essential (see Chapter 5). Finding: Dedicated flyby spacecraft missions to NEOs provide only limited information relevant for hazard mitigation issues. Finding: Rendezvous spacecraft missions can provide detailed characterization of NEOs that could aid in the design and development of hazard mitigation techniques. Such in situ characterization also allows the calibration of ground- and space-based remote sensing data and may permit increased confidence in the use of the remote classification of NEOs to inform future mitigation decisions. HUMAN MISSIONS TO NEAR-EARTH OBJECTS During its deliberations, the committee was briefed on the possibilities of human missions to near-Earth objects. This subject also received attention during meetings of the Human Space Flight Review Committee and was mentioned as part of its “Flexible Path” option in its final report. In the future, NASA’s Exploration Systems Mission Directorate may conduct human missions to one or more near-Earth objects. The committee identified no cost-effective role for human spaceflight in addressing the hazards posed by NEOs. However, if human missions to NEOs are conducted in the future, the committee recommends that their scientific aspects be maximized to provide data useful for their characterization. Recommendation: If NASA conducts human missions to NEOs, these missions should maximize the data obtained for NEO characterization.

### NASA must know the composition of NEO’s; best strategy is “in situ” (in position) observations; that would require space based strategies

Schweickart et al 2010

(Russell L. Chairman, B612 Foundation (Task Force Co-Chair)Report of the NASA Advisory Council Ad Hoc Task Force on Planetary Defense October 6, T http://www.nasa.gov/pdf/490945main\_10-10\_TFPD.pdf)

Recommendation 3: Investigate the Nature of the Impact Threat. To guide development of effective impact mitigation techniques, NASA must acquire a better understanding of NEO characteristics by using existing and new science and exploration research capabilities, including ground-based observations, impact experiments, computer simulations, and in situ asteroid investigation. 3.1. Physical Characteristics. NEO survey programs should provide initial physical characterization of discovered objects. These characteristics include size, reflectivity, and color brightness at wavelengths useful for interpreting first order mineralogical composition. A key element in any defense strategy is to “know thine enemy.” Although the motion of a newly discovered object can reveal whether the orbit is categorized as “potentially hazardous,” the discovery images themselves contain little information about the NEO’s physical nature. In many cases, an object for which follow-up physical characterization is urgently needed does not present another favorable observing opportunity for years. NEO characterization is an ongoing process that begins at the time of discovery. Obtaining basic characterization measurements immediately following discovery takes advantage of the same favorable observing geometry that enabled the NEO’s detection. Simultaneous orbit determination and preliminary physical assessment of the object provides the earliest and most informed basis to evaluate any possible threat. Objects classified as “potentially hazardous” should receive priority for follow-up physical observations from ground-based facilities. In situ characterization of these objects (see 3.2) will provide independent verification of the assessments made from the ground. In situ verification of ground-based characterization capabilities will provide the highest level of confidence for dealing with any near-term NEO threat, for which ground-based measurements may provide the only characterization information available. 3.2. Planetary Defense Characterization Missions. NASA’s science, exploration, and survey missions aimed at NEOs should include determination of the physical characteristics most directly related to Planetary Defense. These include size, mass, density, porosity, composition, rotation period, interior structure, binary nature, surface heterogeneity, and near-surface mechanical and thermal properties. Also useful for Planetary Defense planning are science and exploration mission objectives aimed at determining NEO internal structure and evaluating methods for coupling directly to its surface. At this early stage in our understanding of NEOs, science and exploration mission objectives are highly commensurate with those required for Planetary Defense. These natural synergies between science, exploration, and Planetary Defense should be fully exploited for all missions to these solar system bodies. Understanding the physical diversity or similarity of NEOs over the size range of tens to hundreds of meters, with compositions varying from low-density carbonaceous “rubble piles” to high-density, monolithic nickel-iron bodies, will inform the range of mitigation strategies needed for effective planetary defense.

## Ground & Space Detection Key

### Best approach is both ground and space based; budget constraints, however, will stop implementation in the status quo

Foust 2007

(Jeff, editor and publisher of The Space Review The three D’s of planetary defense March 19, http://www.thespacereview.com/article/835/1)

While current search systems, like LINEAR in New Mexico and Spaceguard in Arizona, are doing a good job finding large NEOs, they are not as well-suited for detecting the far larger numbers of smaller NEOs believed to exist. Current estimates suggest that there may be up to 100,000 NEOs 140 meters in diameter or larger, only a tiny fraction of which have been discovered to date. To deal with this issue, Congress, as part of a NASA authorization bill it passed in late 2005, required NASA to perform a study to investigate ways to discover at least 90 percent of these NEOs by 2020. The study, [a summary of which was released by NASA earlier this month](http://www.nasa.gov/pdf/171331main_NEO_report_march07.pdf), examined a wide variety of ways to do it, from part-time use of existing and planned ground-based telescopes to an array of dedicated telescopes on the ground and in space. By sharing two planned ground-based survey telescopes, the Panoramic Survey Telescope & Rapid Response System (PanSTARRS) and Large Synoptic Survey Telescope (LSST), it would be possible to discover about 83 percent of the potentially hazardous objects 140 meters or larger in diameter by 2020; the 90-percent threshold would be reached in 2026. The 2020 deadline set by Congress could be achieved if those telescopes were augmented with either a dedicated version of the LSST, or a space-based infrared telescope in a Venus-like orbit. In the latter case, this system would find 97 percent of the objects by 2020. The problem with these enhanced systems, however, is their cost. The NASA study estimated that, in fiscal year 2006 dollars, the system that used the shared telescopes plus a dedicated LSST would cost $835 million through 2020. The system with the shared telescopes and the space-based telescope, not surprisingly, was even more expensive: $1 billion through 2017, the date when it would achieve the 90-percent threshold. That’s big money for a program that currently gets only about $4 million a year for current survey efforts. “NASA recommends that the program continue as currently planned, and we will also take advantage of opportunities using potential dual-use telescopes and spacecraft—and partner with other agencies as feasible—to attempt to achieve the legislated goal within 15 years,” the report concluded. “However, due to current budget constraints, NASA cannot initiate a new program at this time.”

### Survey of NEO’s can’t be completed by 2020 deadline; best approach would be a combination of space and ground based solutions

NATIONAL ACADEMY OF SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council <http://www.nap.edu/catalog.php?record_id=12842>)

Regarding the first task of its charge, the committee concluded that it is infeasible to complete the NEO census mandated in 2005 on the required time scale (2020), in part because for the past 5 years the administration has requested no funds, and the Congress has appropriated none, for this purpose. The committee concludes that there are two primary options for completing the survey: Finding: The selected approach to completing the George E. Brown, Jr. Near-Earth Object Survey will depend on nonscientific factors: If the completion of the survey as close as possible to the original 2020 deadline is considered more important, a space mission conducted in concert with observations using a suitable ground-based telescope and selected by peer-reviewed competition is the better approach. This combination could complete the survey well before 2030, perhaps as early as 2022 if funding were appropriated quickly. If cost conservation is deemed more important, the use of a large ground-based telescope is the better approach. Under this option, the survey could not be completed by the original 2020 deadline, but it could be completed before 2030. To achieve the intended cost-effectiveness, the funding to construct the telescope must come largely as funding from non-NEO programs. Multiple factors will drive the decision on how to approach completion of this survey. These factors include, but are not limited to, the perceived urgency for completing the survey as close as possible to the original 2020 deadline, the availability of funds to complete the survey, and the acceptability of the risk associated with the construction and operation of various ground- and space-based options. Of the ground-based options, the Large Synoptic Survey Telescope (LSST) and the Panoramic Survey Telescope and Rapid Response System, mentioned in the statement of task, and the additional options submitted to the committee in response to its public request for suggestions during the beginning of this study, the most capable appears to be the LSST. The LSST is to be constructed in Chile and has several science missions as well as the capability of observing NEOs. Although the primary mirror for the LSST has been cast and is being polished, the telescope has not been fully funded and is pending prioritization in the astronomy and astrophysics decadal survey of the NRC that is currently underway. Unless unexpected technical problems interfere, a space-based option should provide the fastest means to complete the survey. However, unlike ground-based telescopes, space options carry a modest launch risk and a more limited lifetime: ground-based telescopes have far longer useful lifetimes and could be employed for continued NEO surveys and for new science projects. (Ground-based telescopes generally have an annual operating cost that is approximately 10 percent of their design and construction costs.)

### NEO strategies must have both ground and space based approaches to be effective; need to gather necessary information we don’t have and should be budgeted outside of NASA’s current budget

Schweickart et al 2010

(Russell L. Chairman, B612 Foundation (Task Force Co-Chair)Report of the NASA Advisory Council Ad Hoc Task Force on Planetary Defense October 6, T http://www.nasa.gov/pdf/490945main\_10-10\_TFPD.pdf)

8. To achieve the NEO search goals in a timely manner as directed by the 2005 George E. Brown NEO Survey legislation, the nation will likely require acquisition and operation of a space-based survey element in addition to ground-based systems. A spacecraft operating with sensors in the infrared band from an orbit sunward of Earth’s (e.g., a Venus-like orbit) offers great advantages in rapid search and repeat observation frequency. 9. When used in conjunction with ground-based optical observations, radar data can dramatically improve orbit knowledge of recently discovered NEOs. However, radars have limited sky coverage and can observe NEOs only at relatively close range. A modest-aperture, space-based infrared telescope with its advantageous orbital geometry (an observing location and direction different than Earth’s) could enable a much larger total of positional observations over much longer orbital tracks. Such tracking from multiple solar system vantage points (e.g. Earth and a Venus-like orbit) will aid in quickly reducing orbit uncertainties when radar follow-up is unavailable. 10. While the search for the NEO population larger than 140 meters is underway and the necessary orbit precision is being obtained, there will be a transition period or window of perceived vulnerability, lasting at least two decades. Some NEOs will present worrisome probabilities of impact, and sufficient orbit precision to rule out an impact may not be obtained before a decision must be made to launch a deflection campaign. The more rapid search enabled by a space-based system will, by aiding early ground-based follow- up, shorten this window of vulnerability by several years. Impact threats will still appear as the catalog nears completion, but continuing observations will reduce uncertainty and increase warning time. 11. Physical characteristics of NEOs pertinent to Planetary Defense include size, mass, density, porosity, composition, rotation, interior structure, binary nature, and the properties of the surface. Our present knowledge is insufficient to understand the typical range of characteristics for NEOs comprising the potentially hazardous population. This knowledge base is essential for the most effective development and application of deflection measures. Simple physical characterization is also essential for accurate forecasting of impact effects for an object escaping deflection. 12. The Task Force strongly recommends that the cost of NASA Planetary Defense activities be explicitly budgeted by the administration and funded by the Congress as a separate agency budget line, not diverted from existing NASA science, exploration, or other mission budgets.

# Possible Agents

## NASA

### NASA must take the lead in all facets of NEO strategies and mitigation; the agency must be the main conduit for information

Schweickart et al 2010

(Russell L. Chairman, B612 Foundation (Task Force Co-Chair)Report of the NASA Advisory Council Ad Hoc Task Force on Planetary Defense October 6, T http://www.nasa.gov/pdf/490945main\_10-10\_TFPD.pdf)

Recommendation 5: Lead U.S. Planetary Defense Efforts in National and International Forums. NASA should provide leadership for the U.S. government to address Planetary Defense issues in interagency, public education, media, and international forums, including conduct of necessary impact research, informing the public of impact threats, working toward an internationally coordinated response, and understanding the societal effects of a potential NEO impact. The NEO hazard exists within the context of other natural and technological hazards, and that lens of experience shapes citizens’ and decision-makers’ perceptions. As extreme examples of low-probability, high-consequence events, NEO impact threats are especially susceptible to misperception. Few people have witnessed even a small impact into Earth’s surface, yet there is substantial and growing awareness that a devastating NEO impact is possible. 5.1. Societal Leadership. NASA should lead U.S. government efforts, in public and international forums, to educate, coordinate and act in reducing the threat of a NEO impact. With its broad expertise on the nature of the NEO hazard, NASA should cooperate with other elements of society that study, report on, and make decisions about NEO threats. Such societal elements include, but are not limited to: Media reporting newsworthy NEO developments and events The hazards community, including civil defense agencies and emergency responders Military elements with interests and responsibilities for national security space and disaster relief activities Educational institutions (including popular institutions like science museums) responsible for developing an informed citizenry Scientific communities (beyond the astronomical field), which have the expertise to undertake research on the physical, environmental, societal, and economic effects of threatened or actual impacts The space law community, which may be called on to apply legal principles developed in other contexts to the unique circumstances of a NEO impact threat Political leaders responsible for responding effectively and rapidly to unusual events affecting society 5.2. Impact Effects Research. NASA should support research addressing the breadth of physical, environmental, and social consequences of a range of NEO impact scenarios. With its investigation of the NEO hazard, NASA has interests in understanding impact consequences not deeply shared by other U.S. scientific agencies. More research is needed on Earth’s atmospheric response to large impacts during NEO entry and subsequent lofting of ejecta into the atmosphere. The same is true for the direct impact effects on the landscape and human infrastructure, adding to the limited understanding gained from nuclear test data of a half-century ago. Ocean impacts and the characteristics of impact-generated tsunamis require further study. NASA should also investigate the psychological and sociological consequences of a NEO impact, given how unfamiliar such disasters are to the public. 5.3. Impact Simulation. NASA and other PD-relevant agencies should develop representative impact threat timelines (linked to reference deflection missions), and initiate periodic multi- agency response simulations and evaluations. NASA must proactively extend its NEO impact knowledge to coordinating agencies, especially those responsible for disaster response, such as the DHS. Coordinated table-top exercises will be an essential training and evaluation tool in inter-agency impact threat preparations. A detailed impact scenario timeline from early detection to successful deflection or civil defense response will be the nucleus for any exercise. A set of such timelines, representing a plausible variety of cases and consistent with a set of design reference missions (see 4.5) will serve as an essential, multi-agency planning resource.

### The need for a formal agency exists; NASA should have control over this agency

NATIONAL ACADEMY OF SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council <http://www.nap.edu/catalog.php?record_id=12842>)

NATIONAL COOPERATION An effective, comprehensive approach to the NEO hazard will require significant planning, coordination, and cooperation within the U.S. government. It seems sensible to assign responsibility for this NEO hazards program to an existing governmental administrative structure, especially in view of the likely relatively small size of the undertaking. It also seems more efficient to place the program under the control of a single entity in coordination with other relevant government organizations. The coordination could be implemented by way of a standing committee or an interagency task force of the appropriate agencies to organize and lead the effort to plan and coordinate any action to be taken by the United States individually, or in concert with other nations. This committee or task force would have membership from each of the relevant national agencies (NASA and the National Science Foundation [NSF]) and executive departments (Defense, Energy, Homeland Security, Justice, and State), with the chair from the lead entity. (Other relevant agencies and departments might include the Departments of Transportation and of Health and Human Services, the Environmental Protection Agency, the General Services Administration, and the Department of Agriculture.) The first step of the standing committee or interagency task force would be to define the necessary roles and responsibilities of each member agency in addressing the various aspects of the threat, from surveying the sky through civil defense. The lead responsibility for a given task would be assigned to the appropriate agency or department. In view of the intrinsic international nature of the program, a civilian rather than a military agency would have advantages for housing it. Otherwise, one could envision continual internal conflict over military security and classification issues. Of course, any group will have such issues from time to time, but a civilian group could have far fewer such conflicts and also would likely be more acceptable to its counterparts in other nations. In an emergency, the military could be enlisted or appointed by the president to help; the military would maintain currency with the issues through membership in the standing committee or interagency task force. Among the civilian agencies and departments, NASA has the broadest and deepest familiarity with solar system objects and its associated rendezvous missions. The NSF supports ground-based solar system research, but it traditionally responds to proposals rather than initiating and organizing complex programs (the International Geophysical Year being one of the exceptions). The Departments of Defense and of Energy, however, have by far the most important experience with nuclear explosives, necessary for some active-defense missions for changing NEO orbits. For such missions and their preparations, these departments, or at least the latter, would certainly become involved, with coordination being maintained through the standing committee or task force described above. NASA is a possible choice for the lead agency. Within NASA, under its present organization, a natural home for this hazards program would be the Science Mission Directorate (SMD), which deals with solar system science. The current, small hazards program␣with an approximately $4 million annual budget␣is already housed in this directorate. But the hazards program discussed here would be more effective with its own director and budgetary line item(s) to ensure its viability within the much larger SMD. It would, of course, derive benefits from and provide benefits to the science and other programs in the SMD. Organization is also key when mitigation requires civil defense, primarily evacuation. Experience has driven home a lesson: Without prior training for it, evacuation has chaotic and often disastrous attributes. However, training from prior emergencies can yield very successful, almost trouble-free evacuation outcomes, at least in local areas. The “poster child” for such success is the evacuation of San Bernardino County, California, in the face of ferocious fires that attacked the region in the summer of 2007.

### NASA is the most likely agency to conduct research and development of NEO mitigation strategies

Schweickart et al 2010

(Russell L. Chairman, B612 Foundation (Task Force Co-Chair)Report of the NASA Advisory Council Ad Hoc Task Force on Planetary Defense October 6, T http://www.nasa.gov/pdf/490945main\_10-10\_TFPD.pdf)

For more than a decade, NASA has been searching for near-Earth objects (NEOs) that may pose a potential impact threat to Earth. Both the legislative and executive branches are considering what role NASA may play in expanding its NEO search and developing the capability to prevent or mitigate a future impact. The space agency has broad expertise in scientific exploration and characterization of near-Earth asteroids (NEAs) and comets (NECs), and NASA’s deep space operations experience could enable the development of deflection technologies to be used to divert a NEO threatening an impact. The Ad-Hoc Task Force on Planetary Defense of the NASA Advisory Council (hereinafter, “Task Force”) was established on 15 April 2010 in order to advise the Council Chairman, the NASA Administrator, and NASA Mission Directorates on future agency actions related to NEO impact mitigation, or Planetary Defense (see Task Force Terms of Reference in Appendix). The Task Force anticipates that the executive branch, in its current consideration of appropriate agency roles regarding the NEO impact hazard, will assign NASA a lead role for the U.S. government’s activities for Planetary Defense. The recommendations herein reflect this assumption. If NASA is not assigned the leadership role for Planetary Defense, certain Task Force recommendations will apply instead to the responsible federal agency.The Task Force recognizes that other entities have conducted substantial work addressing Planetary Defense challenges. The Task Force relied on this, other primary sources, and new information developed during its deliberations to inform its recommendations. In citing this work, the Task Force has minimized, for brevity, the repetition of supporting material for its recommendations. This material can be found in the References section. Synergies from Planetary Defense Near-Earth objects figure prominently in NASA’s science exploration efforts via future robotic missions, in its search programs to detect a potential impactor, and now in its human exploration plans. Congressional direction in the George E. Brown Survey NEO Survey Act of 2005 (Section 321 of Public Law No. 109-155) regarding a survey of the NEO population, and current Office of Science and Technology Policy consideration of government responsibility for Planetary Defense, indicate that NEO activities will be part of NASA’s exploration and technology efforts.

### NEO strategies would be cost effective and assist NASA in meeting other agency goals

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NASA’s NEO research is a “three-dimensional” activity that advances our knowledge in solar system science, human exploration, and Planetary Defense. For a relatively small incremental investment in instrumentation or capability on science or exploration spacecraft, NEO missions designed for one goal can return substantial information useful to NASA’s Planetary Defense activities. For example, Planetary Defense mission goals (e.g. precision orbit determination; measurements of mass, density, porosity, and rotation state; investigation of the momentum multiplier; searching for NEO satellites, etc.) would also fulfill many fundamental scientific and human exploration objectives. In turn, robotic science spacecraft can demonstrate the precise proximity operations and guidance algorithms necessary for precision “slow push” deflection techniques. In preparation for visits by human explorers, investigation of a NEO’s interior structure, physical properties, and stability of surface materials will furnish data useful for other deflection techniques, such as kinetic impact and regolith ablation. Time is a fourth dimension for NEO research. Early integration of Planetary Defense objectives into NASA’s research and exploration missions provides a cost-effective means to increase the maturity of our technology to meet future impact threats and eliminate duplicate flight missions. Overall, the integration of Planetary Defense investigations into scientific and human exploration missions increases the return from any of NASA’s NEO missions, meeting the needs of managers, policy makers, the science community and the public.

### NASA should pursue an experimental deflection demonstration in conjunction with other international agencies; several strategies ought to be attempted to determine the best options

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4.2 Deflection Research Program. In parallel with impact disaster response planning, NASA should perform the necessary research and development to perform an in-space test of a deflection campaign, with the goal of modifying, in a controlled manner, the trajectory of a NEO. Such a demonstration program should include both a powerful impulse technique (e.g. kinetic impact) and a gradual, precise (e.g. gravity tractor) deflection capability. With sufficient warning, existing technologies are likely adequate for NEO deflection but it is critical for both public and government confidence to physically demonstrate them prior to employment in an impact threat scenario. The European Space Agency, Russian Federal Space Agency, and others have examined and are planning NEO deflection missions, and NASA should aggressively pursue a cooperative deflection capability demonstration. 4.3. Explosive Technologies. Although nuclear explosives are considered a rarely needed and last-resort deflection option, it is prudent that NASA should collaborate with the Department of Energy and Department of Defense to develop an analytic research program to explore the applicability, utilization, and design of nuclear explosion technology for NEO deflection. If a large NEO deflection demands a total impulse greater than that deliverable via multiple kinetic impactors, then detonation of a nuclear device in standoff or other mode may be necessary to avert an Earth impact. Until non-nuclear techniques of comparable capability are proven, NASA should collaborate in nuclear deflection technique analysis and simulation. 4.4: Deflection Physics. NASA should initiate both analytic and empirical programs to reasonably bound the “momentum multiplier” (termed “β”) in kinetic impact deflection. β is the key variable in determining kinetic impact deflection performance. The momentum multiplier describes the extent to which the momentum of ejecta blasted clear by the impact augments the momentum transferred directly to the NEO by the incoming projectile. This parameter is unlikely to be known precisely before an actual deflection, and current estimates vary by factors of five, ten, or more. The success of both mission planning and assessments of deflection feasibility depends strongly on bounding the value of β by analytic and empirical means. Research should include computer hydrocode impact simulations, laboratory gas gun tests, and other appropriate experiments aimed at better understanding the momentum transferred to a target by a kinetic impactor. The sensitivity of the momentum enhancement factor (β) to the target’s composition and structure should be examined, along with the scaling expressions appropriate for impacts at varied velocities and encounter geometries.4.5. Impact Scenarios. NASA should develop a reference set of a few impact threat scenarios and a corresponding set of deflection campaign design reference missions. These reference deflection scenarios should be shared nationally and internationally, forming the basis for future impact gaming exercises. Such impact threat and response scenarios should reinforce the concept that many NEO deflections will result in near-misses occurring periodically in future years on nearly the same calendar day, because the NEO and Earth orbits nearly intersect at that point. At each close- approach, Earth's gravity will deflect the NEO into a new orbit that will again encounter the Earth's orbit and possibly a number of nearby "keyholes" (small regions in space near Earth through which a passing NEO may be gravitationally redirected onto a path to impact Earth). To preclude such a future keyhole passage and subsequent Earth collision, each deflected NEO will need periodic monitoring to determine if some orbital fine-tuning is required.

### NASA and federal government necessary to insure success of the program; may need to re-work ABM treaty

Borchers 2009

(Brent W., Major, USAF Should the USAF be Involved in Planetary Defense?AIR COMMAND AND STAFF COLLEGE AIR UNIVERSITY <http://www.dtic.mil/cgi> bin/GetTRDoc?AD=ADA539693&Location=U2&doc=GetTRDoc.pdf)

All of the previously discussed items are in theory only. None of them have been tested outside of a laboratory and most theorizing has been done in the scientific community without much funding or official input from the Department of Defense or NASA. Even though the preponderance of knowledge on the subject rests with the civilians, at some point the government will have to get involved due to the nature of the threat and size of such an ambitious project. In the past there have been some tests of rendezvous with NEOs but not for the purpose of testing the options we’ve just discussed. The European Space Agency (ESA) plans to send some craft to meet up with asteroids for both study and a deflection exercise. The Rosetta project involves an ESA vehicle orbiting, studying and mapping the makeup of an asteroid. The more ambitious ESA “Don Quixote” project involves two vehicles, one to sit on orbit and provide measurements while a second craft impacts the asteroid at high velocity, resulting in measurements to determine the effect on the asteroids orbital parameters is planned.46 NASA had a joint project with the DOD titled “Clementine I and II” that planned similar tests. One Clementine project was line item vetoed by President Clinton. It was thought this was done because the same technology that could be used to intercept an asteroid or NEO could also be used to intercept an ICBM, and the development of such could violate the Anti Ballistic Missile treaty that the U.S. was held to at the time. The second part of the Clementine went on to map the surface of the moon but soon failed after this and was unable to continue its mission to intercept and study a near earth asteroid. To prove that this capability exists and to further testing efforts international bans on nuclear weapons testing in space would have to be relaxed or ignored.

## DHS

### Response for NEO’s should be made a part of the Department for Homeland Security

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(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council <http://www.nap.edu/catalog.php?record_id=12842>)

The National Response Framework in the DHS is the part of the national government that deals with civil defense. Responsibility for planning for emergencies is centered within it. The framework is especially concerned with the coordination of the numerous local, state, regional, national, and nongovernmental organizations that are or should be involved in disaster anticipation, management, and relief of all kinds. NEOs could be added to and considered explicitly in this framework and would thus become a part of the planning and implementation of the disaster response of the United States. Any needed legislation to achieve this goal could be linked to any national and international policies and structures dealing with disaster prevention and management. The underwriting and insurance industry might be interested in providing actuarial input relevant to these matters. Since the details of the asteroid and comet threat are unknown, a planning philosophy will be most effective if it is based on the need to be flexible and generic. This is necessary because of the wide variety of potential hazards, from airbursts through land impacts to tsunamis, with each covering a broad span of possible severities. The chief unknown with respect to NEO hazards planning will be the size of the need, but if huge, the peril will probably be defined well in advance. In addition to planning a flexible response, a trained cadre of professionals must obtain and set up the equipment and supplies needed to sustain a displaced population. Such preparatory issues are not confined to the asteroid and comet hazard, but have common elements with all other natural hazards, such as earth- quakes, fires, and hurricanes. All of the common elements may be treated similarly and by the same personnel. It makes sense, in any national activity in this civil-defense sphere, to coordinate and collaborate with other nations in the planning and, depending on circumstances, in the implementing of responses to an impending impact event.

## NASA + DHS

### NASA should also work with the Department of Homeland Security on an effective civil defense program

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Recommendation 4: Prepare to Respond to Impact Threats. To prepare an adequate response to the range of potential impact scenarios, NASA should conduct a focused range of activities, from in-space testing of innovative NEO deflection technologies to providing assistance to those agencies responsible for civil defense and disaster response measures. 4.1. Disaster Response. NASA should work with the Department of Homeland Security (DHS) and other relevant U.S. government agencies to assign roles and formulate plans for civil defense, such as evacuation of threatened areas, should NEO deflection prove impractical. The disaster management and response community should plan for the most likely impact scenario: a small (tens of meters in size) NEO striking with only days or weeks of warning. A transparent, effective, credible public communication plan is a high priority, to include topics such as the possible impact area, physical effects, and improved probability estimates as observations improve. The disaster management and response community has not extensively dealt with the threat of NEO impacts, nor is NASA well-versed in the processes or needs of the civil defense community. NASA and the DHS should coordinate their mutual information needs for a NEO impact response as soon as possible.

## USAF

### The United States Air Force could absorb the cost of the plan

Borchers 2009

(Brent W., Major, USAF Should the USAF be Involved in Planetary Defense?AIR COMMAND AND STAFF COLLEGE AIR UNIVERSITY <http://www.dtic.mil/cgi> bin/GetTRDoc?AD=ADA539693&Location=U2&doc=GetTRDoc.pdf)

This brings us to our main question. Who in the U.S. Government needs to shoulder the immense task of managing the project, running the acquisition issues and the funding of such an enormous task? An obvious answer to some would be NASA. They deal exclusively in space and have great experience with launch systems and vehicles and have the necessary engineers and people already on staff to start the task. They also have the current contracts and links with the appropriate civilian agencies and industry that could help the project along via contracted help. Still others would argue that the obvious choice would be the DOD and possibly the USAF. The USAF is already the executive agent for space within the DOD and they already possess the sophisticated satellite tracking capabilities along with the only ICBM force which includes a nuclear capability. The Navy possesses nuclear capability but the Trident launch systems do not have the lift or range capability. The USAF also possess a heavy launch force and have multiple launch vehicles that could be modified or suited to deliver and interceptor an object. Furthermore they have experience with multi billion dollar weapons systems and procurement and acquisition processes. The AF portion of the DOD budget is also already the largest in the nation and could more easily swallow or absorb the funds or excess costs related to such a project.

### The US Air Force could play a crucial role in the development of an effective NEO mitigation program

Borchers 2009

(Brent W., Major, USAF Should the USAF be Involved in Planetary Defense?AIR COMMAND AND STAFF COLLEGE AIR UNIVERSITY <http://www.dtic.mil/cgi> bin/GetTRDoc?AD=ADA539693&Location=U2&doc=GetTRDoc.pdf)

CHAPTER FIVE With all these problems, possible solutions, and political considerations, where does this leave the future of planetary defense and what is the U.S. Air Force’s role in this possible mission? We’ve established that the threat of a NEO impacting the earth is real based on the probabilities the scientists have computed and the evidence of past strikes on the earth and the associated consequences. We’ve also established that in order to prepare for an impact from a NEO we need to track and identify these objects to gain valuable warning time. The USAF can further assist with this effort. Although NASA seems to be doing fairly well in the Spaceguard survey, their efforts can probably be helped by the Air Force Space Surveillance Network (AFSSN). The AFSSN maintains a worldwide presence of radar and optical based tracking stations that virtually cover the globe. These assets could be used to augment the NASA work and confirm some of their observations. A lot of the AFSSN capability remains in the classified arena and cannot be discussed here but some efficiencies could be gained here. The AF also controls most of the satellites in orbit or has a liaison capability with the National Reconnaissance Office (NRO) who controls the NRO satellites. Some of these assets could also be used to track NEOs that seemed to pose a larger than average threat to the earth. The USAF would be in a better position than any other agency to liaise with the NRO to accomplish this. We’ve established that the USAF could help more than it already is and increase the fidelity of tracking by working alongside the NASA Spaceguard survey. How might the USAF help in actually deflecting and/or destroying a NEO whose impact with the planet was imminent? The USAF is uniquely qualified to lead or assist in this effort as they are the only organization who has both the stewardship of various types of nuclear weapons and also owns and maintains the launch vehicles to put them into orbit via modified Minuteman, Peacekeeper, Titan or Delta Evolved Expendable launch vehicles. Some of the USAFs lack of experience at intercepting objects in deep orbit would provide a good partnership opportunity with NASA. USAF launch facilities that exist at Vandenberg AFB in California and those that exist at Cape Canaveral in conjunction with NASAs launch sites in Florida could assist and provide the capability to launch against a single or multiple targets in rapid succession. Many people don’t realize that many of NASA and other government agencies have their payloads placed in orbit via USAF launch systems and vehicles. Furthermore, the USAF has a large space acquisition community and regularly works with many of the commercial space contractors in the nation and internationally. Bringing this acquisition and management experience to bear on the problem of managing a multi billion dollar contract such as the planetary defense system for the U.S. will free the engineers and scientists involved in NASA and other organizations to focus on the technological advancements required for the system to be workable and cost effective. Based on these above general criteria it is essential that the USAF be intimately involved with such a project and co-lead it with NASA while other US organizations could work under both lead agencies. NASA and the USAF have shared an interest and have worked in the environment of space since John Glenn first orbited the earth. NASA’s mastery of the space environment and the USAF mastery of weapons applications would dovetail perfectly for the project of planetary defense. To cut either of these organizations out of the loop would seriously hamper any progress in this area. Regardless of how the U.S. Government proceeds in establishing a plan for planetary defense, it’s important that the subject is given the appropriate level of attention and the world finally takes steps to protect itself from possible impacts. Much work remains to be done in the areas of tracking, prediction and finally deflecting the objects that pose a serious risk of impact. Taking the first step by delegating this task to the USAF and NASA as co-executive agents for the task will set us on the right track to solving this problem. Man has proven time and time again that almost no challenge is too great or formidable for our imagination and application of our full effort. This can be proven again if the U.S. and world governments set us up for success by picking the proper leadership structure to tackle this important problem.

# A2’s

## A2: Asteroids Burn Up

### Even if an asteroid is too small to enter the atmosphere, it can still cause significant damage.

Evans, 3

[Jenifer B. Evans, Frank C. Shelly, and Grant H. Stokes. (MIT) November 2, 2003.Lincoln Library Journal. Detection and Discovery of Near-Earth Asteroids by the LINEAR Program. Volume 14]

As indicated earlier, the primary motivation for searching for asteroids has moved from scientific curiosity to a desire to understand and possibly react to the threat of a collision with an asteroid. As our knowledge of the population of known asteroids continues to increase, we gain a better understanding of the effect of collisions. A collision between the earth and an asteroid is essentially a problem in dissipating kinetic energy. Asteroids with diameters smaller than approximately fifty meters typically dissipate their energy in the atmosphere, although they can cause severe local damage from air blast effects (e.g., the Tunguska collision in 1908, which flattened over eight hundred square miles of forest in Siberia, is believed to have been caused by an asteroid that was fifty to seventy-five meters in size [5, 6]).

## A2: Asteroids Rare

### Although rare, the destruction caused by NEO’s is devastating and must be prevented

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In general, scientists cannot predict precise times and locations of future impacts but can make statistical statements about the probability of an impact. Objects larger than about 30 meters in diameter probably strike Earth only about once every few centuries, and objects greater than about 300 meters in diameter only once per hundred millennia. Even objects only 30 meters in diameter can cause immense damage. The cosmic intruder that exploded over Siberia in 1908 may have been only a few tens of meters in size, yet this explosion severely damaged a forest of more than 2,000 square kilometers (Chyba, 1993; Boslough and Crawford, 1997, 2008). Had an airburst of such magnitude occurred over New York City, hundreds of thousands of deaths might have resulted. Assessing risk is difficult primarily because of the lack of sufficient data. The committee’s best current estimates are given in Chapter 2, where the risk is presented, with its dependence on impactor size and associated average impact frequency, along with damage estimates in terms of lives and property. Figure 1.1 illustrates the estimated frequency of near-Earth object (NEO)1 impacts on Earth for a range of NEO sizes. For impactor diameters exceeding about 2 to 3 kilometers, worldwide damage is possible, thus affecting all of humanity and its entire living space (the minimum size at which impactors can cause global devastation is still uncertain). While such a collision is exceedingly rare, the consequences are enormous, almost incalculable. This presents the classic “zero times infinity” problem: nearly zero probability of occurrence but nearly infinite devastation per occurrence. Humanity has the capacity to detect and perhaps to counter such an impending natural disaster. This capacity, and interest in exercising it, have developed and sharply increased in the space age, most likely sparked by the discovery in the late 1980s of the approximately 200-kilometer-diameter Chicxulub Crater formed by an impact 65 million years ago in the Yucatan Peninsula. The asteroid or comet that caused this crater is estimated to have been about 10 kilometers in diameter; its impact wrought global devastation, likely snuffing out species, including dinosaurs, in huge numbers. Later, in the 1990s, the collision of comet Shoemaker-Levy 9 with Jupiter emphasized that impacts are currently possible.

## A2: Asteroids Too Small

### Recent studies indicate that small objects are more frequent and can cause great damage

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http://www.nap.edu/catalog.php?record\_id=12842)

The committee notes that objects smaller than 140 meters in diameter are also capable of causing significant damage to Earth. The best-known case from recent history is the 1908 impact of an object at Tunguska in the Siberian wilderness that devastated more than 2,000 square kilometers of forest. It has been estimated that the size of this object was on the order of approximately 70 meters in diameter, but recent research indicates that it could have been substantially smaller (30 to 50 meters in diameter), with much of the damage that it caused being due to shock waves from the explosion of the object in Earth’s atmosphere. (See, e.g., Chyba et al., 1993; Boslough and Crawford, 1997, 2008.) The committee strongly stresses that this new conclusion is preliminary and must be independently validated. Since smaller objects are more numerous than larger ones, however, this new result, if correct, implies an increase in the frequency of such events to approximately once in three centuries. All told, the committee was struck by the many uncertainties that suffuse the subject of NEOs, including one other related example: Do airbursts from impactors in this size range over an ocean cause tsunamis that can severely damage a coastline? This uncertainty and others have led the committee to the following recommendation: Recommendation: Because recent studies of meteor airbursts have suggested that near-Earth objects as small as 30 to 50 meters in diameter could be highly destructive, surveys should attempt to detect as many 30- to 50-meter-diameter objects as possible. This search for smaller-diameter objects should not be allowed to interfere with the survey for objects 140 meters in diameter or greater. In all cases, the data-reduction and data-analysis resources necessary to achieve the congressional mandate would be covered by the survey projects themselves and by a continuation of the current funding of the Smithsonian Astrophysical Observatory’s Minor Planet Center, as discussed in the report.

### Airbursts by modest sized NEO’s are most dangerous and could lead to most amount of destruction;

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CHARACTERIZATION ISSUES FOR AIRBURSTS Airbursts created by the entry into Earth’s atmosphere of NEOs with diameters up to a few hundred meters both pose a serious threat at the larger end of the size range of the NEO and offer a unique opportunity to deduce physical characteristics at the small end of the range. Observations of small airbursts have provided almost the only information existing on the bulk strength, density, and composition of small NEOs through their high-speed interaction with Earth’s atmosphere. Although kilometer-sized NEOs are not substantially affected by their atmospheric passage, knowledge of their density and probable strength is important for mitigation efforts, making the study of airburst phenomena a prime focus for characterization efforts. The density of an NEO that enters Earth’s atmosphere is most often the main determinant of where its energy is released. Dense and physically strong bodies (e.g., solid bodies) will be more likely to penetrate the atmosphere intact and impact the surface of Earth. Although much of the energy from such impact events goes into crater formation and excavation, producing melt, ejecta, and seismic shaking and/or tsunamis in ocean events, a substantial fraction of its energy (perhaps as much as two-thirds for the event that produced Meteor Crater, Arizona; see Figure 2.1 in Chapter 2) is nevertheless deposited in the atmosphere. Objects up to a few hundred meters in diameter with low density or physically weak bodies (e.g., highly porous and strengthless rubble piles) are likely to be disrupted during atmospheric entry; all of the energy from such events will be deposited directly into the atmosphere, producing shock waves in the air and heat radiation that may cause more widespread damage on the ground than had the atmosphere been absent. The most notable recorded airburst event occurred in a remote region of Tunguska, Siberia, in 1908 and knocked down or defoliated the trees over an area of more than 2,000 square kilometers. There is a range of estimates for the size of the object that caused this event. Several estimates place the object as approximately 100 meters in diameter. A recent study, as yet not reproduced, suggests that the event was caused by a small (approximately 30- to 50-meter-diameter) NEO exploding at relatively low altitude, about 10 kilometers up (Boslough and Crawford, 2008). Since smaller NEOs are thought to be far more numerous than larger ones, there is a reasonable expectation that the next markedly destructive Earth impact event will be an object in the size range of 30 to 50 meters in diameter. Ground-based studies of NEOs using data on both rotation rates and satellites suggest that most NEOs larger than about 150 meters in diameter are rubble piles, while most smaller ones are monolithic, with enough long-term tensile strength to prevent them from flying apart. The larger objects that are weak rubble piles easily disintegrate during atmospheric entry and create airbursts that somewhat resemble high-altitude nuclear explosions. Smaller monoliths may still be dispersed by aerodynamic forces as these monoliths penetrate deeper into the atmosphere, and they may, or may not produce craters depending on the strength, density, and size of each monolith.

### Composition of NEO’s make airbursts most likely; small NEO’s recovered empirically prove

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Information from the U.S. Department of Defense’s (DOD’s) Earth-observing satellites has shown that high- altitude airbursts from relatively small (1- to 5-meter-diameter) objects occur on a regular basis. This key information shows, for the NEOs encountering Earth, how the number of these objects depends on their size. To date, none of these airbursts has produced appreciable damage. However, two well-observed airbursts have resulted in meteoritic material being recovered from the ground. The recent impacts of the Tagish Lake meteorite parent body over Canada (January 2000) and of asteroid 2008 TC3 over Sudan (October 2008) lend evidence to support the suggestion that airbursts are relatively common. In addition, these events lend some insights into the material composition of these NEOs. The meteorites recovered from these two airbursts are composed of carbon-rich materials, which suggest that their parent bodies were objects composed of physically weak materials compared to those of other meteorite types (e.g., iron-rich materials). This information, along with the substantial fraction of NEOs with satellites, suggests that many subkilometer-sized NEOs are rubble piles or composed of physically weak materials. Therefore, any such NEO found to have an Earth-impacting trajectory would likely deliver its impact energy in the form of an airburst. Airbursts are also detected by the arrays of microbarographic sensors deployed by the DOD and the Com- prehensive Test Ban Treaty (CTBT) Organization. This international network, called the International Monitoring System, consists of seismic, infrasound, radionuclide, and hydroacoustic stations. The data are not publicly available; the scientific community would benefit from unfiltered access to the data produced by these arrays.

## A2:Delay

### Delay means no solvency – The claim that they mitigate the advantage is false security.

Mitchell No Date Given

(William F. Mitchell, CEO of the NEO Safety Foundation “Financing a Planetary Defense System,” Paper presented at the 2007 AIAA Planetary Defense Conference, 5-9 March 2007 (Washington, D.C.) http://www.aero.org/conferences/planetarydefense/2007papers/P5-3--Mitchell-Paper.pdf)

Educate and convince the vast majority of the people that the threat is real and should be their concern. They must believe that their lives and the lives of their children and grandchildren are at stake. The message should be made to the public in no uncertain terms. The danger is deadly, the impact event is certain and the false security of thinking that we have more than ample time to prepare for the threat must be eliminated. The time to build a planetary defense is now. Efforts should start without delay. Everyone must be motivated to participate.

### Must plan now to protect US leadership

Schweickart et al 2010

(Russell L. Chairman, B612 Foundation (Task Force Co-Chair)Report of the NASA Advisory Council Ad Hoc Task Force on Planetary Defense October 6, T http://www.nasa.gov/pdf/490945main\_10-10\_TFPD.pdf)

Conclusions NASA has developed a strong foundation for understanding the NEO hazard and building a long-term capability to counter a potential asteroid impact threat. By taking the steps recommended in this report, the agency can expand this expertise and lead global efforts to develop an effective capability for Planetary Defense. Society now possesses sufficiently mature space technology to provide two of the three elements necessary to prevent future damaging asteroid impacts. NASA currently searches for the largest objects of concern and issues warning information for any asteroid discovered to approach Earth. New ground- and space-based search systems can increase our capability to provide impact warning for the smaller, more numerous asteroids. Although NASA has not demonstrated a specific asteroid deflection capability, the agency’s current spaceflight technology shows that impact prevention is possible. Actual NEO deflection demonstrations are being studied and are excellent candidates to be part of future NEO science and technology missions. The missing third element for NEO impact prevention is the international community’s readiness and determination to respond to a predicted future asteroid collision with Earth. NASA is well-positioned to take a leading role in this government and international response, but to be ready, the agency must move well beyond search, analysis, and warning to develop the practical means for actually changing a threatening asteroid’s orbit. Without the ability to detect the most numerous asteroids, to alter NEO orbits, and to lead a global effort to plan a deflection campaign, the only possible U.S. response would be evacuation and disaster response. If NASA fails to prepare for Planetary Defense, and then a sizeable random NEO strikes Earth without warning, the damage to the U.S.’s leadership and reputation would swell the tally of the event’s devastating effects. NASA should begin work now on forging its warning, technology, and leadership capacities into a global example of how to effectively shield society from a future impact.

### Planning and testing must begin now; long lead times necessary to guarantee success

Borchers 2009

(Brent W., Major, USAF Should the USAF be Involved in Planetary Defense?AIR COMMAND AND STAFF COLLEGE AIR UNIVERSITY <http://www.dtic.mil/cgi> bin/GetTRDoc?AD=ADA539693&Location=U2&doc=GetTRDoc.pdf)

Testing a complicated system like any of the previously mentioned solutions is invaluable because the amount of effort and lead time dedicated to a destruction/deflection mission of a NEO is so great that we might only have one launch or one opportunity. A reason for the long lead time needed is illustrated in this example. If an amount of one megaton of blast energy is needed to deflect an object when it is ten years away from impacting the earth, just a one year slip in the launch time that you can reach the object to deflect it results in 100 times greater energy needed to deflect the object at nine years out versus deflecting it when it was ten years out from earth. Waiting one year causes you to use 100 megatons of blast energy versus one. Having a system that is redundant is also desirable. If one system fails at launch or fails en route to the rendezvous with the object, there may not be enough time to launch a second one with enough energy to move the object unless a second interceptor is launched or ready on the pad at a moment’s notice. Even taking it a step further and launching interceptors with redundant capabilities in sets of threes would seem to limit the chance of complete failure to an acceptable level (if there is such a level when speaking of these types of consequences). Once your interceptor reaches the target how do you ensure and validate that it is working besides the fact that it has arrived on station? How many years or months does an organization have to observe miniscule changes in orbital parameters to ensure that the object’s velocity is being slowed by tenths of meters per second, or how can you ensure that it’s heading is being changed ever so slightly and can be measured to the thousandths or millionths of a degree? New technology or new methods must be developed to provide accurate and timely feedback to ensure the system is working. The stakes are too high and one cannot sit around and wait and assume that the orbit of the object is changing and being affected while we waste valuable time not trying a secondary method or launching a backup interceptor.

## A2: Harms Stay Regionally Contained

### The magnitude of the impact justifies the concern about NEO’s

Borchers 2009

(Brent W., Major, USAF Should the USAF be Involved in Planetary Defense?AIR COMMAND AND STAFF COLLEGE AIR UNIVERSITY <http://www.dtic.mil/cgi> bin/GetTRDoc?AD=ADA539693&Location=U2&doc=GetTRDoc.pdf)

This paper will demonstrate that despite current efforts towards increasing our abilities in planetary defense, we are still inadequately prepared should the need arise to track and deflect an object that is discovered to be on collision course with earth. So what exactly are the chances that another impact similar or greater than this will occur in our lifetimes? First, the Barringer meteor crater isn’t the only example of an object impacting the earth. The earth’s surface is pockmarked with craters created by meteorites much larger and more devastating than the one that created the crater in Arizona. Some are now hidden by oceans or lakes or have been simply buried by the passage of time and some are so large that they can only be noticed from space. Some were not so distant in our past and were close calls like the Tunguska event over Siberia in 1908. This close call involved the air blast of a meteor exploding miles above the earth’s surface and the resulting blast leveled an area the size of the state of Rhode Island or a square almost 45 miles long on each side.4 Researchers currently estimate there are 170 known impact craters on the earth.5 Some of these are as large as the 170 kilometer diameter Chixclub crater in the Yucatan peninsula that was caused by a meteorite thought to have been 10-20 kilometers in diameter. We know that the earth is struck frequently, in geologic terms, by meteors and other near earth objects (NEOs) due to the number of craters, but the true numbers may be even larger. NASA estimates that the earth is struck millions of times per day by NEOs that burn up in the atmosphere that are no larger than pebbles.6 The impact of most of these objects can be neglected because of their small size. However, there are plenty of other objects in our solar system that are large enough to cause major damage if they impact the earth. What is the probability that a meteor large enough to do some harm will survive entry through the earth’s atmosphere and produce an impact that causes wide spread damage and destruction? Furthermore, what is the possibility of a meteor impacting the earth that is large enough to cause the extinction of the human race? The relationship between the size of an object and its chance of striking the earth is inversely proportional. The earth is hit by small objects and debris constantly but a larger object that produces global effects may only impact the earth once every half million years. An impact such as the one that flattened the Siberian forest in Tunguska is thought to happen once every 300 years and it is theorized that it would only occur near a human population center once every 3000 years. Furthermore, these numbers can be extrapolated to tell us that only once every 100,000 years would this impact occur in an urban area and only once every 1 million years would it occur in an urban area within the borders of the United States.7 These odds don’t seem too bad at first, especially considering the last Tunguska sized event was only 100 years ago so we’ve got some time on the average before the next one occurs. It’s hard for humans to imagine events that occur only once every thousands of years. To compare the time periods between the risks, we have to realize that all of recorded human history only takes us back about 6,000 plus years.8 However, another factor needs to be added into the equation. With these events we’re not merely talking about building your house in a 500 year flood plain and hoping during the next 30-40 years that you live in the house no floods raise above the river’s banks. We’re talking about devastation on a global scale, possibly one quarter of the earth’s population wiped out by a single finite event that lasts only a fraction of a second when it strikes the earth. This type of risk is hard to quantify. Essentially when you look at a larger NEO impact event you are weighing the low probability that a large object will strike the earth with the high consequences once such an object does impact the surface or produces an airburst. In short the risk is much greater when the consequences are much greater and the event in question could wipe out the planet versus destroying a few hundred homes like the major floods we’ve seen recently in the Midwest.9

### The impacts of asteroid collisions go global

NEO Sciences Definition Team 3

(Near Earth Project Program, “NASA Releases Near-Earth Object Search Report”, 8/22/’03, http://neo.jpl.nasa.gov/neo/report.html (Near-Earth Objects)

NASA has released a technical report on potential future search efforts for near-Earth objects after a year of analysis by scientists working on this issue. This Science Definition Team was chartered to study what should be done to find near-Earth objects less than 1 kilometer in size. While impacts by these smaller objects would not be expected to cause global devastation, impacts on land and the tsunamis resulting from ocean impacts could still cause massive regional damage and still pose a significant long-term hazard. In 1998 NASA commenced its part of the "Spaceguard" effort, with the goal of discovering and tracking over 90% of the near-Earth objects larger than one kilometer by the end of 2008. An Earth impact by one of these relatively large objects would be expected to have global consequences and, over time scales of a few million years, they present the greatest impact hazard to Earth. Approximately 60% of the estimated 1,000 to 1,200 large near-Earth objects have already been discovered, about 45% since NASA efforts started, and each of the five NASA-supported search facilities continue to improve their performance, so there has been good progress toward eliminating the risk of any large, undetected impactor.

## A2: Long Timeframe For Asteroid Strike

### With asteroids timeframe is a secondary concern because of their catastrophic impact

Easterbrook 8

(Gregg Easterbrook, Fellow @ the Brookings Institute “The Sky Is Falling,” The Atlantic, June. [Online] http://www.theatlantic.com/magazine/print/2008/06/the-sky-is-falling/6807/)

A generation ago, the standard assumption was that a dangerous object would strike Earth perhaps once in a million years. By the mid-1990s, researchers began to say that the threat was greater: perhaps a strike every 300,000 years. This winter, I asked William Ailor, an asteroid specialist at The Aerospace Corporation, a think tank for the Air Force, what he thought the risk was. Ailor’s answer: a one-in-10 chance per century of a dangerous space-object strike. Regardless of which estimate is correct, the likelihood of an event is, of course, no predictor. Even if space strikes are likely only once every million years, that doesn’t mean a million years will pass before the next impact—the sky could suddenly darken tomorrow. Equally important, improbable but cataclysmic dangers ought to command attention because of their scope. A tornado is far more likely than an asteroid strike, but humanity is sure to survive the former. The chances that any one person will die in an airline crash are minute, but this does not prevent us from caring about aviation safety. And as Nathan Myhrvold, the former chief technology officer of Microsoft, put it, “The odds of a space-object strike during your lifetime may be no more than the odds you will die in a plane crash—but with space rocks, it’s like the entire human race is riding on the plane.”

## A2: Misuse/Militarism

### Effective international regulations and the lack of an effective reentry vehicle prevent abuse of PDS

Urias et al 96

[COL (Sel) John M. Urias Et. Al., Planetary Defense: Catastrophic Health Insurance for Planet Earth,” A Research Paper Presented To Air Force 2025,October 1996, http://csat.au.af.mil/2025/volume3/vol3ch16.pdf]

International concern for use of these weapons leads to many political questions and misgivings. Ironically, these devices "could be notably straightforward to create and safe to maintain because they derive from vast research and development expenditures and experience accumulated during the forty-five years of the Cold War."46 Technically, without an appropriate reentry vehicle, these devices could not be used as ballistic weapons, though there is always the possibility of terrorism or misuse. In any event, effective international protocols and controls could be established through the United Nations to minimize downside potential. The debate will certainly continue, however, as evidenced in *The Deflection Dilemma: Use vs. Misuse of Technologies for Avoiding Interplanetary Hazards:* "The potential for misuse of a system built in advance of an explicit need may in the long run expose us to a greater risk than the added protection it offers."47 The greatest challenge involves the building of international coordination, cooperation, and support. The threat of ECOs is a global problem and one which the entire world community should be concerned with. Coordination between nations, international organizations, DOD, NASA, DOE, academia, 22 and others in the scientific community is essential in establishing the building blocks for a credible PDS. It is necessary to build trust, coordinate resources, consolidate efforts, and seek cooperation with and support for similar efforts in the international community.

## A2: Mitigation Impossible

### Mitigation decisions are political, not technical; decisions as to which methods to develop are critical

NATIONAL ACADEMY OF SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council <http://www.nap.edu/catalog.php?record_id=12842>)

In all cases, the decision to initiate mitigation is a sociopolitical decision, not a technical decision. This decision is implicit in earlier sociopolitical decisions about which methods of mitigation to develop, and it also depends on the level of probability that is considered to require mitigation. The committee’s recommendations regarding the minimum approach to mitigation and more aggressive approaches are discussed later. The subject of mitigation is rife with uncertainty. The effect on Earth of a given NEO depends critically on the velocity at which the NEO impacts Earth, a factor that is traditionally ignored in studies of the hazard. The decisions on mitigation must be based on the mass of the NEO rather than on its diameter, because mass is the quantity that most affects the effectiveness of any mitigation and the diameter for a given mass can vary by roughly a factor of two. The variation in diameter implies a factor-of-two variation, depending on the NEO’s density, of the size of an NEO that can be moved far enough to miss Earth. Clearly an earlier warning allows a smaller action to be sufficient, but quantifying this relation is very uncertain. The effectiveness of most but not all methods also depends critically on the physical properties of the NEO. Humanity’s ability to mitigate depends on the details of the intercepting trajectory. There are also significant differences depending on whether the discussion of mitigation is limited to current technology or includes likely future technology such as the next generation of heavy-lift launch vehicles. Thus the committee’s discussion of the range of applicability will show overlapping and uncertain ranges. Realistic mitigation is likely to include more than one technique, if for no other reason than to provide confidence. In any case of mitigation, civil defense will undoubtedly be a component, whether as the primary response or as the ultimate backup. Finding: No single approach to mitigation is appropriate and adequate for completely preventing the effects of the full range of potential impactors, although civil defense is an appropriate component of mitigation in all cases. With adequate warning, a suite of four types of mitigation is adequate to mitigate the threat from nearly all NEOs except the most energetic ones.

## A2: No Tech

### The technology for asteroid detection exists, it’s only a question of our commitment

Urias et al 96

[COL (Sel) John M. Urias Et. Al., Planetary Defense: Catastrophic Health Insurance for Planet Earth,” A Research Paper Presented To Air Force 2025,October 1996, http://csat.au.af.mil/2025/volume3/vol3ch16.pdf]

We should also realize that the technology required for a system to mitigate the most likely of impact scenarios is, with a little concerted effort, within our grasp. There are no current means for preventing many such natural disasters as earthquakes, tornadoes, and typhoons. Some of these disasters can not even be detected in time to give adequate warning to the affected population. Such is not the case with ECOs. Humanity certainly has the technology that, with a relatively modest investment, to warn of an impending catastrophe, maybe years or decades in advance. In most cases, an associated mitigation system could use the latest nuclear explosives, space propulsion, guidance, and sensing and targeting technologies, coupled with spacecraft technology. These technologies already are related to defense capabilities, but how they are developed for use in space (and what effects they have) will offer invaluable experience for defense efforts. We can maximize our investment by turning to the commercial world for technology development and highlight opportunities for dual-use possibilities.19 Space operations will continue to grow at a rapid rate as a factor in United States military capabilities limited primarily by affordable access.

### NEO insurance is as necessary as that for earthquakes; question of viability is a political, not scientific, one

NATIONAL  ACADEMY  OF  SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council NATIONAL ACADEMY OF ENGINEERING INSTITUTE OF MEDICINE NATIONAL RESEARCH COUNCIL http://www.nap.edu/catalog.php?record\_id=12842)

Although the possibility of a large NEO impact with Earth is remote, conducting surveys of NEOs and studying means to mitigate collisions with them can best be viewed as a form of insurance. It seems prudent to expend some resources to prepare to counter this collision threat. Most homeowners, for example, carry fire insurance, although no one expects her or his house to burn down anytime soon. The distinction between insurance for the NEO collision hazard and other “natural” hazards, such as earthquakes and hurricanes, is that the possibility of detecting and preventing most serious collisions now exists. In the case of earthquakes, for example, despite extensive efforts, primarily in China, Japan, and the United States, neither the epoch nor the severity of an earthquake can yet be reliably predicted. Governments do nonetheless fund the analog of an insurance policy through studies of this hazard and through the design and construction of earthquake-resistant structures and in development of plans for response and recovery. The goal is to reduce both the number of fatalities and the damage to property from earthquakes. According to figures from the NRC (2006) report *Improved Seismic Monitoring*␣*Improved Decision-Making: Assessing the Value of Reduced Uncertainty*, the United States alone now spends well in excess of $100 million annually on this suite of earthquake-related efforts. The annual death rate in the United States from earthquakes, averaged over the past two centuries for which data are available, is approximately 20 per year, with 75 percent of that figure attributed to the 1906 San Francisco Earthquake, mostly from related fires. For Japan, both the expenditure and the fatality figures are far larger. China and other parts of Asia have also suffered massive casualties from earthquakes. The September 2009 earthquakes that caused loss of life in Indonesia, Samoa, and American Samoa, and the devastating January 2010 earthquake in Haiti and February 2010 earthquake in Chile, highlight this ongoing threat to human life. Given the low risk over a period of, say, a decade (see Chapter 2), how much should the United States invest in NEO insurance? This question requires a political, not a scientific, answer. Yet the question bears on the committee’s charge. The committee was asked to recommend the optimal approach for each of the tasks, with the definition of “optimal” left to the committee. A unique characteristic of the “NEO research premiums,” which distinguishes them from the usual types of insurance, is that the premiums would be directed entirely toward the prevention of the catastrophe. In no case, however, is it wise to consider the application of techniques more than a few decades into the future. The technologies available at that time would likely be both more efficient and more effective, rendering present approaches obsolete. However, it is not wise to wait for those future technologies, leaving Earth unaware and threats to Earth unmitigated in the meantime.

## A2: Nuclear Mitigation Good

### Nuclear weapons not the best weapon to deflect NEO’s; must consider many other options

Foust 2007

(Jeff, editor and publisher of The Space Review The three D’s of planetary defense March 19, http://www.thespacereview.com/article/835/1)

Deflection For many years—dating back at least to the Project Icarus study in the late 1960s (see [“Giant bombs on giant rockets: Project Icarus”](http://www.thespacereview.com/article/175/1), The Space Review, July 5, 2004)—the preferred method for dealing with a NEO found to be on an impact course with the Earth was to hit it with one or more nuclear weapons. This was based on the assumption that asteroids were big hunks of rock and/or metal that could be simply pushed by the force of a nuclear blast. In recent years, however, research into asteroids, including spacecraft missions to or past several asteroids like Eros and Itokawa, have challenged this approach. Small bodies in particular are less likely to be integral chunks of rock than “rubble piles”: agglomerations of smaller objects loosely held together by self-gravity. Attempting to deflect these objects with a nuclear blast could have, in the words of NASA astronaut Ed Lu, “unintended consequences”. Lu, a member of the board of directors of the B612 Foundation, an organization devoted to the study of asteroid deflection and impact threat mitigation, said at the AAAS conference that nuclear weapons or even a kinetic impact, like that used on NASA’s Deep Impact mission, could break apart a rubble pile asteroid, creating complications in tracking and dealing with all the fragments. “If you do break it up into pieces, what’s your Plan B?” said Lu, who likened such a fragmentation to the orbital debris created by a Chinese ASAT test in January and the controversy that followed. “Essentially what you’re doing is creating orbital debris on a solar system scale… What would be the uproar if we were to break up an asteroid?” “If you have a way of doing a controlled deflection, you should do that first,” Lu said. And Lu and fellow astronaut Stanley Love have come up with an alternative: the “gravity tractor”. The gravity tractor would be a spacecraft that positions itself near a threatening asteroid, and maintains its position using ion thrusters. The hovering spacecraft imparts a feeble but steady gravitational force that tugs at the asteroid, gradually changing its trajectory. While the gravity tractor would only make a minor change in the asteroid’s orbit, it would be useful for cases like Apophis where only a slight change is needed to prevent a collision, and other cases where there is plenty of warning. Moreover, since the gravity tractor never makes physical contact with the asteroid, there is no need to be concerned about the asteroid’s composition, structure, spin rate, or other factors that pose hazards to an explosion or impact approach. Nor, Lu added, would it require new technology, since ion engines have already been used on a number of spacecraft, such as Deep Space 1. Interestingly, though, the recently-released NASA report summary isn’t as generous in praise of the gravity tractor or other so-called “slow push” approaches, such as a tug physically attached to the asteroid or a mass driver that propels small pieces of the asteroid away from the main body. “‘Slow push’ mitigation techniques are the most expensive, have the lowest level of technical readiness, and their ability to both travel to and divert a threatening NEO would be limited unless mission durations of many years to decades are possible,” the NASA report concluded. The report instead fell back on the old approach of nuclear weapons, but with a slight modification: instead of exploding them on or underneath the surface of the asteroid, they would be detonated at some distance above the surface. “While detonation of a nuclear device on or below the surface of a threatening object was found to be 10-100 times more efficient than detonating a nuclear device above the surface, the standoff detonation would be less likely to fragment the target,” the report concluded. “A nuclear standoff mission could be designed knowing only the orbit and approximate mass of the threat, and missions could be carried out incrementally to reach the required amount of deflection.”

### Nuclear weapons only current option; larger NEO’s may require undiscovered technologies to be destroyed

NATIONAL ACADEMY OF SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council <http://www.nap.edu/catalog.php?record_id=12842>)

Conclusions Nuclear explosives can provide considerable protection against a potential NEO impact. This may be the only current means to prevent an impact by a large hazardous object (>500 meters in diameter) with a warning time under a decade or by a larger object (>1 kilometer in diameter) object with a warning time of several decades. With decades of warning for such large objects, the preferred approach uses a standoff detonation. Neutron output has certain advantages (Dearborn, 2004), as the energy coupling is relatively insensitive to the surface composition and density of the NEO. The simulations show that speed changes (␣*V* ) on the order of 2 cm/s are achievable with gravitational binding mostly maintaining the NEO as a single body. About 2 percent of the body mass is ejected, evolving to such a low density that it would likely pose no threat to Earth. Very low yield surface explosives also showed great promise for speed changes on the order of 1 cm/s. As the NEO size decreases and the required yield of the nuclear explosive drops below the tested regime, which extends down to about 0.1 kilotons, the kinetic impact approach will have to be used. Although the nuclear option provides considerable mitigation potential, for NEOs above some size the tested limits of nuclear explosives will become inadequate. Devices in the nuclear stockpile have equivalent energy releases of megatons of TNT, but NEOs larger in diameter than about 10 kilometers are likely to require larger explosive energies, a regime for which devices have not been tested or simulated. Modeling the shock dissipation of highly porous materials appears to be the primary uncertainty for both impactors and standoff bursts. This uncer- tainty holds particularly true for NEOs with very low density aggregates that can exist only in low-gravity environ- ments. At present, the simulations have not examined the effects of the range of structures, shapes, and rotational states, but with Defense Threat Reduction Agency support to extend the present studies, these simulations could be done. Currently the United States and several other nations maintain nuclear stockpiles and the infrastructure to build them for purposes of national defense. Efforts to reduce those stockpiles continue, but it seems likely that they will exist for some decades. When defense concerns no longer apply, the governments involved may either accept the longer response time for a Manhattan Project-like effort or decide whether adequate safeguards can be developed so that some entity could maintain a small number of nuclear explosive packages to allow humanity to counter an NEO that could, for example, cause mass extinctions. Finding: Other than a large flotilla (100 or more) of massive spacecraft being sent as impactors, nuclear explosions are the only current, practical means for changing the orbit of large NEOs (diameter greater than about 1 kilometer). Nuclear explosions also remain as a backup strategy for somewhat smaller objects if other methods have failed. They may be the only method for dealing with smaller objects when warning time is short, but additional research is necessary for such cases.

## A2: Politics – NASA Popular

### Even during a recession, the public is committed to NASA and space

Jones 9

[Jeffrey Jones. July 2009. Majority of Americans Say Space Program Costs Justified. Gallup. http://www.gallup.com/poll/121736/Majority-Americans-Say-Space-Program-Costs-Justified.aspx]

On the eve of the 40th anniversary of the U.S. moon landing, a majority of Americans say the space program has brought enough benefits to justify its costs. The percentage holding this view is now at 58% and has increased over time.Notably, those old enough to remember the historic moon landing are actually somewhat less likely than those who are younger to think the space program's costs are justified. Among Americans aged 50 and older (who were at least 10 years old when the moon landing occurred), 54% think the space program's benefits justify its costs, compared with 63% of those aged 18-49. The July 10-12 Gallup Poll also finds that most Americans continue to express support for the current level of funding for NASA (46%) or an expansion of it (14%). But the 60% holding these views is on the low end of what Gallup has measured since 1984, when the question was first asked. The two lowest readings of 46% and 53% were found in a pair of 1993 polls. In 1993, as now, Americans had highly negative evaluations of the economy, and the results suggest that when Americans have a negative outlook on the economy, they are apparently less willing to spend money for space exploration. In addition to a struggling economy, the lower 1993 NASA ratings are due to a number of problems that plagued the agency, including losing contact with the Mars Observer and several last-minute cancellations of planned space shuttle missions. The high point in support for current or larger funding levels for NASA was 76% in January 1986, immediately after the space shuttle Challenger disaster. Fifty-eight percent of Americans say NASA is doing an excellent (13%) or good (45%) job. The agency's ratings have been stable over the last several years. The high point was 76% in late 1998 after 1960s astronaut John Glenn made a return trip to space, and the low point was in September 1993.Ratings of NASA vary by education. Sixty-three percent of college graduates say NASA is doing an excellent or good job, compared with 55% of Americans without a college degree. The educational differences are even greater in opinions on space program spending, with more than 7 in 10 college graduates saying the space program's benefits justify its costs and that NASA spending should be kept the same or increased. Only a slim majority of college non-graduates share these views.Americans remain broadly supportive of space exploration and government funding of it. In fact, Americans are somewhat more likely to believe the benefits of the space program justify its costs at the 40th anniversary of the moon landing than they were at the 10th, 25th, and 30th anniversaries. Although support for keeping NASA funding at its present level or increasing it is lower now than it has been in the past, the fact that 6 in 10 Americans hold this view in the midst of a recession suggests the public is firmly committed to the space program. Results are based on telephone interviews with 1,018 national adults, aged 18 and older, conducted July 10-12, 2009. For results based on the total sample of national adults, one can say with 95% confidence that the maximum margin of sampling error is ±3 percentage points. Interviews are conducted with respondents on land-line telephones (for respondents with a land-line telephone) and cellular phones (for respondents who are cell-phone only). In addition to sampling error, question wording and practical difficulties in conducting surveys can introduce error or bias into the findings of public opinion polls.]

## A2: Sagan

### It’s physically impossible to use PDS to steer an asteroid into the earth but they could be mined for valuable resources

Oberg, 98

[James Oberg, “ASTEROID DEFLECTION & THE FUTURE OF HUMAN INTERVENTION IN THE EARTH'S BIOSPHERE,” Futures Focus Day Symposium sponsored by Commander-in-Chief, US Space Command Colorado Springs, Colorado July 23, 1998 , http://abob.libs.uga.edu/bobk/oberg.html]

For example, Dr. Carl Sagan and some of his colleagues suggested that it was statistically more dangerous to build an asteroid defense system than simply to wait for the impacts. Their argument was based on the thesis that a system-in-being could under some circumstances be abused by "a madman" to deliberately divert otherwise-harmless objects toward an Earth impact. Although admittedly unlikely, this manmade danger was deemed MORE likely than the original natural threat of asteroid impact. But this view is erroneous. The concern fails to account for operational issues in navigation, targeting, guidance and control, issues which real-world spaceflight operators deal with on a daily basis. By assuming that a space rendezvous -- bringing two objects into contact -- is merely an inverse process of avoidance -- guaranteeing that two objects do NOT come into contact, this concern is unrealistic. The "avoidance" maneuver is already in the repertory of spaceflight operators today, in low Earth orbit. If the predicted path of a piece of space debris comes "close enough" (defined in the dimensions of the avoidance zone around the shuttle), the shuttle makes a small orbital adjustment to take it (and the zone centered on it) away from the predicted path of the candidate impactor. Rendezvous is also routine in low Earth orbit, but it is a far different process than merely reversing the avoidance maneuver. As the active vehicle nears the target it receives more and more precise relative position data (navigation), which it converts into desired course corrections (targeting), which converts into required rocket burns (guidance), and which it then performs -- to the required level of precision -- using onboard rockets (control). As the range and time-to-contact drops, so does the size of the uncertainty zone around the target, where the chaser is aiming. At the same time, the effect of rocket maneuvers on miss distance also drops rapidly -- they have less time to propagate and grow. Unless the approach is flown very precisely, the predicted miss distance can easily drift outside the "uncertainty zone" to such a great distance that the active vehicle's rockets simply cannot bring the aim point back onto the target fast enough. In other words, there is not enough "control authority" in the system. And the active vehicle flies past the target. The rendezvous fails. For the proposed asteroid-deflection schemes of the next several decades at least, their control accuracy is far too poor to perform a "rendezvous", a deliberate collision, with Earth. Such systems would be fully effective in diverting dangerous asteroids, but would be physically unable to do the opposite, bring them into contact with Earth. As a threat for misuse, they would panic only those who don't understand real space operations. Sagan however was not off base in raising the question about deliberately steering asteroids closer to Earth, because at some future point there will be excellent reasons to want to do this. Starting with the smallest trackable objects -- the 100-meter rocks -- it's plausible later in the next century to bring some of them back into high-earth orbit for mining. They contain commercially attractive amounts of metals and water, especially in competition with the cost of such materials brought up from Earth. And at a range of several hundred thousand kilometers from Earth, missing an orbital aim point by tens of thousands of kilometers will not matter.

## A2: Status Quo Detection Solves

### Current tracking systems work; although recent sightings indicate little risk, constant surveillance is necessary

Greene 2011

(Nick, Asteroid On Collision Course With Earth How Much Danger Does Asteroid 2002 NT7 Or Others Pose to Earth

http://space.about.com/cs/asteroids/a/asteroidimpact.htm downloaded 6/21/11)

On July 9, 2002, the Lincoln Near Earth Asteroid Research Project Laboratory program funded by the United States Air Force and NASA) in New Mexico detected a 1.2-mile-wide (2 km) asteroid. It has an orbit around our sun of 837 days, and early calculations indicate there is a small chance that this asteroid will collide with Earth on February 1, 2019. Astronomers from NASA and around the world will be monitoring the asteroid, known as 2002 NT7, but say that the calculations are very preliminary and the actual chance of it striking our planet are minimal, it may not be on an actual collision course. Donald Yeomans, of NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California says, "The threat is very minimal." Scientists say that more observations of the object will be made over the next few months to help calculate the course of asteroid 2002 NT7 more accurately. "An object of this size would be expected to hit the Earth every few million years,” continued Yeomans, “and as we get additional data I think this threat will go away." The Near Earth Object Program4 is a NASA5 project established in 1998 to help coordinate, and provide a focal point for, the study of those comets and asteroids that can approach the Earth's orbit. The program is operated by the Jet Propulsion Laboratories. They would be the first organization to react and alert NASA if an asteroid, comet, or meteor were found to be on a collision course with Earth. While they are monitoring this new threat, they give 2002 NT7 a rating of “1” on the Torino Impact Hazard Scale.6 According to NASA, asteroids big enough to cause catastrophic destruction could theoretically hit Earth every million years, or at longer intervals. On June 14, 2002, asteroid 2002 MN, which was the size of a soccer field, passed within 75,000 miles of the Earth. That’s less than one-third of the distance to the moon. Had this object struck the Earth, it would have released the energy of a large nuclear weapon. This was one of the closest encounters we have had since scientists have been keep track. The result of an impact by 2002 NT7 would be destruction of “biblical proportions” as Billy Bob Thornton’s character says in Armageddon, but, don’t panic yet. "One way or another, this thing is coming off the risk page," said Donald Yeomans. He calculates the odds of a strike at about one in 250,000, and says those odds will likely be adjusted even lower. ***Update*** It appears that we dodged a bullet this time with asteroid 2002 NT7. NASA's Near Earth Object Program released this statement: *"*With the processing of a few more observations of asteroid 2002 NT7 through July 28, we can now rule out any Earth impact possibilities for February 1, 2019*. While we cannot yet completely rule out an impact possibility on February 1, 2060, it seems very likely that this possibility will be soon ruled out as well as additional positional observations are processed. "Because the SENTRY system tracks a multitude of test particles in an effort to map the uncertainties of the asteroid's future positions, some of these test particles can take slightly different dynamical paths. Hence there are currently two entries for 2060 in our IMPACT RISK table. The entry with the higher risk (larger Palermo Technical Scale) would be the value that would then take precedence."* While this particular asteroid appears to not be a threat to Earth at this time, the Near Earth Object Program and other agencies continue to monitor space for other threats. After all, it is a big universe, and there are a lot of asteroids and comets out there.

## A2: Status Quo Mitigation Solves

### Different impacts of NEO’s require different responses; current technologies don’t address most serious threats

NATIONAL ACADEMY OF SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council <http://www.nap.edu/catalog.php?record_id=12842>)

5 Mitigation Impacts on Earth by near-Earth objects (NEOs) are inevitable. The impactors range from harmless fireballs, which are very frequent; through the largest airbursts, which do not cause significant destruction on the ground, on average occurring once in a human lifetime; to globally catastrophic events, which are very unlikely to occur in any given human lifetime but are probably randomly distributed in time. The risks from these NEOs, or more specifically scientists’ assessment of the risks in the next century, will be changing as surveys are carried out. Given the inevitability of impacts, and noting that the entire point of surveys is to enable appropriate action to be taken, how can the effects of potential impacting NEOs be mitigated? The amount of destruction from an event scales with the energy being brought by the impacting object. Because the range of possible destruction is so huge, no single approach is adequate for dealing with all events. For events of sufficiently low energy, the methods of civil defense in the broadest sense are the most cost-effective for saving human lives and minimizing property damage. For larger events, changing the path of the hazardous object is the appropriate solution, although the method for changing the path varies depending on the amount of advance notice available and the mass of the hazardous object. For the largest events, from beyond global catastrophe to events that cause mass extinctions, there is no current technology capable of sufficiently changing the orbital path to avoid disaster.

### Mitigation of NEO’s conceptually valid, but technology doesn’t exist to execute the strategies

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In this chapter the committee considers four categories of mitigation: • • • *Civil defense*␣involving such efforts as evacuating the region around a small impact, *Slow-push or -pull methods*␣gradually changing the orbit of an NEO so that it misses Earth, *Kinetic impact*␣delivering a large amount of momentum (and energy) instantaneously to an NEO to change its orbit so that it misses Earth, and • *Nuclear detonation*␣delivering a much larger amount of momentum (and energy) instantaneously to an NEO to change its orbit so that it misses Earth. For impacting NEOs that are sufficiently small (tens of meters to perhaps 100 meters in diameter) and not very strong (typically not iron meteoroids), the destruction on Earth will be caused by an airburst and its associated blast wave and thermal pulse, as was the case of the Tunguska event above Siberia in 1908. Events like this cause destruction over areas up to thousands of square kilometers, and evacuation and sheltering are not only plausible but often the most cost-effective approach for saving human lives. Airburst events will also be the most frequent, occurring on average every couple of centuries. They are also the events that are likely to have the least advance warning. For larger events, actively changing the orbit of the hazardous object is likely desirable. The choice among the three methods␣the slow-push and -pull method, kinetic impact, and nuclear detonation␣depends both on the mass of the NEO that has to be moved and on how early the NEO is determined to be hazardous, as well as on the details of the orbit. The mitigation options are laid out in Table 5.1, which lists the applicability of each option to a given threat. Table 5.2 shows the regimes in which each mitigation method is applicable. Note that Table 5.2 brings in an additional important aspect of the problem, international coordination, which is discussed in more detail in Chapter 7 of this report. Although all of the primary mitigation strategy methods are conceptually valid, none is now ready to implement on short notice. Civil defense and kinetic impactors are probably the closest to deployable but even these require additional study before they can be relied on.

## A2: Treaties Block

### No treaty restricts asteroid mitigation and even if it did we wouldn’t follow it during a crises

Urias et al 96

[COL (Sel) John M. Urias Et. Al., Planetary Defense: Catastrophic Health Insurance for Planet Earth,” A Research Paper Presented To Air Force 2025,October 1996, http://csat.au.af.mil/2025/volume3/vol3ch16.pdf]

Therefore, even though no existing treaties specifically prohibit the employment of a PDS, collectively, they provide enough legal restrictions to seriously affect the ability of operators to use it effectively when faced with a major extraterrestrial threat. In our extreme case involving the impending impact of an asteroid or comet and where the survival of the human race is potentially at risk, we assume that appropriate exceptions would be approved, allowing the use of nuclear weapons or other weapons of mass destruction to mitigate the threat. Indeed, these weapons could serve as the only means of saving the earth. Fortunately, none of the existing treaties restrict the employment of detection devices-- whether they be earth-, space-, or planet-based--that would serve as major components of the PDS. As discussed in the “Concept of Operations (CONOPS)” section, our three-tier PDS concept includes near-, mid-, and far-range detection systems. Obviously, early detection and classification of an asteroid or comet as an ECO allows more reaction time and permits greater flexibility in developing viable courses of action. Therefore, our PDS concept places significant emphasis on detection at the greatest possible range.

### All planetary defense techniques can be supported under existing law.

Kunich 97

(Lt. Col. John C. Kunich, Staff Judge Advocate, 50th Space Wing, Falcon Air Force Base “Planetary Defense: The Legality of Global Survival,” The Air Force Law Review, Volume 41 [41 A.F.L. rev. 119). LexisNexis)

Planetary defense is a very new concept in every respect, including the attendant legal issues. Until very recently, the notion that mere mortals might foretell and prevent "acts of God" such as a massive asteroid strike was pure science fiction. But myriad modern advancements in scientific and technological disciplines have brought the mission of planetary defense within the realm of human capability. Given that we can defend the Earth, the question of whether we may has now arisen for the first time. For any non-lawyer blessed with even a modicum of common sense, it might seem ludicrous even to suggest that it could be illegal to defend the Earth from space-borne destruction. The prospect of averting potential global annihilation is so manifestly good and noble that there would seem to be no question that we should do all we can to develop, maintain, and if necessary use every means available in its support. As lawyers (with or without common sense) know, however, the law sometimes does operate counter-intuitively, and sometimes does cause unjust results in a given case. Fortunately, in the case of planetary defense, the law is on the side of common sense. As has been demonstrated herein, all likely components of a planetary defense system, whether in the surveillance or the mitigation phase, can be supported under existing international and space law. Some tools are more clearly within the bounds of legality than others, but in every instance a strong argument can be made in support of legality.

## A2: Spending DA

### $250 million would be an appropriate and optimal budget to defend the planet

NATIONAL ACADEMY OF SCIENCES 2009

(Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies ISBN 978-0-309-14968-6 Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies; National Research Council <http://www.nap.edu/catalog.php?record_id=12842>)

*$250-million level.* At a $250-million annual budget level, a robust NEO program could be undertaken unilaterally by the United States. For this program, in addition to the research program a more robust survey program could be undertaken that would include redundancy by means of some combination of ground-and space-based approaches. This level of funding would also enable a space mission similar to the European Space Agency’s (ESA’s) proposed Don Quijote spacecraft, either alone, or preferably as part of an international collaboration. This space mission would test in situ instrumentation for detailed characterization, as well as impact technique(s) for changing the orbit of a threatening object, albeit on only one NEO. The target could be chosen from among those fairly well characterized by ground observations so as to check these results with those determined by means of the in situ instruments. The committee assumed constant annual funding at each of the three levels. For the highest level the annual funding would likely need to vary substantially as is common for spacecraft programs. Desirable variations of annual funding over time would likely be fractionally lower for the second level, and even lower for the first level. How long should funding continue? The committee deems it of the highest priority to monitor the skies continually for threatening NEOs; therefore, funding stability is important, particularly for the lowest level. The second level, if implemented, would likely be needed at its full level for about 4 years in order to contribute to the completion of the mandated survey. The operations and maintenance of such instruments beyond this survey has not been investigated by the committee. However, were the Large Synoptic Survey Telescope to continue operating at its projected costs, this second-level budget could be reduced. The additional funding provided in the third and highest level would probably be needed only through the completion of the major part of a Don Quijote-type mission, under a decade in total, and could be decreased gradually but substantially thereafter. Finding: A $10-million annual level of funding would be sufficient for continuing existing surveys, main- taining the radar capability at the Arecibo and Goldstone Observatories, and supporting a modest level of research on the hazards posed by near-Earth objects. This level would not allow the achievement of the goals established in the George E. Brown, Jr. Near-Earth Object Survey Act of 2005 on any time scale. A $50-million annual level of funding for several years would likely be sufficient to achieve the goals of the George E. Brown, Jr. Near-Earth Object Survey Act of 2005. A $250-million annual level of funding, if continued for somewhat under a decade, would be sufficient to accomplish the survey and research objectives, plus provide survey redundancy and support for a space mission to test in situ characterization and mitigation.

### Efforts to track and mitigate NEO’s are ongoing; upfront cost would be $250 million per year for 10 years, but would be reduced significantly once strategies and technologies were developed

Schweickart et al 2010

(Russell L. Chairman, B612 Foundation (Task Force Co-Chair)Report of the NASA Advisory Council Ad Hoc Task Force on Planetary Defense October 6, T http://www.nasa.gov/pdf/490945main\_10-10\_TFPD.pdf)

1.2. PD Activities. The PD program plan should include a near-term effort to accomplish the George E. Brown NEO Survey goal in a reasonable period of time. This act directs NASA to detect, track, catalog, and characterize the typical physical attributes of at least 90 percent of NEOs with sizes of 140 meters or larger. The PDCO should plan and budget for the incremental costs of maintaining the planetary radar tracking and characterization capabilities at the National Science Foundation’s Arecibo and NASA’s own Goldstone facilities, in addition to the space-based element noted in Finding 7. Support should continue through those facilities’ planned life cycles, including any programmed upgrades to their capabilities. Radar observations, when used in conjunction with optical observations of new NEO discoveries, are more effective than optical means at significantly improving knowledge of an object’s orbit and reducing prediction uncertainties. In turn, increased orbit precision and reduction of the error ellipse in a NEO’s predicted position reduces the likelihood of a worrisome probability of impact situation, and subsequent need for taking mitigation actions before a sufficiently precise miss distance or impact location is determined. If radar eliminates just one of these worrisome situations, it would more than offset its long-term operations costs. 1.3. Planetary Defense Budget. In the out years, the PDCO should plan and budget for long- term, continuous monitoring of the NEO population, beyond the interval required for reaching the near-term discovery goals. NEO orbits evolve over time, both episodically (due to gravitational encounters) and gradually (due to non-gravitational perturbations) and the NEO database will require periodic updates following the initial, intensive search and discovery period. New arrivals joining the NEO population from the main belt will also require discovery and cataloging. Once the catalog is substantially complete, existing ground-based elements will likely be sufficient for such follow-on monitoring. Therefore, Planetary Defense funding requirements for detection, early warning, and mitigation/deflection demonstrations are substantially front-loaded. The Task Force finds that the Planetary Defense program plan is likely to require an annual budget of approximately $250 million to $300 million per year during the next decade to meet the mandated 140-meter search goal; execute selected NEO characterization missions; develop and demonstrate NEO deflection capabilities; and develop the analytic and simulation capacity necessary for NASA’s PD role. Once the search for potentially hazardous objects is substantially complete, the task shifts to ongoing monitoring and catalog maintenance. After flight demonstrations of the primary deflection concepts are completed, further experiments would be integrated into scientific or exploration missions. The PD program budget could then recede to operations and maintenance levels (approximately $50 million to $75 million annually).