AF/A8XC
Natural Impact Hazard (Asteroid Strike) Interagency Deliberate Planning Exercise After Action Report
December 2008

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EXECUTIVE SUMMARY

Future Concepts and Transformation Division (AF/A8XC) hosted a Natural Impact Event Interagency Planning Exercise, 4 Dec 2008, in Alexandria, Virginia. Twenty Seven Subject Matter Experts from across US Government, including DOD, DOE, DOS, DHS, NASA, and NSC participated in a single day tabletop exercise to explore "whole of government" response to an impending asteroid strike.

The specific scenario involved a mythical asteroid, "2008 Innoculatus." It was a binary asteroid consisting of a 270m rocky rubble pile projected to strike the Gulf of Guinea and a 50m metallic companion asteroid projected to strike in the National Capital Region (NCR). The scenario was selected to maximize exposure to the diversity of threat (variation in size, composition, land/water strike), stress both national and international notification, and provide useful pre-planning should an actual effort need to be mounted against the asteroid Apophis when it has a small probability to pass through a gravitational keyhole in 2029 and perhaps return to strike the Earth seven years later in 2036.

Players were broken into two teams. The first team focused on disaster response and was told the asteroid was discovered 72 hrs from impact. The second team focused on deflection/mitigation was told the asteroid had been discovered seven years from impact, and to design a "strawman" deflection plan using existing capabilities.

The major insights are summarized below (for an expanded discussion, see section 6):

1.1 The NEO impact scenario is not captured in existing plans

While a number of useful analogs exist, as well as procedures that could be used or adapted, at the present time they have not been so adapted, and attempts to do so in the moment are likely to be much less successful than advance preparation.

1.2 The NEO impact scenario should be elevated to higher level exercises with more senior players

Players suggested that the scenario was mature enough, interesting and compelling enough for elevation to higher levels of visibility and increased levels of detailed examination. Players suggested that National Planning Scenarios need to include a NEO impact as one of the scenarios. Players recommended incorporation of a NEO impact scenario into a number of formal planning exercises.

1.3 Proper planning and response to a NEO emergency requires delineation of organizational responsibilities including lead agency & notification standards.

Players consistently remarked that the complexities and overlapping nature of this contingency required advance delineation of responsibilities, formalization of the notification process, and clarification of authorities and chains of command, including authorities for delegation and supported/supporting relationships. Players thought it was important to think through and document this prior to any actual NEO emergency.

1.4 Players were not able to achieve consensus on which agency should lead the NEO deflection/mitigation effort

No obvious consensus emerged on which agency should have lead for a deflection effort. Expertise is widely distributed across US government agencies. Players held widely divergent views in terms of organizational equities whose resolution will require a policy decision at a higher level. In the absence of policy guidance, players felt an actual deflection attempt would likely mirror the Manhattan Project

1.5 There is a deficit in software tools to support senior decision-making and strategic communication for disaster response & mitigation for a NEO scenario.

None of our command centers to support decision makers have the necessary tools to make quick assessments. Players expressed a need for a "National Decision Support System" for natural impact scenarios and events. Such a system would need to tighten up the federated nature of impact prediction and impact effects prediction, integrating models for impact location and uncertainty prediction, kinetic effects prediction, plume, and tsunami effects, and feed evacuation planning models

1.6 There are significant effects a NEO impact would generate that are not adequately captured in existing models.

Players highlighted the fact that current models inadequately address several effects likely to significantly affect accurate damage / effect estimates. These include the effect of blast plumes on Low Earth Orbit (LEO) satellites, electromagnetic effects that could affect electrical power infrastructure, seismic effects, effect of terrain on blast dissipation and focusing, coupling of air-blast to tsunami response, and atmospheric distribution/dispersion of hazardous materials.

1.7 The public may be aware of an impending NEO impact before senior decision-makers.

The NEO detection community conducts its work openly using Internet communications and Web-based datasets, so it is very likely that information on a new discovery of high interest will be available to the public before NASA can complete adequate verification and validation of potential impact and provide a news release, or even speed notification to the POTUS and appropriate agencies.

1.8 Lead time for evacuation requires decisions be made before best information is available

States and local authorities require a certain lead time in order to plan and implement evacuation, and the error ellipse under current capabilities is not likely to adequately constrain the possibilities to allow effective decisions.

1.9 Public safety and tranquility require that the federal government be able to rapidly establish a single authoritative voice & tools to present critical information

Given the concern of what the public might know before it even gets to leadership, there needs to be a plan to put forward a single authoritative voice backed up with tools that clearly present information to support state and local authorities and reduce the chance of panic and counter-productive movement.

1.10 The preferred approach for short-notice NEO deflection was stand-off nuclear

In this scenario, given the short lead time (less than a decade), players chose to go with a solution they felt was low mass, provided high energy density for deflection, leveraged existing national capabilities, and had comparatively high technological readiness level (TRL). Some players suggested a Memorandum of Understanding (MOU) between NASA, DOE and DOS may be necessary to preserve the required capabilities and infrastructure to execute the nuclear option.

PREFACE

Audience: This document is written to be useful to two primary audiences. First, the participants, so that they have a useful record of the event in which they participated, and second, those who are working to advance the general state of disaster preparedness for the contingency of a Natural Earth Impactor (Asteroid or Comet), particularly those who may design subsequent exercises. Few individuals have the time to independently research and assemble the information and expertise to recreate such an event. With this in mind, I have chosen to err on the side of too much information, rather than too little, and provide everything an individual or agency should need to reconstruct a similar scenario.

Disclaimer: This report summarizes player opinions in the context of a single wargame; it does not represent the opinion or position of AF/A8XC, the Air Force, DoD, or any participating agency.

Apologies for Errors: As the official rapporteur for this event and author of this report, I have endeavored to accurately capture what transpired at the event. No doubt I have unintentionally introduced some inaccuracies, perhaps even some as egregious as getting a person's name or title wrong, and for that I apologize. I also would have liked for this to be a formal, academic-quality report, but due to time constraints and a desire to get it out to the participants in a timely manner, this is not to be, so I hope many may find it useful and will not judge it too harshly.

Acknowledgements: I wish to acknowledge and thank those individuals who significantly contributed to this event. First, I would like to thank the players and participants who voluntarily gave up their time to tackle such an unusual topic, and their supervisors and organizations who made their outstanding expertise available. In particular, I would like to thank Brig Gen Smith from NSC, and Mr. Gil Siegert from OSD Policy who played the POTUS, and added so much to the event. I would also like to thank Col Mark Bucknam who was helpful in the construction of the scenario, and provided many of the players. The players from Joint Staff and Checkmate were also surprise MVP's who filled in valuable expertise when others could not make it. I would like to thank those who helped with the modeling and simulation support for this event, including Don Yeomans at NASA JPL, Jay Melosh at University of Arizona, Mark Boslough at Sandia, and Steve Ward at UC Santa Cruz. I also owe a debt to those who have advanced the topic generally, including Dr. Simon "Pete" Worden, Brig Gen, USAF (ret), the team who put together the AIAA Planetary Defense Conferences, especially Bill Ailor, and Dr. Bong Wie, who took the major step of creating the first academic research center and hosting the pre-cursor Deflection workshop which crystallized the problem of Command & Control. It is also appropriate for me to thank my own superiors, who gave me the freedom to explore this topic, and the foresight and courage to be the first to host such an event, even when it is unclear which organization "ought to." I am proud of my service for taking this leadership role. Lastly, I would also like to extend particular thanks to Mr. Lindley Johnson of NASA Headquarters, who has worked tirelessly since the 1994 Air Force SpaceCast 2020 paper to see this problem properly addressed, and without which this workshop would not have happened.

Respectfully,

PETER A. GARRETSON, Lt Col, USAF
Chief, Future Science and Technology Exploration
HQ USAF

2 INTRODUCTION

2.1 Confronting the Challenges of the Future

Air Force Future Concepts (AF/A8XC), or "AF DeepLook" is the Air Force's internal long-range think tank, charged with looking beyond the current Fiscal Year Defense Plan (FYDP). A8XC's stated mission is to:

> "*Explore, develop, advocate and link future concepts, capabilities, promising technologies and their program funding to continue transforming the Air Force into a more effective fighting force."*

A8XC fulfills this charge to explore, develop, and link future concepts through a constant environmental scan and search of the horizon for relevant threats, opportunities, and constraints that may shape, advance or constrain Air, Space and Cyber Power. A8XC provides compensatory analysis, and looks particularly for those aspects of the future that are not yet properly or fully considered in Air Force or national planning assumptions, such as the culmination of current trends or the exploration of foreseeable surprises that could create organizational shock. A8XC then hosts events that create the time and space for the Air Force to confront these challenges of the future, however uncomfortable. Such events help inoculate the Air Force against potential future shocks, allow it to safely red-team and challenge current assumptions. By creating occasions where the AF can confront challenges to its existing assumptions and planning for the future and then "back-casting to the present," it helps ensure viability and adaptability, and builds lead-time for AF and national leadership to change its plan and create organizational coping mechanisms.

2.2 Futures Game & Title X Wargaming

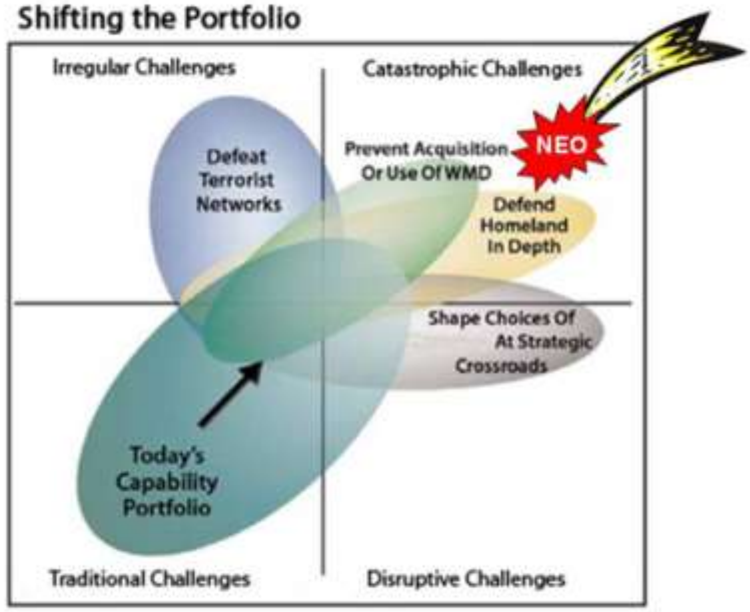
A primary responsibility of A8XC is the execution of CSAF's Title X responsibility to conduct the Air Force Futures Wargame (FG) series. Per AFI 10-2305 ("Wargaming"), the purpose of Title 10 war games is to:

- Explore new concepts and capabilities
- Study/refine emerging operational concepts
- Prevent technical/strategic/operational surprise
- Evaluate strategic plan/vision – assess alternatives
- Use plausible scenarios to improve understanding of future challenges and potential responses
- Guide follow-on studies, analyses, mod/sim to address key insights, questions, and issues
- Outputs may also impact Experimentation, Concept Development, Concepts of Operation

FG is the official AF game associated with long-term future concepts and future force structure constructs. It is used to explore alternative futures and force structure to support strategic planning inputs. (AFPD 90-11) It is a tool to test new ideas and make sure the AF is on the right vector to address the future environment, in order to understand what forces the AF should possess 25 years into the future, "backcasting from the future" rather than forecasting from the present. Toward this end, an additional purpose of Futures Game established by Gen Fogleman was to generate debate on uncomfortable and threatening issues.

This event was one of several seminar events held in support of AF Futures Game 2009 (FG'09) to confront known deficits in interagency cooperation and deliberate planning.

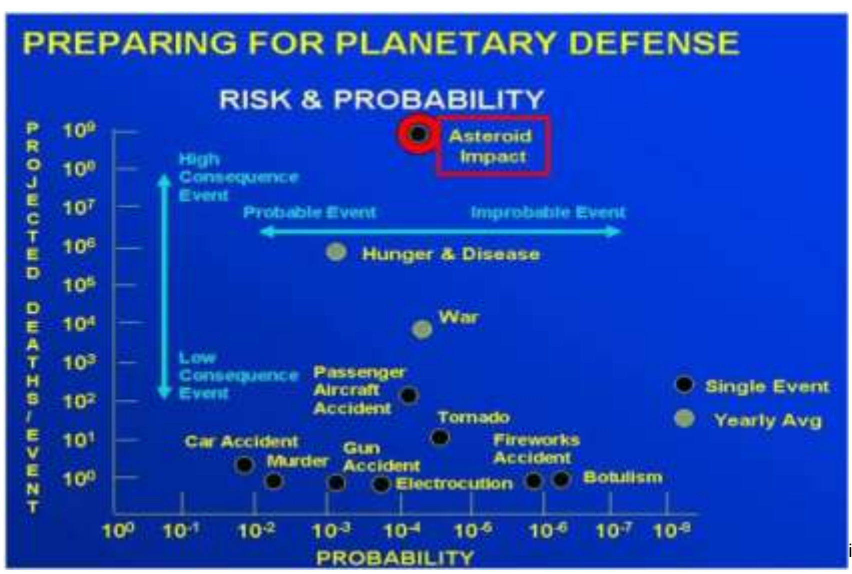
2.3 Why a Natural Impact Event?



Slide Depicting the New Challenge Space from QDR'04

2.4 Roots in QDR'04 "Catastrophic" Rebalancing: Looking for Disruptive Shocks

The selection of this particular topic has its roots in QDR'04, which directed the services to rebalance their portfolios by accepting greater risk in traditional warfare to better address emerging irregular, disruptive and catastrophic threats. A8XC subsequently conducted an extensive review of foreseeable threats to national security, high consequence, disruptive shocks, and potential future roles and missions prior to selection of its scenario for Futures Game 2005.



Understanding the Risk of High Consequence Low Frequency Events

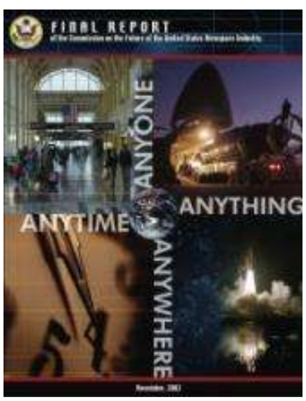
2.5 Unprepared and Uncomfortable

One high consequence event for which it appeared the Air Force was not suitably prepared was the topic of a natural Earth-impact event, such as from a comet or asteroid, referred to in past AF literature as "Planetary Defense."

2.6 A Strategic Deficit between Problem Identification and Action

A8XC was confronted with this deficit from multiple sources. Literature review of past AF future studies such as SpaceCast2020 and AF2025 both suggested an asteroid or comet strike could be an extreme threat to national security, and that Planetary Defense might become a future AF mission. (Find both at: http://www.nss.org/resources/library/planetarydefense/index.htm)

The topic of Planetary Defense had also been addressed both by congressional hearings as well the 2002 Presidential Commission on the Future of the United States Aerospace Industry, which stated:



"The Commission believes that these studies should be broadened to include detection of asteroids. U.S. Strategic Command officials are also reviewing a concept for a clearinghouse that gathers and analyzes data on potential Earth impacts from asteroids. In addition, the National Security Space Architect is currently, as part of the Space Situational Awareness Architecture, integrating the use of space and ground-based surveillance systems. Given these actions, planetary defense should be assigned to DoD in cooperation with NASA. The Commission believes that the nation needs a joint civil and military initiative to develop a core space infrastructure that will address emerging national needs for military use and planetary defense."

Very clear recommendations had also been provided in the 2004 AIAA Position paper and 2007 Planetary Defense Conference white paper.

It was clear, however, that despite this forethought, no action had been taken or was on-going to prepare in a meaningful manner. The importance of the topic and the reality of its deficit were confirmed by a number of invited speakers hosted by A8XC, including Col Michael Kelly, AF CONOPS for Homeland Security (AF/XOX-HLS, later AF/A5XS-HLS), Mr. Lindley Johnson of NASA, Lt Col, USAF (Ret), Mr. Jim Oberg, and Dr. Simon "Pete" Worden, Brig Gen, USAF (Ret).

Ultimately, a man-made WMD event was selected for the FG'05 scenario, but Planetary Defense remained an active area of exploration, advocacy, and incubation within A8XC (see Appendix F), until its selection for a seminar event for Futures Game 2009.

2.7 Why Compelling in 2008?

Several factors conspired to make Natural Impact / Planetary Defense a compelling topic for a Futures Game 2009 seminar. First, in the intervening three years, A8XC had laid considerable groundwork for such an event, including the outlines of a scenario and identification of key players. Second, A8XC perceived a number of external events for which neither USAF, DOD, nor interagency policy were ready to address. These included:

- The presentation of draft international protocols to the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) by the international Association of Space Explorers (ASE)[ii] in February of 2009
- The First International Planetary Defense Conference[iii] in April of 2009
- A Congressional tasking (H.R. 6063) to the National Research Council to review and report to congress on current NEO efforts by Oct 2010
- A Congressional tasking (H.R. 6063 which became the 2008 NASA Authorization Act[iv]) to the President's Office of Science and Technology Policy (OSTP) to, by Oct 2010:
    - Develop a policy for notifying Federal agencies and relevant emergency response institutions of an impending near-Earth object threat, if near-term public safety is at risk; and
    - Recommend a Federal agency or agencies to be responsible for—
        - (A) protecting the United States from a near-Earth object that is expected to collide with Earth; and
        - (B) implementing a deflection campaign, in consultation with international bodies, should one be necessary.
- Knowledge of preparation by various space advocacy groups[v] to put forward this topic front and center to the new administration
- The prognosis that within 10-15 years our detection capabilities are projected to improve so significantly that we will be aware of not one (Apophis), but 50-100 asteroids sizeable enough to penetrate the atmosphere and create WMD-like effects that are on close Earth approach trajectories within the next 100 years and warrant active monitoring or deflection.

Operational Analysis in the 1995 AF2025 study, and the more recent 2008 Blue Horizons study also indicated that force structure for Planetary Defense scored surprisingly well in future force structure trades across a range of alternate futures suggesting a synergy with other national security missions. A recent technical memorandum by AFRL (07-440, Cambier & Mead, 2007) also highlighted significant synergies with larger national goals and in-space propulsion.

Lastly, in Aug of 2008 the Directorate of Air Force Strategic Planning (A8X) received a formal nomination to include Natural Impact Events in Air Force Strategic Planning activities from NASA HQ (see Appendix E).

2.8 Scoping of Event and Filling the Need for Contingency Response Planning

In scoping the needs for this particular event, A8XC considered what had already been accomplished in previous Planetary Defense Conferences, and recent events such as the Joint Space Team meeting on 29 Oct, and the 23-24 October event in DC hosted by the University of Iowa Asteroid Deflection Research Center (ADRC). This event was co-sponsored by A8XC, and included representatives from AFRL, NASA, DTRA, NSF, DHS, and DIA, as well as members of the Congressionally-tasked National Research Council (NRC) to examine the current state of deflection technologies. These events confirmed that the most significant deficit was in command and control (C2) that might be facilitated through an interagency response exercise. This view was consistent with previous recommendations:

"An Open Letter to Congress on Near Earth Objects" from a number of prominent astronauts, scientists, journalists, historians, and policy analysts, dated July 8, 2003:

> **NEO Contingency and Response Planning:** Initiate comprehensive contingency and response planning for deflecting any NEO found to pose a potential threat to Earth. In parallel, plan to meet the disaster relief needs created by an impending or actual NEO impact. U.S. government/private sector planning should invite international cooperation in addressing the problems of NEO detection, potential hazards and actual impacts.

2007 Planetary Defense White Paper:

> **Conduct an Impact Response Exercise**—a well-scripted and well-designed tabletop exercise, driven by improved gaming, modeling and simulation resources to increase understanding of the evolution of an impact disaster and demands on response agencies and communication systems. For many natural disasters, agencies responsible for assisting those affected conduct simulations involving all segments of disaster response to identify issues and develop solutions. An unexpected NEO impact should be added to the set of disasters simulated. The disaster could be either from an ocean impact, where the effects could be experienced by a long expanse of coastline and possibly affect several or many nations, or from a land impact. The simulation would focus on effects of a 50- to 140-meter class NEO, a size that would likely impact without warning. Ideally, the exercise would involve all stakeholders that would be involved in a response, including local and national governments, military organizations, disaster responders, and members of the press. http://www.aero.org/conferences/planetarydefense/2007papers/WhitePaperFinal.pdf

Such recommendations were clearly within the province and expertise of AF Wargaming, and neither the topic-specific expertise, nor the wargame-specific expertise was likely to reside in another organization. A8XC was in a unique position to provide a contribution to fulfilling the intent of existing Executive and Congressional guidance to advance our state of preparedness for this threat and emerging mission.

Because other organizations (OSTP, NRC) were examining the policy discussions through high-level interagency formal processes, A8XC sought to examine how we would execute in the absence of those decisions, should a threat be presented today, and what potential AF contributions and required capabilities might be.

A8XC therefore constructed an Action-Officer (AO) level game of actual executors (NASA Minor Planet Center, NASA JPL, National Military Command Center, Air Force Operational Group, Department of Homeland Security, and Department of State, Department of Energy Labs, and Air Force Research Labs, and executing Combatant Commands), to discuss potential responses for disaster response and mitigation.

[redacted]

3 Methodology and Objectives

3.1 Methodology

This event was a tabletop “wargame” or exercise, not unlike a Major Accident Response Exercise (MARE), where various representatives from their respective agencies provided in-role responses to postulated events.

Twenty Seven SMEs (see Appendix C) from across US Government attended. A plausible near-term scenario, based upon a known potentially hazardous asteroid (Apophis), and recent experience with 2008 TC3 was constructed and briefed to the players. Players then acted in-role to fulfill NSC/POTUS intent to respond appropriately and provide options and identify current capabilities, expertise as well as known shortfalls. Results are summarized in this document.

3.2 Purpose

Advance our state of preparedness with respect to the rare but extremely high consequence contingency of a natural Earth impact event and offer insight into Air Force equities, responsibilities, and actions in this context, including possible future technical capabilities and organization.

3.3 Objectives

The seminar had four objectives:

- With Subject Matter Experts (SMEs), explore the capabilities and limits of our current capability for a relatively near-term threat to:
  - Create a base-case “strawman” template for follow-on planning and benchmark for comparison
  - Understand gaps to guide long-range science and technology investment
- Sensitize non-space agencies to:
  - The nature and seriousness of the threat and:
  - The kind of information they could ask for and receive
  - The kind of options that are available
- Identify shortfalls in current command and control and interagency collaboration / cooperation to:
  - Understand AF component
  - Lead creation of a template for actual response
  - Provide quality insights as appropriate to support:
    - Congressionally-tasked National Research Council (NRC)
    - Office of Science and Technology Policy (OSTP) to comply with its Congressional tasking to assign a lead agency
- Ensure USAF readiness comply with:
    - Executive Order 12655 (Emergency Preparedness)
    - NSPD 49 National Space Policy,
    - DOD Directive 3025.1 (Support to Civilian Authorities)
    - DOD Directive 5100.46 (Foreign Disaster Relief)
    - DOD Directive 5100.1 (Functions of the DoD and Its Major Components)
    - Readiness to accept lead agency should it come to the USAF or should USAF be tasked to supply forces or act in a supporting capacity
      - Provide data to allow an informed USAF position

4 THE SCENARIO SELECTION & EXERCISE DESIGN

4.1 The Diversity of the Threat

The Near Earth Asteroid threat is very diverse. Asteroids vary in size (a few meters to many kilometers), composition (metallic, stony-metal, rubble-piles), and whether they are single or multiples (a primary object with small "moons" - 16% of NEOs). An asteroid strike can occur on land or strike in water, generating a large tsunami. The location of the strike might strike domestically or abroad, and might affect just one or many nations. A strike might happen with no warning, little warning, or years to decades of warning.

This exercise, the first ever of its kind, sought to expose players to the full spectrum of possible situations. It was deliberately constructed to maximize the participation of all players and generate discussion across the breadth of possible notification and interagency execution relationships.

NOTE TO FUTURE SCENARIO PLANNERS: This event was meant to be a top-level survey of broad-brush considerations. Future scenario planners for follow-up events might make significant progress by examining a much more constrained scenario, perhaps focusing in depth on response domestically or internationally, or in-depth mitigation, attempting to generate a very complete straw-man plan for a specific body.

In order to examine both national and international, both water and land impacts, both rubble piles and dense metallic objects, both insufficient warning time for mitigation, and barely sufficient time for mitigation, a mythical binary asteroid, "2008 Innoculatus" was constructed.

4.2 Scenario Considerations & Selection

A8XC considered a scenario using a 1km or larger asteroid due to its extremely high consequences, but rejected it for the following reasons:

- NASA's Spaceguard efforts and capabilities have been very successful in cataloging a majority of the Potentially Hazardous Objects (PHO's) larger than 1km, and so it is likely that such a threat would come with at least a decade of warning
- Decades of warning allow significant technological development and a diversity of options that are extremely threat specific which do not necessarily provide insight into current issues
- A8XC wanted to examine a threat that was barely within the capabilities of extant component systems to mitigate to get a sense of the upper limit of those capabilities
- Smaller threats are much more numerous and strike with significantly greater frequency
- Smaller threats are not currently well cataloged or consistently detectable with current capabilities and are more plausible to generate short-warning time and strategic surprise
- Players first exposed to the problem may be able to more easily identify with objects and events for which there is readily available evidence or relevance (Barringer Crater, Tunguska, and Apophis)

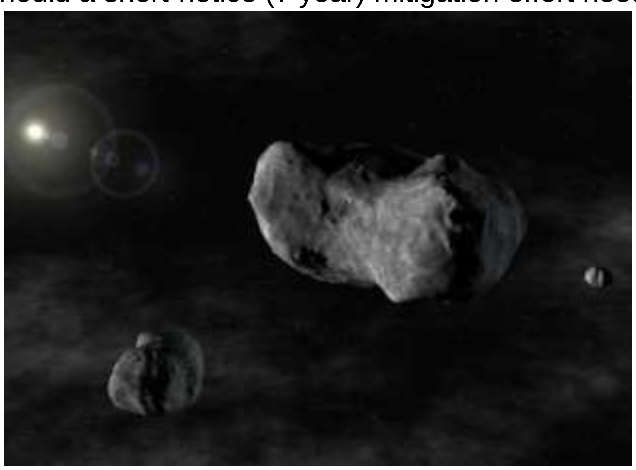
The specifics of the scenario selection were influenced by the following:

- **Tunguska** Event anniversary: 2008 was the 100 year anniversary of the Tunguska event, and Tunguska class strikes (30-50m size objects) are thought to occur with frequencies on the order of a few hundred years.
- **Apophis**: Widely publicized concerns over the asteroid Apophis, which will pass inside our geostationary satellite orbits in 2029 and might pass through a gravitational keyhole which might result in a strike in 2036

- **2008 TC3**: Our recent experience with a short notice discovery and tracking of an asteroid that impacted over the Sudan on Oct 7, 2008, with less than 24 hrs notice.
- **2008 BT18**: A recent discovery of a binary NEO consisting of a 600m larger object and a 200m smaller object which passed closest to the Earth (6x the distance to the Moon) on July 14, 2008, which was only first discovered last January.

Because the existence of binary asteroids is not well known, and because of the desire to examine both the specific case of a strike entirely within the US (NORTHCOM / FEMA responsibility), and abroad (Regional COCOM & State Dept responsibility), a binary object was selected.

Because of the very real possibility that no significant action may be taken regarding Apophis till it passes the gravitational keyhole in 2029, the orbital period, characteristics, synodic period, and size mirroring the asteroid Apophis were selected in order to provide some real-world planning value, should a short-notice (7 year) mitigation effort need to be mounted.




4.3 2008 Innoculatus

The specific scenario constructed by A8XC postulated a mythical asteroid, “2008 Innoculatus.” Innoculatus was a heterogeneous, binary asteroid with a synodic period similar to Apophis consisting of a large 270 meter “rubble pile” destined to strike near Nigeria in the Gulf of Guinea, and a smaller, 50 meter metallic body, similar to that which created Barringer crater in Arizona, that would strike in the National Capital Region (NCR).

NOTE TO FUTURE SCENARIO PLANNERS: While a heterogeneous binary object met the objectives of this seminar to introduce both national and international aspects, future planners should be aware that a binary object would likely be more homogeneous in composition (rubble & metal), would not strike so far apart (US & Africa), and would create significant complications and opportunities for deflection.

4.4 Modeling and Simulation Support

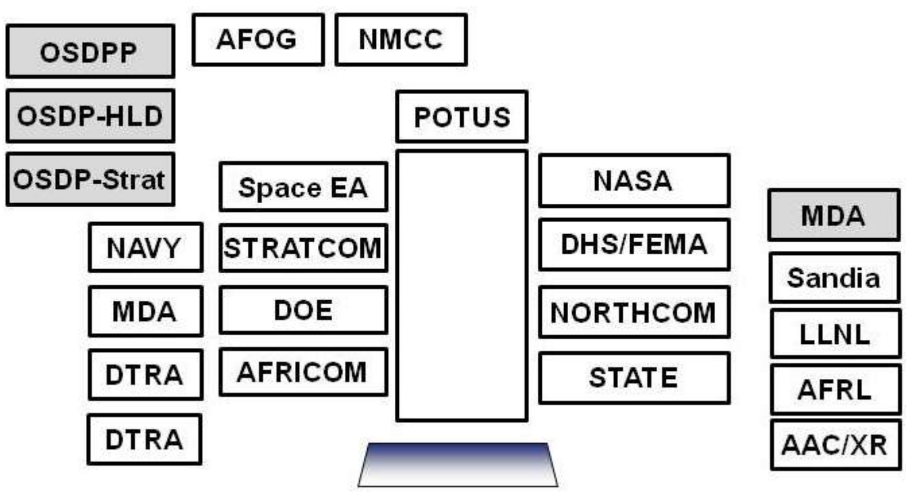
A8XC worked with NASA HQ, Mr. Lindley Johnson, the Minor Planet Center (MPC), and Mr. Don Yeomans at NASA JPL to construct scenario specifics, and timeline of information.

A8XC and NASA also engaged various experts to help players visualize and understand the scale of the threat:

- Jay Melosh at the University of Arizona Lunar and Planetary Laboratory for cratering effects (example at: http://www.lpl.arizona.edu/impacteffects/)
- Mr. Mark Boslough of Sandia National Laboratories (SNL), for Airburst Simulations (example of at: http://www.sandia.gov/news/resources/releases/2007/asteroid.html)
- Dr. Steven Ward of University of California at Santa Cruz for Tsunami simulations, (example at: http://es.ucsc.edu/~ward/)

NOTE TO FUTURE SCENARIO PLANNERS: While these products added significantly to our exercise, it is important to note that none are currently part of US disaster response infrastructure, and might not be immediately available to real decision makers. Some players also felt that in a single day seminar, the large amount of technical details left too little time to actually "work the problem."

4.5 Participant/Player Layout and Team Construction



Player/Participant Room Layout for Exercise

A8XC solicited and put together two teams of AOs likely to be involved in the nuts & bolts of an actual response to play their respective agencies. Interested parties from OSD Policy Planning, OSD Strategic/Space Policy, OSD Homeland Defense, Joint Staff J5, and Air Force Checkmate also attended, and filled in as supporting players.

Given the obscurity of the scenario, attendance was exceptionally good (~25). Every seat in the room was filled with Joint Staff, OSD, and 3 services (AF, Navy, USCG), 5 civilian agencies (NASA, DOE, State, DHS, NSC), 3 DOD agencies (NSSO, DTRA, MDA), and 3 Laboratories (Sandia, LLNL, AFRL).

The event was held at the UNCLASSIFIED level, but was limited to government-only personnel and US Citizens. International players (threatened nations in Gulf of Guinea, space-capable nations

(Russia, China, India, Japan), external interested organizations (B612, ASE, SFF, NSS, Planetary Society) and press were not represented.

NOTE TO FUTURE SCENARIO PLANNERS: Future planners may wish to reconsider the above decisions regarding attendance:

- Significant expertise in this area exists outside government, in industry, academia, and Government Support Organizations (for example Aerospace Corp, United Space Alliance, JHU/APL, Iowa State Asteroid Deflection Research Center).
- The significant international component of some impact scenarios and ALL deflection scenarios suggests consideration of actual or simulated international components.
- External interested organizations are highly knowledgeable, and likely to supply alternate and perhaps disruptive “authoritative voices” in the media.
- Press / Media might provide very useful considerations and may be pre-educated.

NOTE TO FUTURE SCENARIO PLANNERS: From player critiques, it was clear that the presence of high level individuals and their expertise, particularly Brig Gen Smith from NSC, and Mr. Gil Siegert from OSD Strategic Policy significantly added to the event. A number of player critiques felt this exercise or one like it should be held at a higher level.

Because we desired to examine both response and mitigation, but maximize the cross-talk and minimize confusion, the exercise was designed in such a manner as to split the players into two teams but keep a common scenario with the only difference being the available time to impact. In both cases, we provided what we thought was the minimum warning time available though we opted to just use a single scenario, but alter the time till impact as a variable.

4.6 Event Structure

The event itself was held at the A8XC facility in the Hoffman Building on Eisenhower Avenue on 4 December 2008. The planned structure / timeline for the event was:

0800 Informal networking over donuts
0900 NASA Situation Brief & POTUS Tasking
1000 Split into Teams: What would we do?
1100 Initial Team Plan with POTUS and team requests for information (RFIs)
1100-1200 Working Lunch
1200-1215 Planetary Science Team Update
1215-1600 Teams continue to work action plans
1600 Team Outbrief Action Plans & Discussion
1700 Collect surveys & Adjourn

The actual event deviated slightly. At NASA Request, A8XC opened the event with a background briefing. The briefing was given “in role” as a background brief to the POTUS on the current state of deliberate planning for the eventuality of a natural impact, past recommendations, extant guidance, recent and upcoming national and international events. NASA’s brief was also “in role” providing an initial situation brief to the POTUS and assembled heads of agencies, followed by a background on the Near Earth Object (NEO) program at NASA, followed by a “current situation” update. Round-table introductions followed. A significant period of discussion and questions followed in the “Joint Session,” which because of its value was allowed by the facilitators to run long.

Once the scenario was established, the teams were split between the Disaster Response & Notification Team, and Mitigation/Deflection Team for a working lunch.

- The Disaster Response Team was asked to consider response to *2008 Innoculatus* if it was discovered only 72 hrs to impact (I-72hrs).
- The Mitigation/Deflection Team was asked to consider a response to *2008 Innoculatus* if they had only one synodic period (7 years)

The “Joint Session” convened following lunch because of the need for some players to share their expertise (for example, Mark Boslough had information both for estimating blast effects and deflection, and there was a need for the Dept of State representative to be involved in discussions in both notification and deflection planning). Mark Boslough gave an overview of lessons learned from his supercomputer modeling of airburst phenomena.

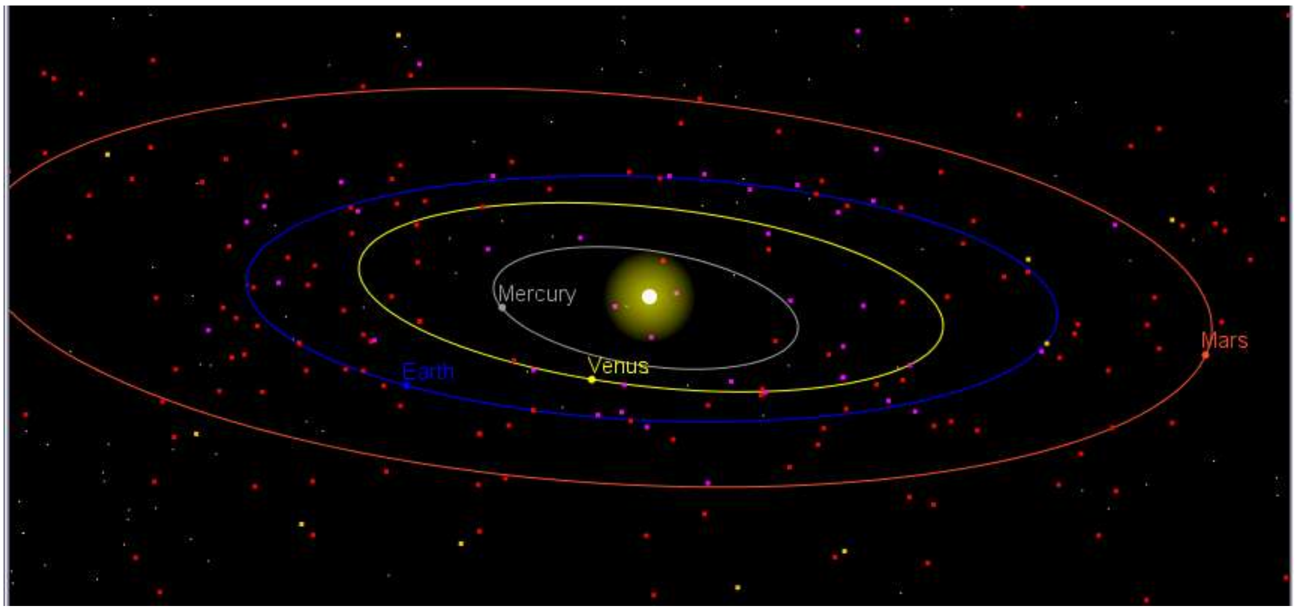
Players then broke into their respective teams in separate rooms to discuss required actions. Results were then outbriefed at the end of the day. Results of individual player feedback can be found in attached appendix B.

5 BACKGROUND ON THE NEO THREAT

This section summarizes the real-world introductory information given to the players:

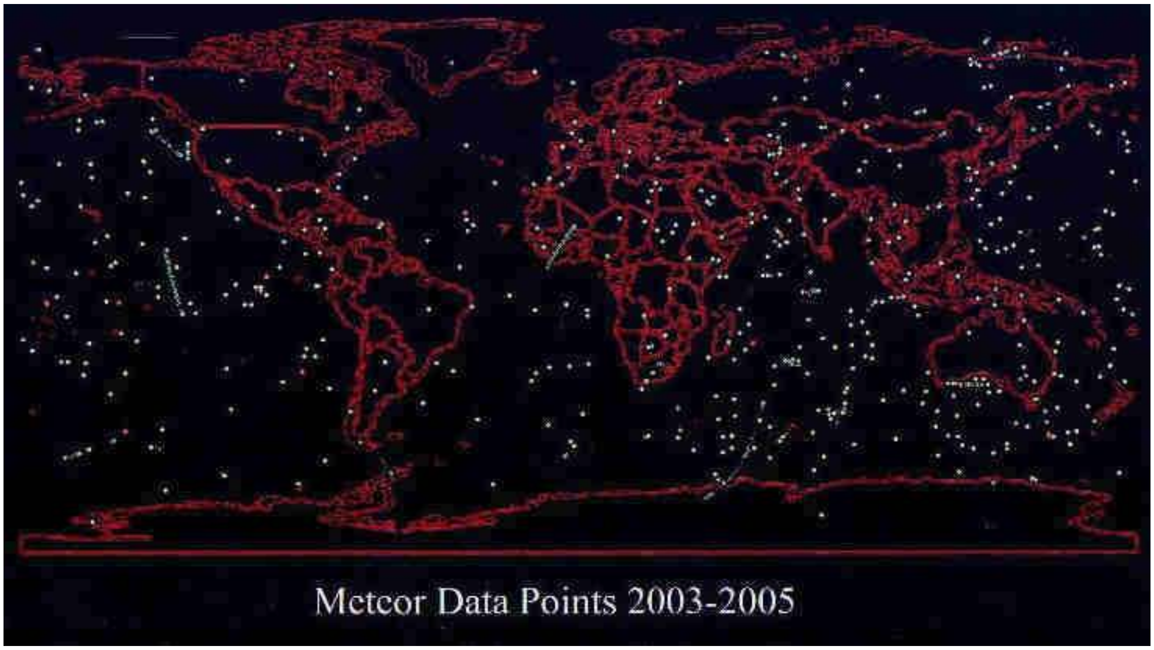
5.1 Background Brief to Simulated-POTUS on Current State of Preparedness

The image most people have of our inner solar system is of isolated planets separated by large volumes of quiet, empty peaceful space. That image exists because our educational establishment has not caught up with current planetary science. A8XC began the seminar by showing a NASA Marshall Space Fight Center (MSFC) simulation depicting the whizzing swarm of potentially hazardous objects weaving in and out of Earth's orbital plane, and a quote from the current NASA administrator, Mike Griffin on the seriousness of the threat.



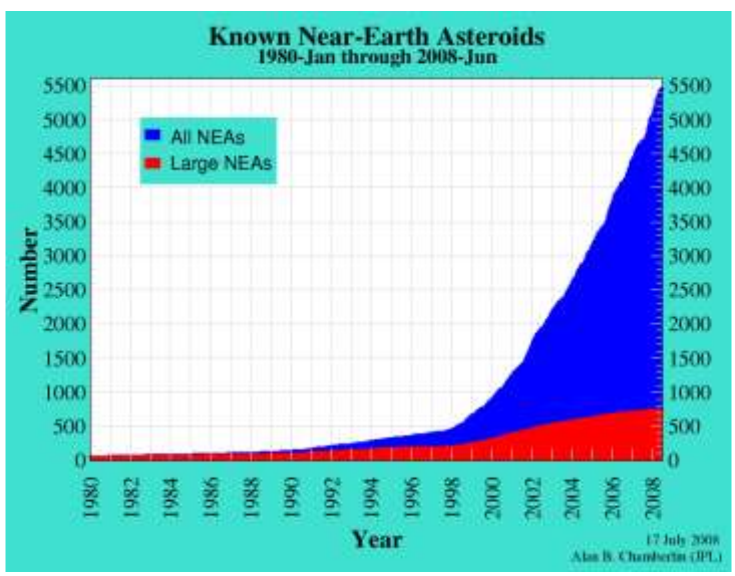
Potentially Hazardous Objects (NASA MFSC AsteroidSim)

> *Mister Chairman and members of the subcommittee, thank you for giving me this opportunity to comment on* ***the greatest natural threat to the long-term survivability of mankind, an asteroid impact with the Earth****. Throughout its history, the Earth has continuously been bombarded by objects ranging in size from dust particles to comets or asteroids greater than 10 km in diameter. Although the probability of the Earth being hit by a large object in this century is low,* ***the effects of an impact are so catastrophic that it is essential to prepare a defense against such an occurrence****.*
>
> *An overall Earth protection system must have* ***three components****. First, a search system is needed to* ***identify any potential NEO impactors****. Second, a series of* ***detailed investigation missions are needed to understand the structure****, composition, rotational state, and other physical properties of potential impactors. And finally,* ***deflection technologies are needed*** *to change the speed of a NEO to ensure that it will not impact Earth.*
>
> *It is estimated that a* ***30-year advance warning would be required*** *to have a reasonable assurance of deflecting a NEO from a collision with Earth. Thus, if a future impactor were identified today, the* ***time to explore the characteristics of the NEO, develop a deflection system, deliver it to the NEO, and apply the deflection early enough to prevent an impact, requires about a 3-decade lead time****.*-- Mike Griffin, 2005, Testimony to Congress



Detected Airburst (Bolide) Events between 2003 and 2005

*U.S. early warning satellites detected a flash that indicated **an energy release comparable to the Hiroshima burst. We see about 30 such bursts per year,** but this one was one of the largest we have ever seen. The event was caused by the impact of a small asteroid, probably about 5-10 meters in diameter, on the earth's atmosphere.* --Statement of **Brigadier General Simon P. Worden**, Vice Director of Operations, United States Space Command



Near Earth Asteroid Discovery Statistics (neo.jpl.nasa.gov/stats/)

At the time of writing, there were 761 NEOs (694 NEAs and 67 NECs) larger than 1 kilometer, and an additional 5,058 smaller bodies, for a total of 5,819 known NEOs (http://neo.jpl.nasa.gov/stats/). Of those, **1,012** are larger than 150m and classified as Potentially Hazardous Objects (PHOs).

[NOTE: For a more thorough understanding of the threat and mitigation, the National Space Society maintains an exceptional on-line library at:
http://www.nss.org/settlement/asteroids/ and
http://www.nss.org/resources/library/planetarydefense/index.htm]

The potential threat to national and international security posed by Near Earth Objects have been articulated in a number of forums going back at least as far as 1994 when both the American Institute of Aeronautics and Astronautics (AIAA) and the USAF (SpaceCast 2020) put out white papers (available at the National Space Society's (NSS) online planetary defense library: http://www.nss.org/resources/library/planetarydefense/index.htm). This was recently reaffirmed by the Congress in the 2008 NASA Authorization Act (see entire act in Appendix G):

Congress makes the following findings:

(1) Near-Earth objects pose a serious and credible threat to humankind, as many scientists believe that a major asteroid or comet was responsible for the mass extinction of the majority of the Earth's species, including the dinosaurs, nearly 65,000,000 years ago.

(2) Several such near-Earth objects have only been discovered within days of the objects' closest approach to Earth and recent discoveries of such large objects indicate that many large near-Earth objects remain undiscovered.

(3) Asteroid and comet collisions rank as one of the most costly natural disasters that can occur.

(4) The time needed to eliminate or mitigate the threat of a collision of a potentially hazardous near-Earth object with Earth is measured in decades.

(5) Unlike earthquakes and hurricanes, asteroids and comets can provide adequate collision information, enabling the United States to include both asteroid-collision and comet-collision disaster recovery and disaster avoidance in its public-safety structure.

(6) Basic information is needed for technical and policy decisionmaking for the United States to create a comprehensive program in order to be ready to eliminate and mitigate the serious and credible threats to humankind posed by potentially hazardous near-Earth asteroids and comets.

(7) As a first step to eliminate and to mitigate the risk of such collisions, situation and decision analysis processes, as well as procedures and system resources, must be in place well before a collision threat becomes known.

A8XC reviewed that the threat had been identified, and that our knowledge had advanced significantly, and that there was extant guidance in the form of an **Executive Order 12656**[vi] on **Disaster Preparedness** to have sufficient capabilities at all levels of government to meet essential defense and civilian needs during any national security emergency, including natural disasters,. The order acknowledges that effective preparedness requires identification of functions that would need to be performed during such an emergency, development of plans for performing those functions, and development of the capability to execute such plans. It tasks each Federal department or agency to be prepared to respond adequately to ALL national security emergencies, and to consider national security emergency preparedness factors in the conduct of regular functions. It further directs that functions that are shared by more than one agency shall be coordinated by the agency having primary responsibility and supported by the heads of other departments having related responsibilities. It further directs each department to support interagency coordination to improve preparedness and response and to maintain decentralized capabilities where feasible and appropriate.

An open letter to Congress in 2003 by a number of high profile citizens, made a number of recommendations toward accomplishing this, including:

> 3. **NEO Contingency and Response Planning:** Initiate comprehensive contingency and response planning for deflecting any NEO found to pose a potential threat to Earth. In parallel, plan to meet the disaster relief needs created by an impending or actual NEO impact. U.S. government/private sector planning should invite international cooperation in addressing the problems of NEO detection, potential hazards and actual impacts.[vii]

Subsequently, the 2007 AIAA Planetary Defense Conference white paper also recommended a scripted tabletop scenario:[viii]

> 2.3.1. **Conduct an Impact Response Exercise—a well-scripted and well-designed tabletop exercise, driven by improved gaming, modeling and simulation resources to increase understanding of the evolution of an impact disaster and demands on response agencies and communication systems.** For many natural disasters, agencies responsible for assisting those affected conduct simulations involving all segments of disaster response to identify issues and develop solutions. An unexpected NEO impact should be added to the set of disasters simulated. The disaster could be either from an ocean impact, where the effects could be experienced by a long expanse of coastline and possibly affect several or many nations, or from a land impact. The simulation would focus on effects of a 50- to 140-meter class NEO, a size that would likely impact without warning. Ideally, the exercise would involve all stakeholders that would be involved in a response, including local and national governments, military organizations, disaster responders, and members of the press.

However, at present, **no such effort had been undertaken**, and the players have no existing processes to lean upon. For this scenario, no contingency plans exist and the scenario has not been previously wargamed. There were no requirements documents, no Memorandums of Understanding (MOUs), no Standard Operating Procedures (SOPs).

Part of the problem is that Planetary Defense overlaps, or falls in the cracks of bureaucratic responsibility between so many disparate agencies none of which have a direct mandate for primary responsibility, but the coordination of which are required for a successful response, including:

-

- **DHS:** Which has the mission to lead a unified national effort to secure America against threats and hazards to the nation.
  - **FEMA**[ix]: Which has responsibilities to help, respond, recover, mitigate effects, reduce the risk of loss and prevent disasters from occurring.
  - **Coast Guard**[x]: Which has the responsibility and mechanisms to notify and protect the coasts, ports, and ensure the safety of maritime vessels.
- **DOD:** Which is tasked to provide the military forces needed to deter war and to protect the security of our country.
  - **NORTHCOM**[xi]: USNORTHCOM anticipates and conducts Homeland Defense and Civil Support operations within the assigned area of responsibility to defend, protect, and secure the United States and its interests.
    - **NORAD:** Responsible for the North American Air Defense mission
  - **STRATCOM**[xii]: Which exercises combatant command authority from the national command authority (NCA), maintains significant expertise regarding Weapons of Mass Destruction, maintains command over our nuclear forces, global missile defense, space situational awareness and space control. Moreover, it commands, or is provided forces by:
    - **DTRA**[xiii]: Which owns significant expertise in weapons effects relevant to blast-effect modeling and estimation of effects for deflection.
    - **MDA**[xiv]: Which due to its mission to develop and field ballistic missile defense systems, has relevant expertise in high-speed collisions and seeker heads.
    - **AFSPC**[xv]: Which provides Space Situational Awareness, Launch, and Space Control in support of Homeland Security and Defense
- **NASA**[xvi]: Which runs the Near Earth Object Observation Program, has almost all interplanetary navigation expertise, deep-space communications, and significant launch facilities and capability
- **DOE**[xvii]: Which owns most nuclear and high-energy physics expertise, including nuclear device design
  - **NNSA[xviii]:** responsible for the management, security and transport of the nation's nuclear weapons, and responds to nuclear and radiological emergencies in the United States and abroad
- **NSF**[xix]: Which owns or funds terrestrial optical and radar telescope/astronomy facilities
- **NOAA**[xx]: Which maintains expertise in oceanic sciences and mechanisms for tsunami warning, as well as environmental monitoring satellites

This problem was recently recognized by Congress. In the 2008 NASA Authorization Act, there is a tasking for the President's Office of Science and Technology Policy (OSTP) to take initial steps toward solving this problem by making a recommendation to Congress:

> **Section 804 directs:**
>
> **Not later than 2 years after the date of enactment of this Act, the Director of OSTP shall--**
>
> **(1) develop a policy for notifying Federal agencies and relevant emergency response institutions of an impending near-Earth object threat, if near term public safety is at stake; and**
>
> **(2) recommend a Federal agency or agencies to be responsible for protecting the Nation from a near-Earth object that is anticipated to collide with Earth and implementing a deflection campaign, in consultation with international bodies, should one be required.**

However, at the present, and for the purposes of this tabletop exercise, that guidance would not be available for two years, and so exercise participants must decide how best to execute in the absence of such guidance.

For the benefit of players, A8XC reviewed some of the extant DoD equities, including the QDR'04 tasking to rebalance its portfolio of capabilities to consider catastrophic challenges, and existing DoD responsibilities under DoD Directive 3025.1, Military Support to Civil Authorities for domestic situations, and DoD Directive 5100.46, on Foreign Disaster relief. A8XC also noted the tasking from QDR to and the results of the 2002 *Presidential Commission on the Future of the United States Aerospace Industry* had recommended planetary defense should be assigned to DoD in cooperation with NASA, but that no action had been taken.

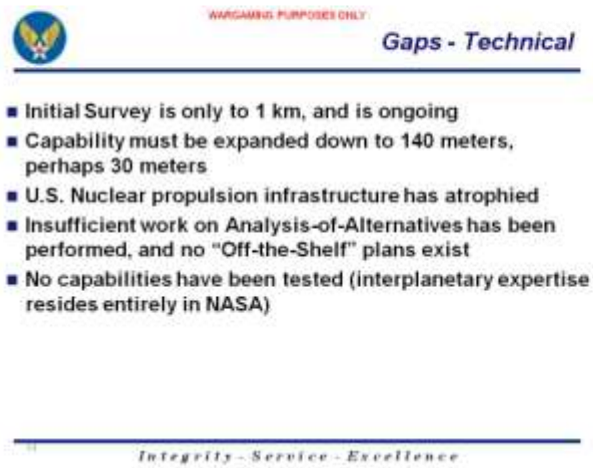
The briefer then reviewed the assignment of responsibilities under the current National Space Policy, **NSPD-49**:

> Space activities have improved life in the United States and around the world, enhancing security, **protecting lives and the environment**, speeding information flow, serving as an engine for economic growth, and revolutionizing the way people view their place in the world and the cosmos.
>
> Increase and Strengthen Interagency Partnerships. The challenges of the 21st century require a focused and dedicated unity of effort. Interagency partnerships provide opportunities to jointly identify desired effects, capabilities, and strategies. Departments and agencies shall **capitalize on opportunities for dynamic partnerships** -- whether through collaboration, information sharing, alignment, or integration.
>
> To achieve the goals of this policy, the Secretary of Defense shall:
>
> Have responsibility for space situational awareness; in this capacity, the **Secretary of Defense shall support the space situational awareness requirements** for the Director of National Intelligence and conduct space situational awareness for: the United States Government; U.S. commercial space capabilities and services used **for national and homeland security** purposes; civil space capabilities and operations, particularly human space flight activities; and, as appropriate, commercial and foreign space entities;
>
> Maintain the capabilities to execute the space support, force enhancement, **space control, and force application missions**;

And the specifics functions specified for the hosting service under **DoD Directive 5100.1**:

> Functions of the Department of Defense and Its Major Components
>
> 6.6.3.1. **The Air Force**, within the Department of the Air Force, includes aviation and **space forces, both combat and service**, not otherwise assigned. The Air Force is **responsible for the preparation of the** air and **space forces necessary for the effective prosecution** of war and **military operations short of war**, except as otherwise assigned and, according to integrated joint mobilization plans, for the expansion of the peacetime components of the Air Force to meet the needs of war.

The briefer then turned to provide a brief overview of relevant activity (see section 1.7 above) in the national and international arenas to sensitize the players to importance of activities such as this exercise to ensure the US Government was adequately prepared.

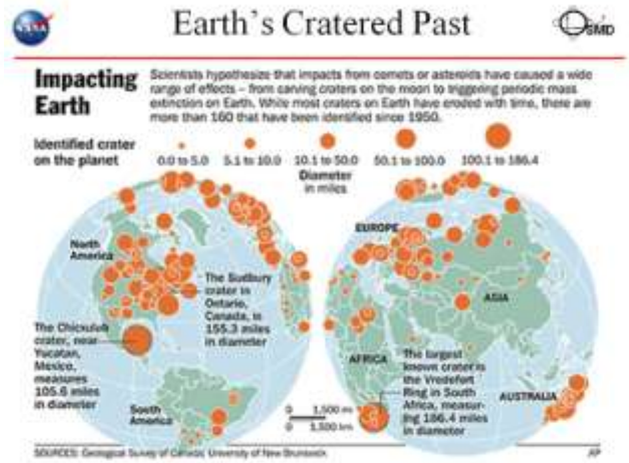


The opening briefer summarizing the gaps in preparedness already discussed above, as well as the current technical gaps in detection and mitigation.

The opening briefer then concluded by mentioning that the technologies for successful mitigation had significant synergies with other national needs, and that polls in 2002 and 2005 indicated exceptionally high public support for planetary defense as a space goal.[xxi]

5.2 Near Earth Object Program Brief

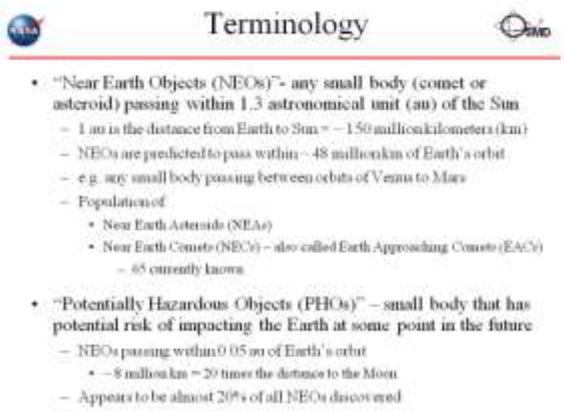
The players were then given an overview of the existing NASA NEO program, it history, current status and recent relevant events:

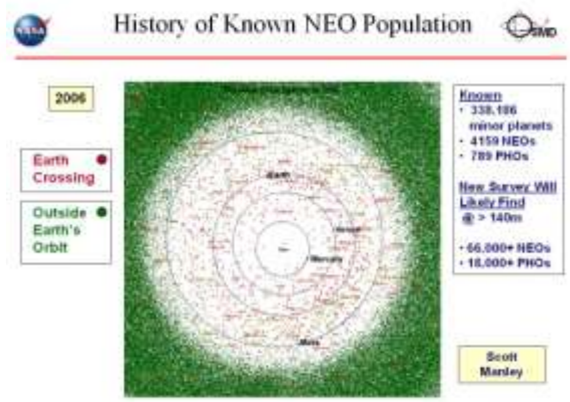


Mr. Lindley Johnson, NASA HQ, Near Earth Object Observation (NEOO) Program Executive introduced the participants to the fact that while not widely known, over 160 impact craters have been identified on Earth and more are discovered all the time. Earth has been hit every bit as often as the Moon, but because Earth is a living planet with large ocean areas, weather & hydrologic cycles, and moving tectonic plates, impact formations get eroded or covered up.

The briefing opened with the example of Barringer Crater (Meteor Crater) in Winslow Arizona as a tangible example of the destructive power of even very small (50m) impactors.

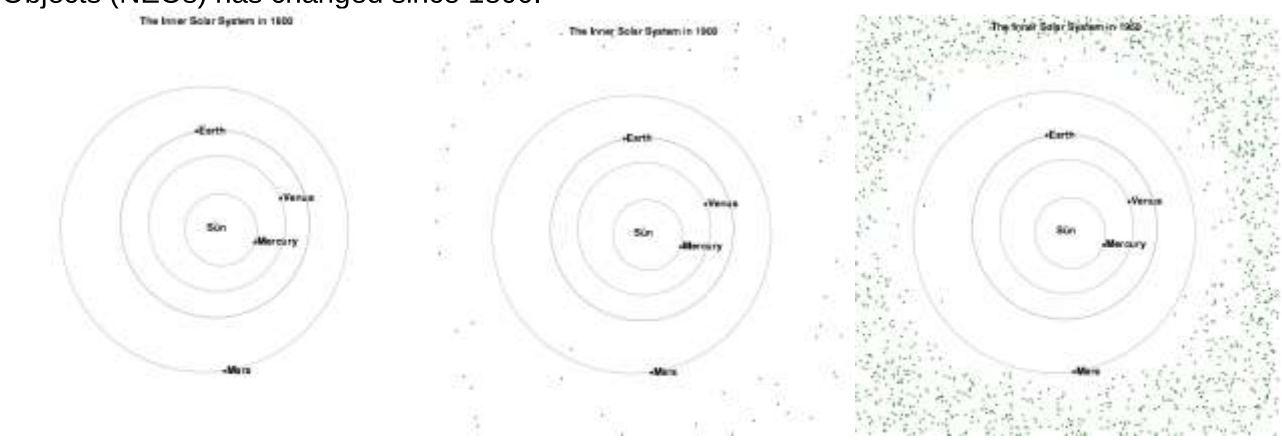
The Barringer impactor is estimated to have released 5 Megatons TNT-equivalent energy on impact, creating a 1.2 km wide crater, which would have instantly incinerated every living thing within a 10km diameter fireball, a blast pressure pulse killing or severely wounding large animals out to 24km, and producing hurricane force winds as far out as 40km.



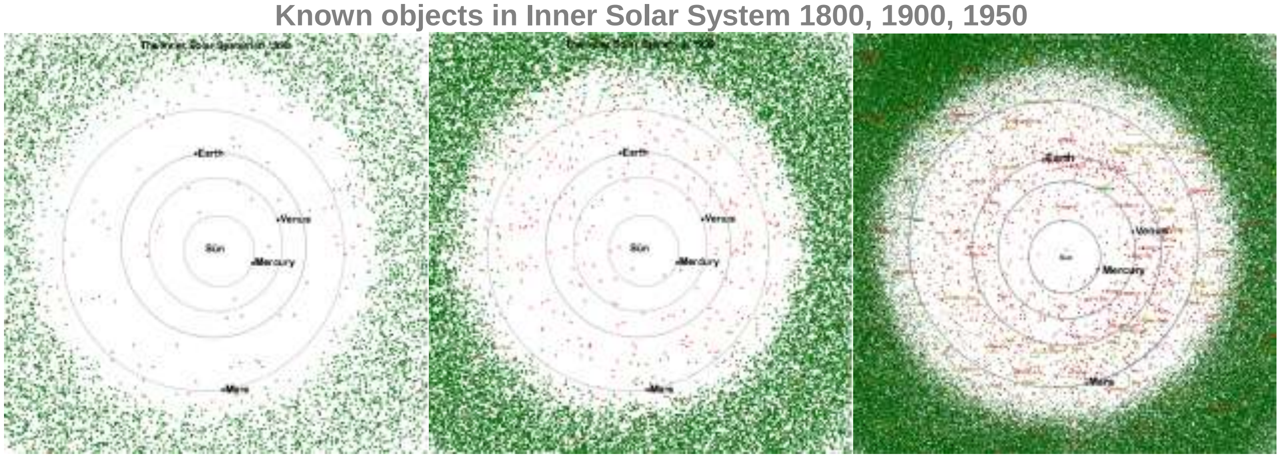


Players were then introduced to the formal terminology of Near Earth Objects (NEOs) which include any small body passing within 1.3 Astronomical units (AU) of the Sun, that includes both Near Earth Asteroids (NEAs) and Near Earth Comets (NECs). At the time, there were 5,032 known NEOs.

A smaller subset of these, approximately 20% are considered Potentially Hazardous Objects (PHOs), currently defined as any small body with a potential of impacting the Earth at some point in the future. At the time, there were 842 known NEOs with diameters $\geq$ 1 km. NASA briefed the current numbers of NEOs, PHOs, and the fact that an improved survey aimed to discover objects larger than 140m is likely to find 66,000 NEOs and 18,000 PHOs. The following charts illustrate graphically how our understanding of our inner solar system and the presence of Near Earth Objects (NEOs) has changed since 1800.

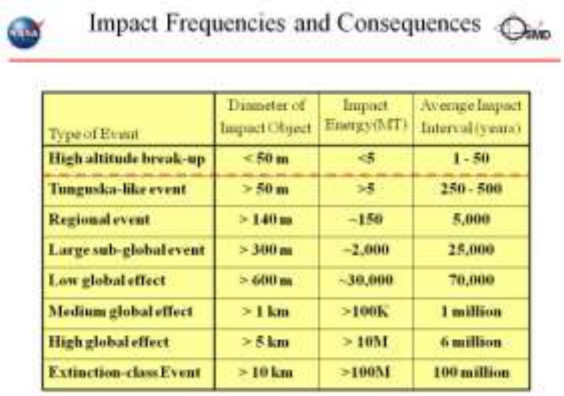


Known objects in Inner Solar System 1800, 1900, 1950

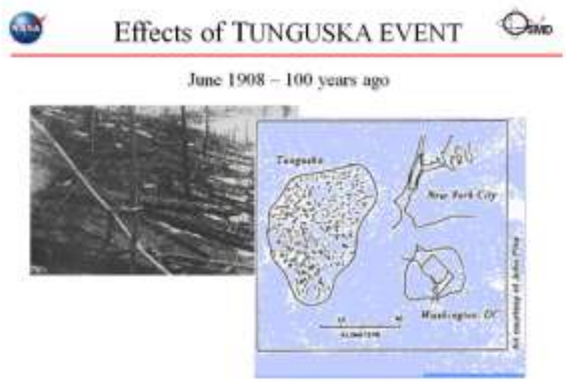


Known objects in Inner Solar System 1990, 1999, 2006

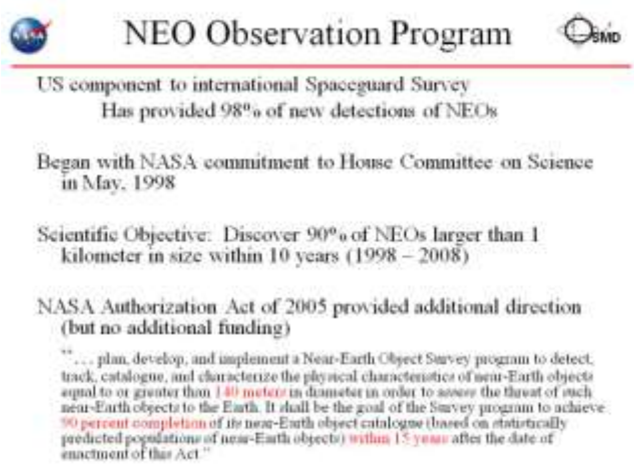
The state of planetary science and knowledge of the threat has clearly evolved and illustrates one reason why our national preparedness infrastructure must also evolve.



Type of Event	Diameter of Impact Object	Impact Energy(MT)	Average Impact Interval (years)
High altitude break-up	< 50 m	<5	1 - 50
Tunguska-like event	> 50 m	>5	250 - 500
Regional event	> 140 m	~150	5,000
Large sub-global event	> 300 m	~2,000	25,000
Low global effect	> 600 m	~30,000	70,000
Medium global effect	> 1 km	>100K	1 million
High global effect	> 5 km	> 10M	6 million
Extinction-class Event	> 10 km	>100M	100 million

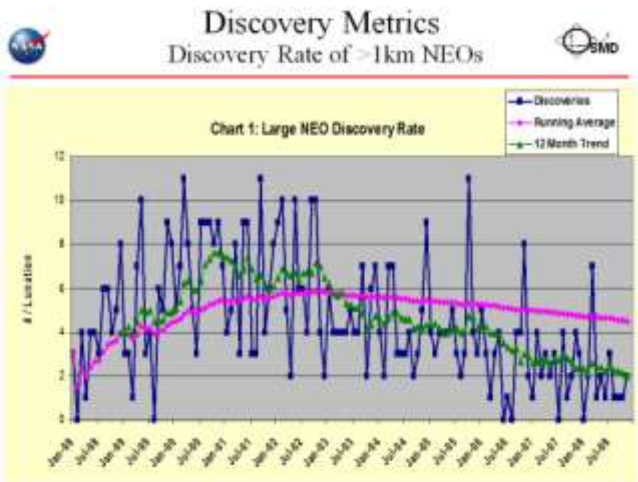


Then followed a discussion regarding the current estimates of impact frequencies and level of consequences. This included a discussion of yield equivalents: high altitude bursts if < 50 meter diameter, < 5 megatons; 1908 Tunguska-sized, 50 meter diameter, 5 megatons[xxii], occurs about once per > 250 years; 140 meter diameter, 150 megatons[xxiii], occurs about once per 5,000 years; Apophis 270 meter diameter, 1 gigaton[xxiv], 1 in 45,000 chance of impact on April 13 (Fri), 2039 in or off-shore of Costa Rica; and 5 other PHOs with non-zero probabilities of impact in 50 years. Mr. Johnson then discussed the only major known NEO event in modern human history. The 1908 impact Tunguska, Siberia was at the lower end of the NEO threat, perhaps only 30 meters, and did not even reach the ground, but created a large airburst, and released sufficient energy to devastate an area equal to the entire National Capital Region (NCR).

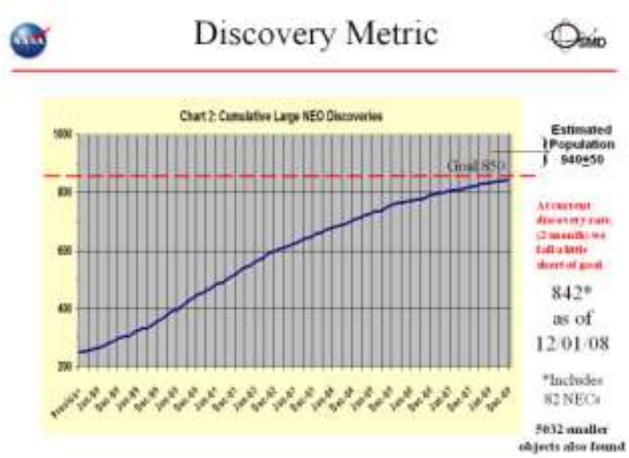


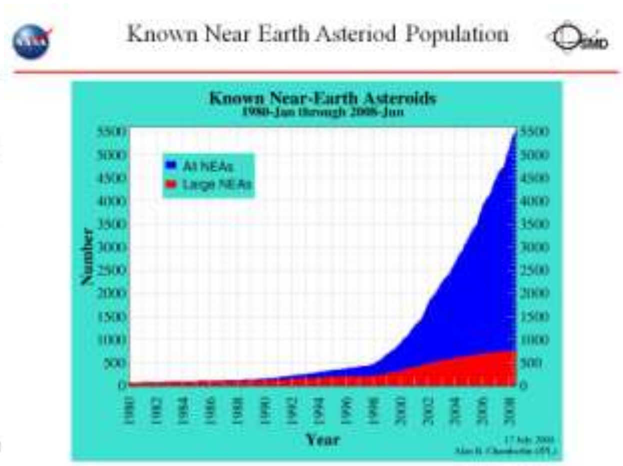
Mr. Johnson then briefed the participants regarding the history and current status of the NEO Observation Program, which began with a congressional request in 1998 to discover 90% of NEOs larger than 1km within 10 years. Those ten years have nearly expired and NASA will not quite reach this goal, but it is very close. Congress has since requested NASA expand its observation program to discover 90% of Near Earth Objects larger than 140m within 15 years, but provided no additional funding. He stressed that the current program has essentially reached the observation limits of the 1-meter telescopes which NASA has funding to operate; but that there are about 100,000 NEOs with diameters of > 140 meters; and about 1,000,000 NEOs with diameters of > 50 meters. Studies have shown a more optimal sensor for such a mission would be a ½ meter IR telescope in a Venus-like orbit.

The NEOO program at its peak (2005) consisted of nine telescopes operated by five search teams (Spacewatch, NEAT, LONEOS, LINEAR, and Catalina Sky Survey), the Minor Planet Center (MPC), and NEO Program Office at NASA JPL.

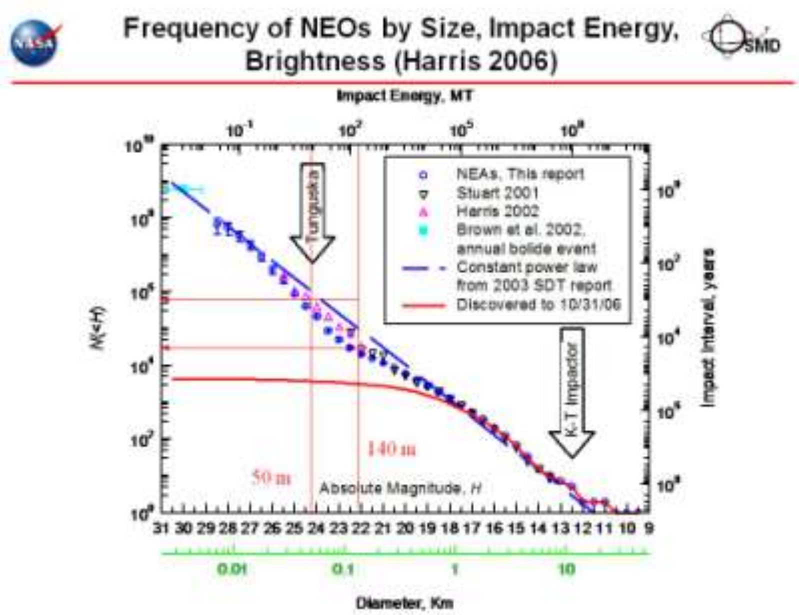


Mr. Johnson reviewed the discovery rate matrix, explaining that the discovery rate of large NEOs is tapering off and that the smaller telescopes are now less able to make meaningful contributions, particularly to the smaller, dimmer objects as small as 140m. Such objects require larger aperture telescopes with specific software to dwell on a particular part of the sky and subtract out the stars.





The above charts both show the success of the NEO program so far in approaching the expected population (of approximately 1000 large NEOs) as well as the large number of NEOs found once there was a program in place to look for them.



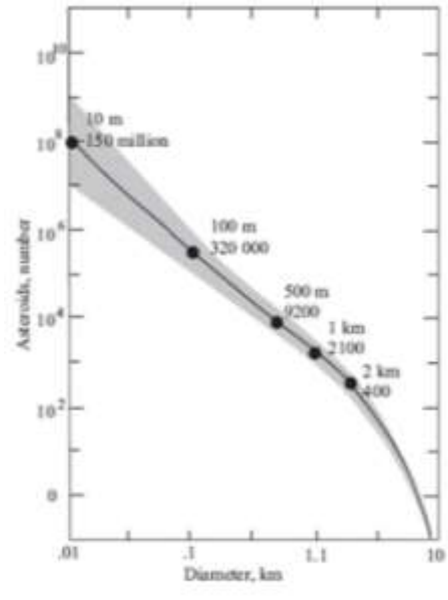
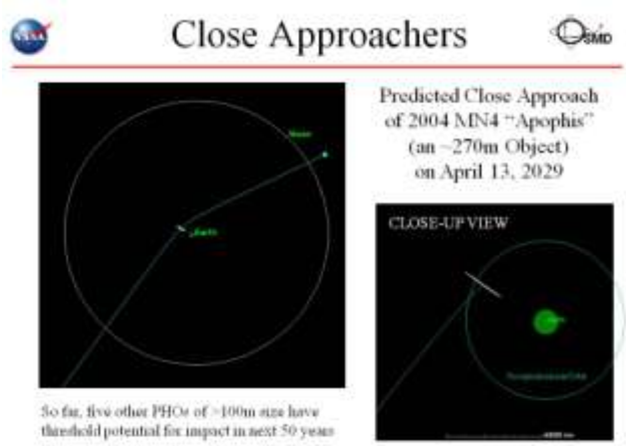
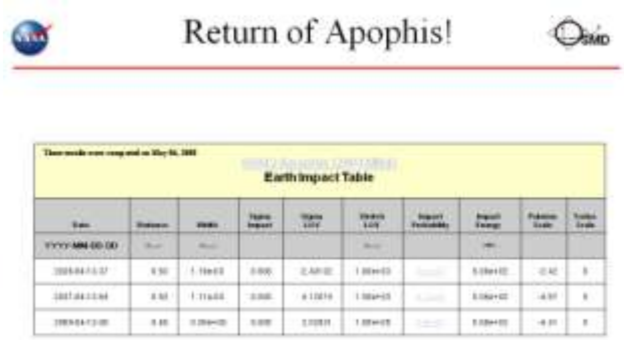


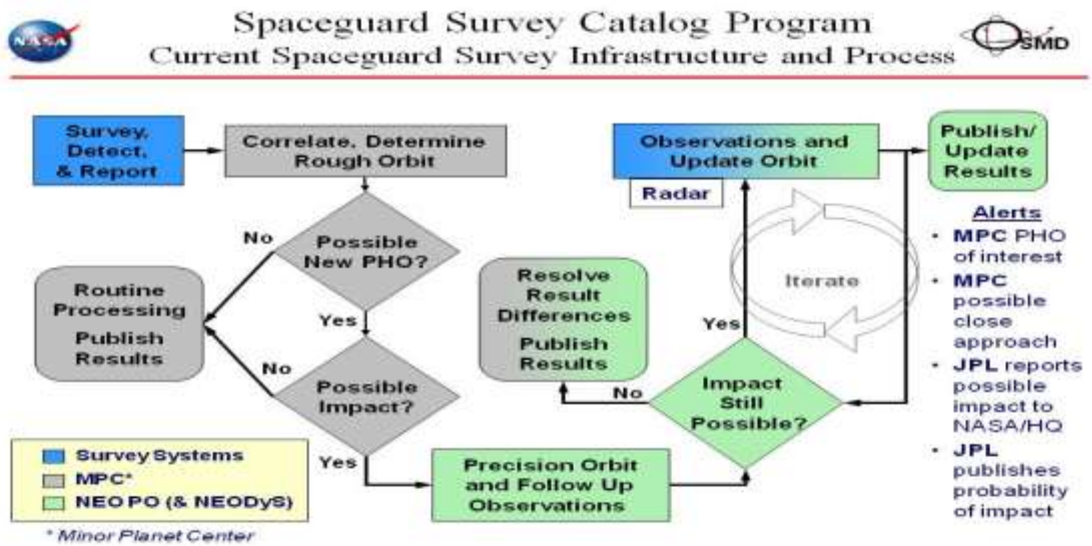
Figure 1. Estimated number of Earth-crossing asteroids. xxv

The briefing then turned to discuss the predicted population of NEOs which closely follows a constant power law. While the expected population of large NEOs is around 940 plus or minus 50, the population of NEOs 140m in size is expected to reach 66,000. Unless an object comes close enough to be measured with RADAR, the size and mass of an object are estimated based upon its brightness by assuming an average reflectivity (or “albedo”).





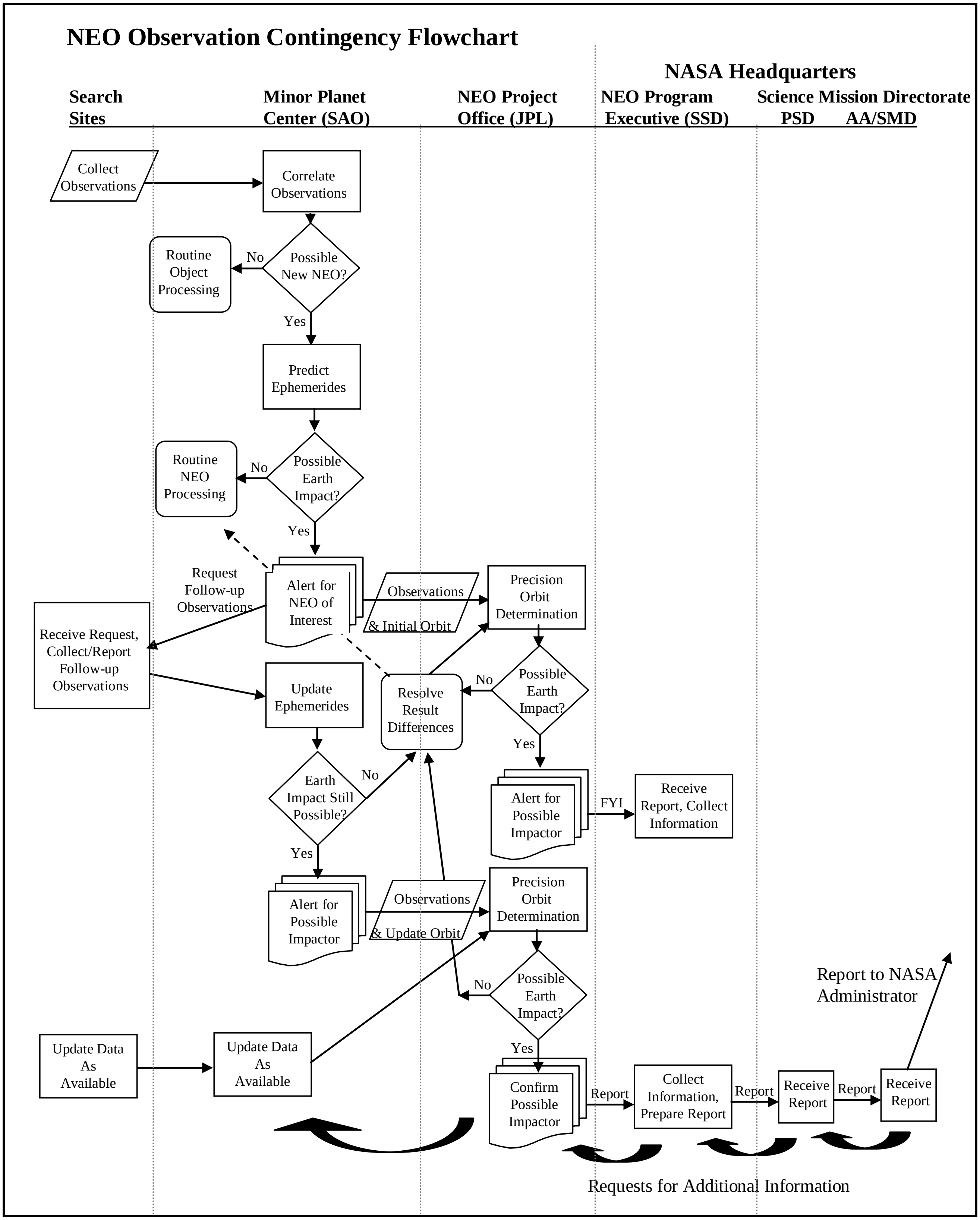
Of particular concern in the community recently is object 2004 MN4 “Apophis” which is a 270m sized asteroid. Apophis will come inside the geostationary orbit belt in 2029. It may pass through a gravitational keyhole at that time that could result in a strike on return to the Earth in 2036. While Apophis receives the greatest amount of press (and Congressional interest), there are five other Potentially Hazardous Objects >100m in size that have threshold (greater than one in one million) potential for impact in the next 50 years.



Mr. Johnson then reviewed the procedures of the Spaceguard Survey Catalog Program. It begins with the participating survey telescopes. The telescopes are not coordinated or tasked; rather they compete for the highest statistics (number of discoveries). The entire sky is not under constant surveillance. Surveying is complicated by the fact that you cannot survey from the ground except at night, cannot survey with significant moonlight, and cannot survey on cloudy nights. Coverage is further reduced by the limited field of view of the telescopes and the need to keep the telescope focused on a specific section of the sky long enough to capture enough signature of these very dim objects. The end result is that an area equivalent to the full sky is only surveyed approximately every 90 days – more than long enough for smaller objects to escape detection.

NASA does have an existing contingency procedure (in the form of a draft contingency plan) to deal with a possible impact and internal and external notification:

- **New Object**: As new objects are found by the survey systems (today these are all ground-based telescopes), they are passed to the **Minor Planet Center (MPC)**.
  - Today such an object is mostly likely to be found by the **Catalina Sky Survey**.
  - In a few years it may be **Pan-STARRS**
- **Possible PHO**: The MPC does a rough initial orbit calculation to determine if it is a Potentially Hazardous Object (PHO). If so, MPC issues an alert that there is a possible PHO of interest and issues circulars to generate additional observations.
- **Possible Close Approach**: If MPC's rough orbit determination suggests that an impact is possible, it issues an additional alert of a possible close approach to **NASA HQ**, and forwards the case to the **NASA JPL SENTRY** program for high accuracy orbit determination and circulars for follow-up observations by other systems.
  - While smaller telescopes and amateur astronomers are not able at this point to provide value in initial detection, once an object's position on the sky is known, they are often able to provide valuable follow-up observations.
  - Precision orbit determination and impact predictions are verified and validated by comparing results with a parallel trajectory prediction capability at the European NEO Dynamics Site (NEODyS).
- **Possible Impact & Probability**: If after precision orbit and follow-up observations do not eliminate a possible impact, NASA JPL sends an alert reporting a possible impact to **NASA HQ** and publishes the probability of impact and Torino Scale (consequence) evaluation.



NASA Methodology Discovery to Notification

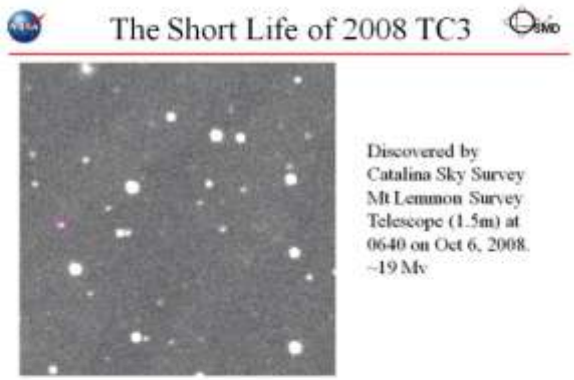
Notification Criteria: NASA also has guidelines for the release of information on Near Earth Objects. The current policy requires a release of information if a discovery meets the following criteria:

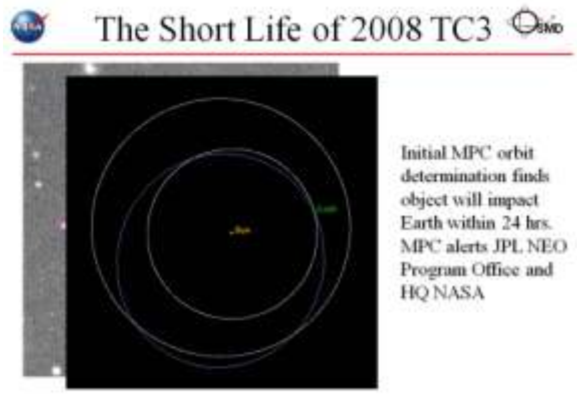
A. Discovery of any object with a predicted 1 percent or greater Earth impact probability whose entry into the Earth's atmosphere would likely generate a release of energy that could affect:
    - Populated areas
    - Bodies of water or land features
    - Satellites, airliners and other forms of transportation

B. Any object whose discovery and/or orbit prediction has generated inaccurate and potentially harmful media attention.

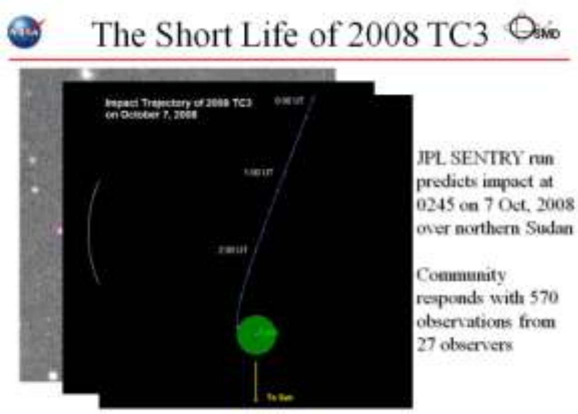
- **External Notification:** NASA policy mandates that the NASA's Office of External Relations (OER) directly notifies the following agencies.
    - The **National Security Council (NSC)/Director for Space Policy**
    - The **White House Office of Science and Technology Policy** (OSTP)/Assistant Director for Space and Aeronautics
    - The **National Military Command Center (NMCC)/ Duty Watch Officer**
    - **Joint Space Operations Center**, Vandenberg Air Force Base/Duty Watch Officer
    - The U.S. **Department of State/Deputy Assistant Secretary of State for Science**, Bureau of Oceans and International Environmental and Scientific Affairs
    - The U.S. **Department of Homeland Security/Operations Center Duty Watch Officer** (if the event will impact, or occur over, the territory of the United States)
    - **Office of Legislative and Intergovernmental Affairs** and the **Office of Public Affairs** regarding the release of public information will follow the same procedures used to coordinate all news media products. OLIA will notify congressional staff, if appropriate, after consultation with the Chief of the Office of Strategic Communications
- **Media Notification:** The current NASA PAO policy specifies that release of NEO contingency information by any NASA entity to the news media is the responsibility of the Associate Administrator for Public Affairs, in accordance with NPG 8621.1. Any contingency-related information or reports will be approved by the Associate Administrator or designee for the Science Mission Directorate (SMD) prior to public release. The policy designates appropriate spokesmen and coordination of accurate information.
    - NOTE: "The NEO **detection community conducts its work openly using Internet communications** and Web-based datasets, so it is **very likely that information on a new discovery of high interest will be available to the public before NASA can provide a news release**. Although it is important to expedite the news release process on a high interest object to the extent possible, it is of higher priority to be the definitive source for accurate information."

This process was recently exercised during a real world event, when an object was discovered within 24 hrs of impact.

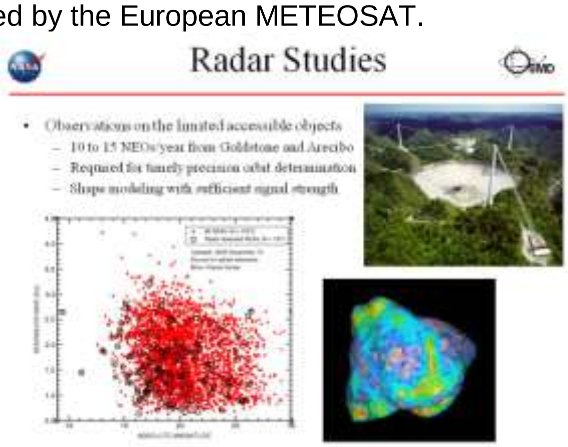




2008 TC3 was discovered by the Catalina Sky Survey approximately 20 hours prior to impact. (Note: this was a very dim, 2-5m sized object detected approximately 450,000kms from Earth!) Initial MPC orbit determination found object would impact within 24 hrs and alerted JPL program office and NASA HQ. JPL SENTRY program predicted impact at 0245 on 7 Oct 2008 over Northern Sudan. The community responded with 570 additional observations from 27 observers. An important point is that like 2008TC3, an object could be obscured from continuous observation by factors such as the shadow of the Earth (or brightness/washout from the Sun/Moon).



NASA predictions turned out to be extremely accurate in time and location. The object caused a 1.2 kiloton fireball in the high altitude, and lit up the skies as bright as the full Moon, which was observed by an airliner, and detected in the infrared by the European METEOSAT.



Mr. Johnson showed the first pictures of the atmospheric trail left by the small meteor and discussed participant concerns of how such an event might be interpreted over areas under high tension, such as the Middle East or India/Pakistan.

Mr. Johnson used the 2008 TC3 event to highlight a few important points:

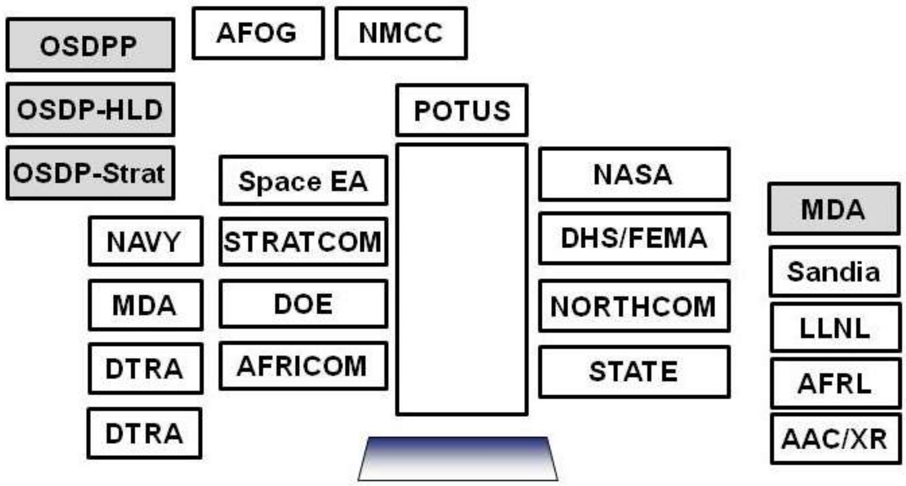
- This was a historic first: the first time that any impacting object had been discovered in advance and tracked to a predicted impact
- There was initial uncertainty about the accuracy of predictions, but the predictions turned out to be extremely accurate, and validates the confidence in NASA models for the purpose of contingency planning
- This was a chance event. In another week the Catalina Survey would not have been surveying because of the brightness of the full Moon.

A final topic of discussion was the role that Radar studies play in asteroid characterization and orbit determination. Radar cannot typically assist in discovering new objects, but data from planetary radars (Arecibo in Puerto Rico owned by the National Science Foundation (NSF), and the NASA JPL Goldstone facility in the Mojave desert) can very precisely determine the orbit of the object and provide rough images of the size and shape of asteroids if they pass within their view at close enough range. These planetary radar can observe and track objects out to 20 million miles and image them when within 5 million miles (20x the distance to the Moon).

6 INFORMATION PRESENTED TO PLAYERS

Prior to the event, players were given very limited information[xxvi] to mimic the actual state of knowledge of key officials in a real-world scenario, and allow the event to develop as information become available.

6.1 Assembly and Background Briefs

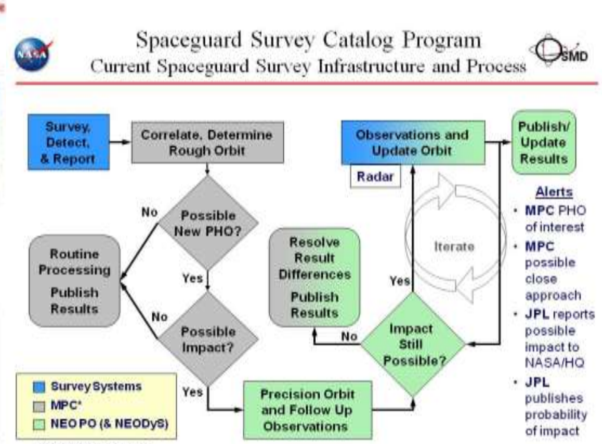


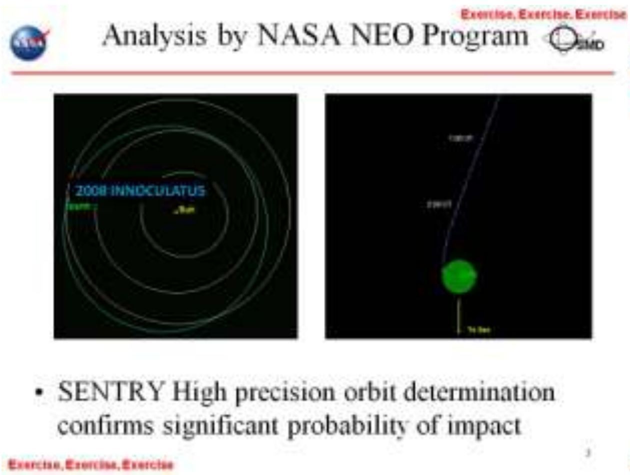
Player/Participant Room Layout for Exercise

Participants assembled as if they were a high level task force assembled by the President for this specific purpose, in a meeting chaired by the POTUS. All briefings and deliberations were given and received "in-role" starting with a background brief on the current state of preparedness and indeterminate organizational responsibility, followed by initial NASA Scenario brief and NEO background brief (see background section on real-world information).

6.2 Initial Situation Information (Impact -60 hrs)

The initial scenario brief from NASA to the players contained the following information:





Approximately 10 hours ago, an asteroid was discovered by the Catalina Sky survey which appeared to be a potential Earth impactor. It appears the point of closest approach would be in approximately 72 hours. Circulars (requests) were issued for additional observation. It appears to be of significant size (~300 meters) and NASA SENTRY program confirmed significant possibility of impact, leading to a current assessment of "5" on the Torino scale: "Close encounter with significant threat of regional destruction"

The orbital trajectory intercepts the Earth along a path that goes from the West Coast of the US across the CONUS through the Western African Gulf of Guinea. US Government Agencies have been notified via NASA Office of External Relations (OER) (See background section for description of this process), and exercise players were now participants in a short-notice assembled task force.

Players noted the following:

- **Most likely case is no warning**: A given telescope can only survey 2-3 weeks out of the month due to Moon brightness. It takes nearly 90 days to survey the entire sky and most objects of concern smaller than 1km are undiscovered. While happenstance detections like 2008 TC3 and the mythical asteroid in this scenario are possible, the most likely scenario at this time is an impact with no warning at all.
    - **Better Sensing:** NASA 2007 Analysis of Alternatives Study Report to Congress suggested that the ideal tool to speed discovery of remaining PHOs and retire the

risk of a strike with little or no warning would be a space-based ½ meter Infrared (IR) telescope in a Venus-like orbit

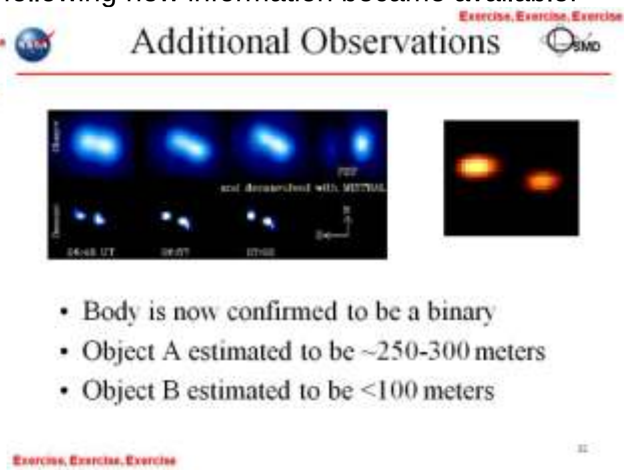
- **Single Points of Failure**: Several key players in MPC, JPL, and NASA HQ represent single points of failure
- **Latency:** 10 hours had already elapsed from discovery to notification
    - From notification to high precision orbit determination for 2008 TC3, the time from discovery to precision orbit calculation was approximately 8:30 minutes as reported in the media
    - MPC is not manned 24 hours. While mobile/pager, remote access capabilities do exist, realistic latencies could be as much as 14 hours
- **POTUS last to know:** The science based NEO detection community conducts its work openly using Internet communications and Web-based datasets, so it is very likely that information on a new discovery of high interest will be available to the public before NASA can complete discovery and trajectory verification and validation and speed notification to the POTUS and appropriate agencies. The POTUS will either know from NASA or from the media, but even if the POTUS hears first, the time delay before it is widely known in the media is likely to be exceptionally short.
- **Space Policy Coordinating Committee (SPCC):** The most likely initial group to take up such an emergency in real life would be a Space Policy Coordinating Committee, which could be convened in the White House situation room in 45 minutes. SPCC is interagency; NSC has lead, though it may delegate lead authority. What makes this event unique is that it is a space event in notification, but response is a ground event in execution, probably led by DHS & State.
- **Downstream Actions?**: While it is known that NASA followed its procedure and notified State, NMCC, JSPOC, with 2008 TC3, it is unknown what each organization did with that information. Players thought it was unlikely that a NEO event was captured in existing checklists/procedures. It does not appear that something similar to a Missile Event Conference was convened based on notification. Players wondered if knowledge of such an event constituted a reportable item to Russia under OPREP 3 reporting criteria.
- **SORTR/MOTR not Triggered:** Players commented on the need for a process like the Maritime Operational Threat Response (MOTR), a pre-designated interagency telecom to derive tactical responses and policy determinations as needed in response to an actual operation to address interagency crisis response. Players discussed that NASA communication of a potential impact does not currently trigger a Space Operational Threat Response (SORTR) or missile event conference.
- **Not Captured:** Players, including OSD and Joint Staff players confirmed that at present this event was not captured. There are no procedures in DoD for this contingency, and no plan in existence to substantiate any action.
- **Similarity to Nuke in City:** Players felt that NORTHCOM plans for response to an improvised nuclear device in a city probably had the greatest resemblance, but that it was purely reactionary, after the event, whereas this scenario called for action beforehand, and action that would need to be adaptive and ad hoc.

Players wrestled with the following:

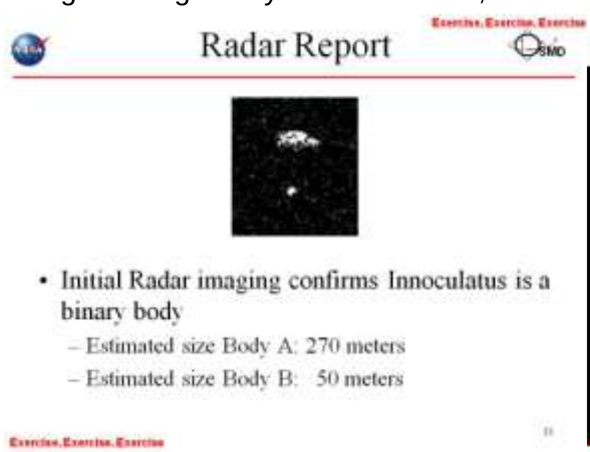
- **Every hour counts:** Time for action was already inside the timeframe to begin coastal evacuation preparations, and “every hour counts,” but at time of notification, the error ellipse was so large that it included both Atlantic coasts, and a large swath of the CONUS as well as Africa.

- **When will I know more?:** A deficit identified in this workshop was the lack of models/tools for NASA to articulate to national decision makers when new information and observations would be available (windows of observation, types of observation), and how the error ellipse was likely to change over time.
  - **12 hr wait:** Depending on response, it is likely officials would have to wait 12 hrs from initial discovery before they could get a more accurate impact prediction
  - **Need to understand how error ellipse collapses:** Decision makers had a very serious need to understand how uncertainty would be reduced and when.
- **Greater Danger in Mishandling:** There was greater danger in panic and a mishandled evacuation.
  - There was clearly a need for a single authoritative, credible spokesman
  - There was clearly a need for tools which would clearly communicate graphically and geographically the danger to decision makers and then to the public
  - Players requested that impact track/ellipses be overlaid on population density maps
  - There is a need for a capability to rapidly identify optimal critical evacuation paths
- **Local Authorities & Press banging at the door**: While the Federal Government did not have any quality advice to give, the Media, States, and local authorities would be asking.
- **State & Local Officials won't wait for Uncle Sam:** Local and State Authorities would be getting information from the media and would need to make decisions immediately—the Federal Government emergency response would be in support to the Governors.
- **Must Balance Risk of Action and Inaction:** Failure to suggest a plan might result in rash actions by others and the presence of alternate "authorities" such as in the press. Suggesting a plan too early might create disruptive movement and counterflow.
- **Chasing own tail with false options:** Players wasted significant time inquiring into technical options for literally last minute deflections that would have no hope of success.
  - Could MDA fragment it with ballistic missile interceptors? No, this is equivalent to shooting a bullet at the mass of a car expecting to stop it
  - Could STRATCOM/AFSPC launch an ICBM to deflect? No, ICBMs only have sub-orbital capability and no required seeker-heads, but interceptions must occur much further away from Earth to allow any success at deflection.
  - Could STRATCOM/AFSPC launch an ICBM to disrupt it? No, ICBMs only have sub-orbital capability and no required seeker-heads, and a disruption this near impact would be too late to reduce the amount of mass hitting the biosphere, and would likely just "make radioactive rocks" with less predictability of where they would strike
- Some players expressed concern that a system so open might be able to be spoofed. Discussion suggested that this could be possible, but only by a fairly sophisticated actor, and the openness also likely leads to rapid detection of the spoof attempt.
- **Another "set of eyes"?:** Players inquired about back-up/confirming calculation, and were informed there exists a similar capability in Italy (NEODyS), but it is not robustly supported.
- **Today's Military Eyes Can't Help:** While AFSPC and NRO both possess assets (both ground and space-based) that in principle could provide additional observations to reduce uncertainty, they are not currently equipped with the necessary capabilities, such as the software required to detect and track objects not in Earth orbit.
- **Two Major Problems:** Participants felt there were two major concerns. First, an immediate need to determine how soon, where, and when to notify every affected country, offer HUMRO assistance, and prepare federal agencies for homeland reaction. Second, in the longer term, there was a need for a policy on how to respond, such as international agreements, at least with spacefaring nations, as well as for development of relevant deflection technologies.
- **International Partners?**: Some players felt that other spacefaring nations, particularly Russia would have significant capabilities to bring to any deflection effort.

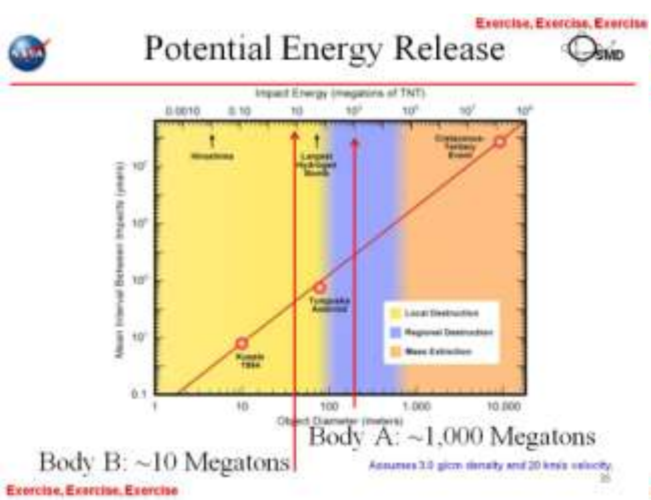
As the players continued their deliberations, the following new information became available:

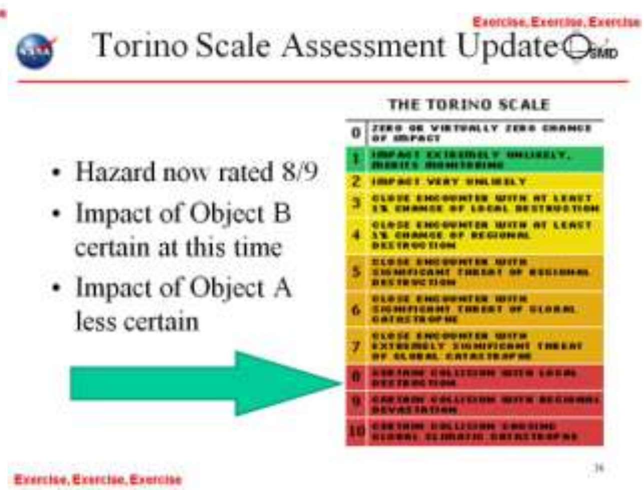


Subsequent observations by NASA assets suggest that the object was in fact, a binary object consisting of a large body 250-300 meter, and a smaller object, less than 100 meters in size.

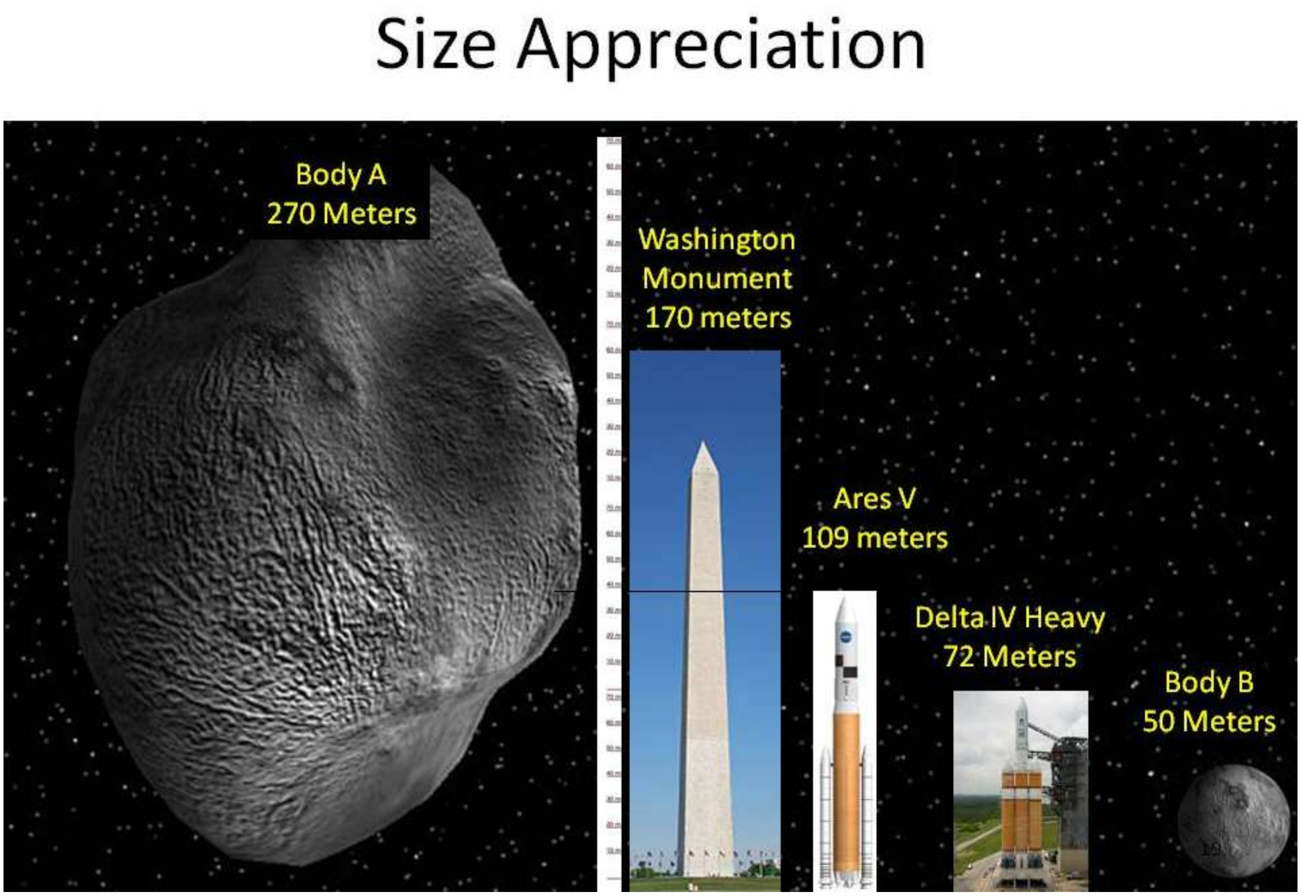


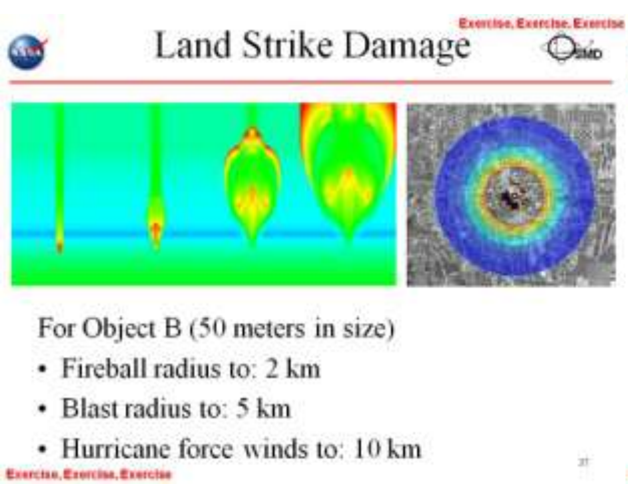
Initial radar imaging confirmed that the asteroid is a binary body. High precision orbit determination confirmed the potential for impact along the plane of orbital intersect.

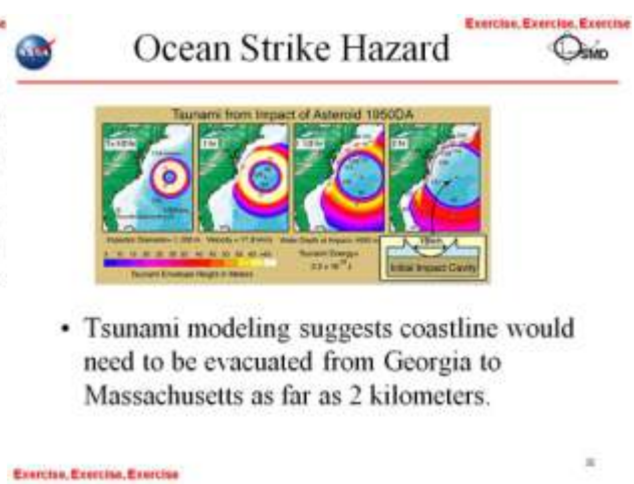




The larger 270m body would release 1,000 Megatons TNT equivalent impact energy, while the smaller would release 10 megatons. Torino scale was updated to 8, “Certain collision with local destruction” for the smaller object.

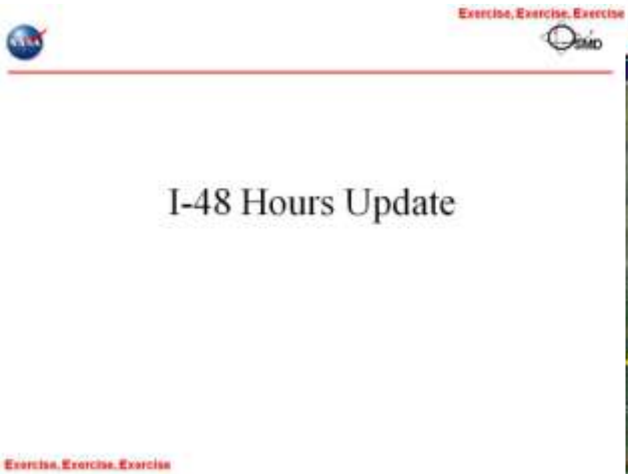


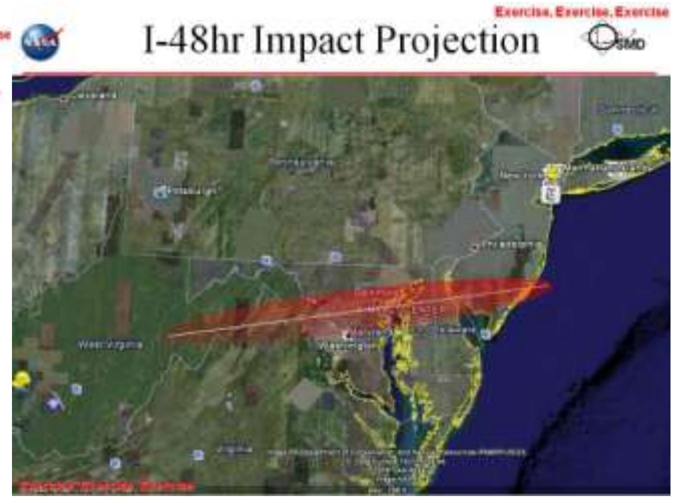




The smaller object would significant damage on land or on sea. Mr. Johnson reviewed the blast and cratering modeling from the University of Arizona.

6.3 Update at Impact-48hrs





Twelve hours after initial notification, NASA was able to provide a significant update. They were able to correlate the current sighting with a previous "found observation" seven years ago from the "lost asteroid list," as well as new observations which greatly reduced the error ellipse for both bodies.

The larger body, Object A is thought to have a mass of 13.4 metric tons and will impact Earth's atmosphere at 17km/sec slowing to 12-13km/sec at ground impact and is projected to release 252 Megatons at impact. It appears to be a loosely held together "rubble pile".

The smaller body, Object B appears to be a more solid "iron" (8,000 kg/m2), and will release some 10 Megatons on impact, slightly larger than Barringer crater. Its impact probability has been narrowed to 50km wide by 500km long error ellipse with 3 sigma accuracy that the impact will fall within it.

The smaller body would strike near the East Coast, with a small possibility of water impact, and a significant probability it might threaten the National Capital Region (NCR). The larger body looked like it might strike in the Gulf of Guinea or Nigeria.

University of Arizona cratering experts offered the following regarding the smaller body for a land impact:

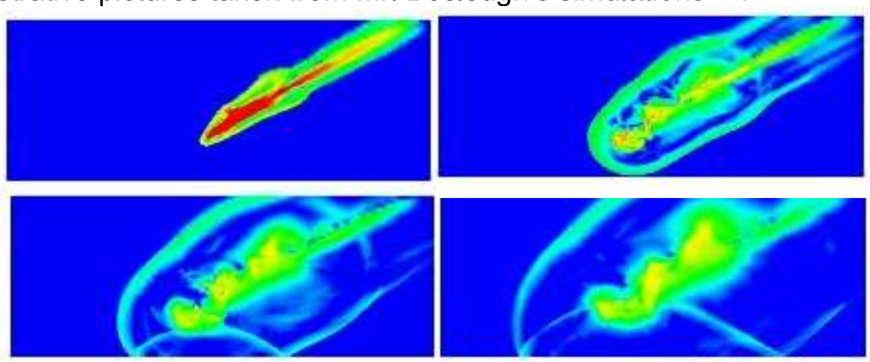
- 1.5 km diameter crater 150m deep
- At 2.5 km - Absolute devastation with 100% casualty from fireball
- At 5.0 km - 370mph air-blast and equivalent to 5.2 on Richter scale earthquake. Estimated 66% casualty rate if not warned to seek adequate shelter. All food frame houses, most forests/trees, and majority of multistory buildings would be destroyed
- At 10 km - 120 mph Hurricane Force winds. 20-25% casualty rate if not warned to take cover. Heavy damage to wood frame houses.
- At 15 km - 40 mph winds
- Total area: 1,000 square kilometers (10km x 10km) damage and casualties. If no warning, casualties may exceed 150,000 in the densely populated metro areas.

6.4 Participant Discussion at I-48hrs

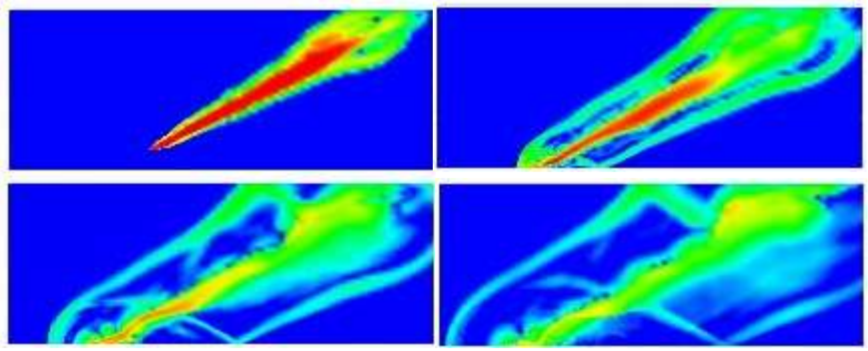
Mark Boslough from Sandia added considerably to the discussion pointing out several important additional considerations:

- **Certainty in time & location, but not yield:** We can have high confidence (90%) in the time and location of impact, but not yield. Yield may vary significantly.
  - Our models have little real-world information to compare to for validation.
  - Without radar, the size is estimated based on albedo. As a rough correlation, a halving of albedo equates to an increase factor of 8 in yield.
- **Dual Epicenters:** There is more than one “epicenter” to consider. There is the center based upon the actual impact (ground shock), but there is also another center (at some distance along the track before impact) based upon where the majority of impact energy is deposited in the atmosphere (airburst). There is always some airburst component.
- **Terrain Effects:** Actual blast effects are strongly influenced by local terrain (ridges, valleys), which are not modeled.
- **Persistent Firestorm:** The fireball generates persistent vortical / mushroom like patterns hotter than the temperature to melt rock.
- **Impact Ejecta:** Impact ejecta is significant and may throw significant size boulders as far as 10km
- **Non-circular Blast Pattern:** Because of the displaced blast center and vortical patterns, the blast and fireball pattern is not circular, but more like “butterfly” or a D with rounded corners.
- **Space Plume:** The penetration through the atmosphere creates a region of high temperature low density air surrounded by cold air. This functions like a rocket nozzle channeling the fireball plume out hundreds to thousands of kilometers into space, depending on the impactor’s size. This plume of supercharged gas could cause significant effects or damage to satellites in LEO, and effect that has not been much studied. (This was actually observed when Comet Shoemaker-Levy 9 struck Jupiter in 1994).
- **Uncharacterized Electromagnetics:** There is reason to think that the impact and fast-moving plume may generate significant electromagnetic effects which are uncharacterized. Players expressed concern that EMP-like effects would cause a regional black-out.

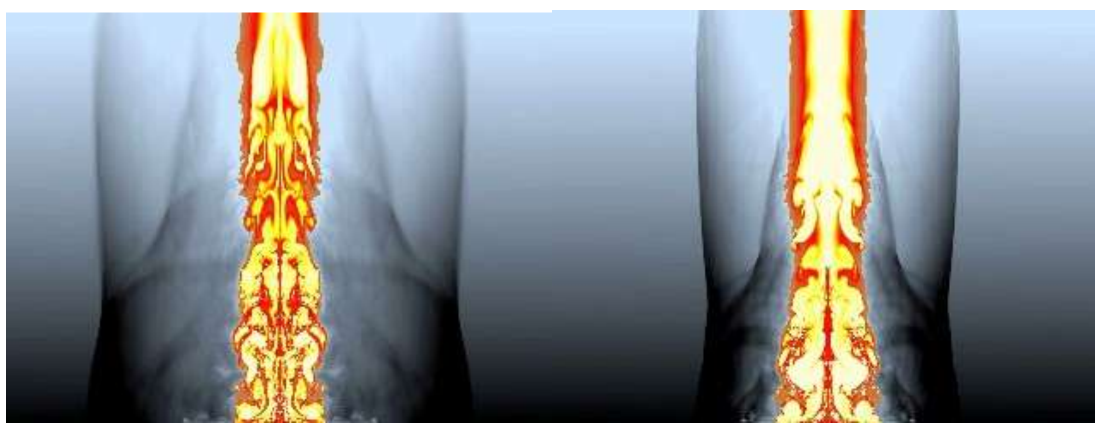
Below are some illustrative pictures taken from Mr. Boslough’s simulations[xxvii]:



Example simulation of an airburst (note all impacts will have some airburst component)



Example simulation of ground impact. Note displaced center of pressure / blast wave.



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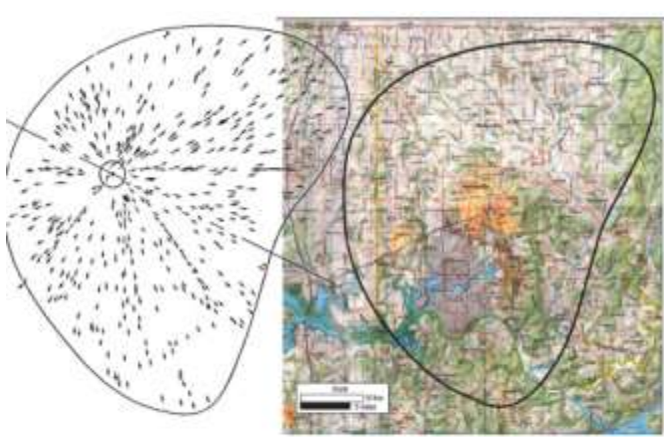
Example simulation of "pillars of fire." Note persistent firestorm vortices at several levels including ground (hot enough to melt rock). This plume of super hot gas & particulate matter (which could be generated by objects as small as 30m) can reach hundreds to thousands of miles into space and affect satellites. Violence of plume may last as long as 15 minutes



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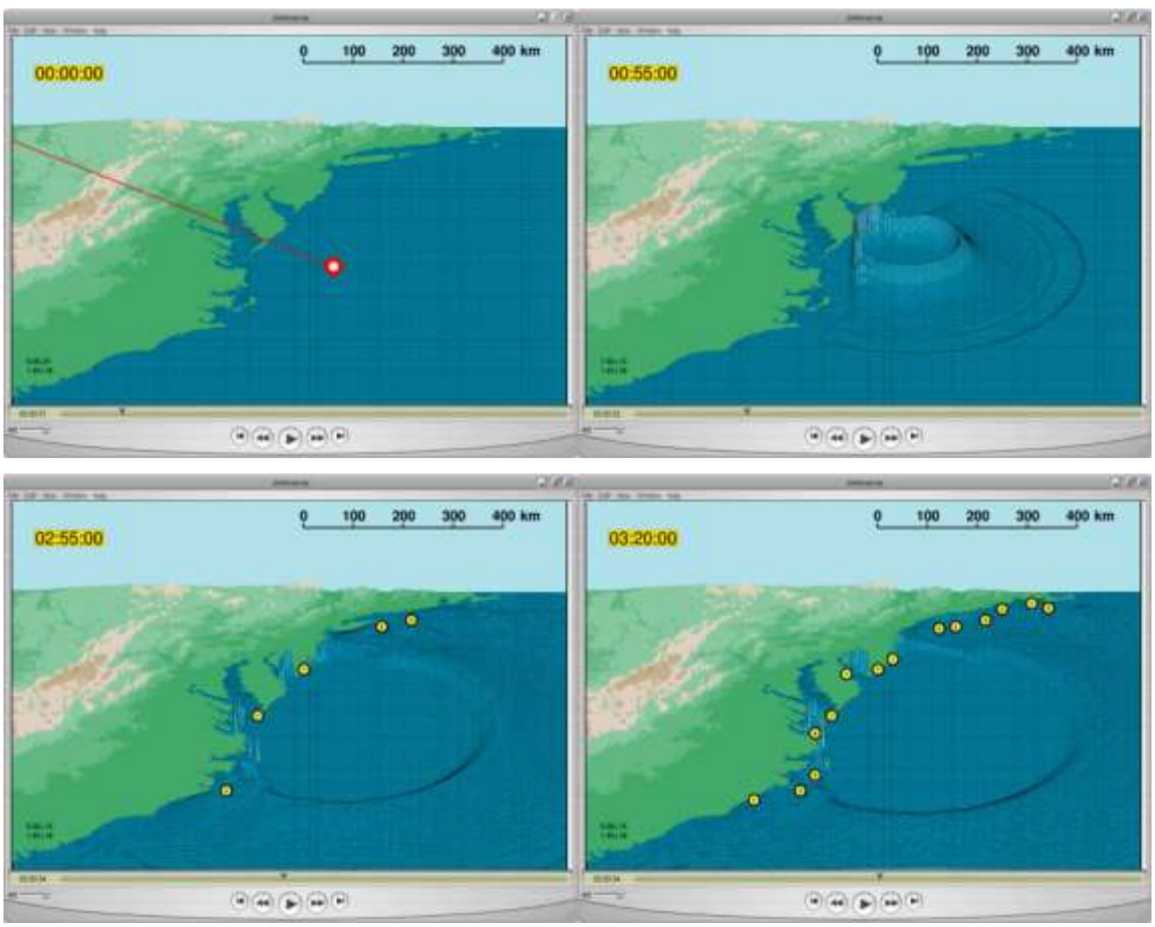
Non-uniform, non-circular blast pattern, as seen in the Tunguska event and validated in supercomputer models; Tunguska event overlaid on Washington DC Area.

Other players also brought out the following points:

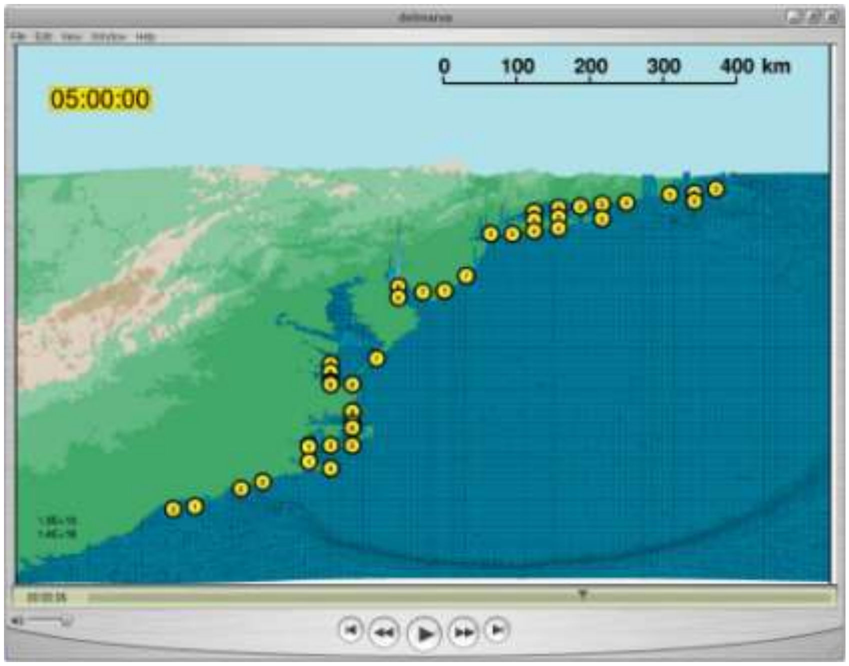
- **Ash Effects**: The threshold of environmental change due to ash deposition is not known. Significant ash from volcanic eruptions have caused changes in growing seasons and hazards to air traffic.
- **Debris Plume:** There will be a significant plume, affected by actual winds, which has not been be modeled, but could be modeled in DTRA's HPAC program.
- **HAZMAT:** Depending on where the strike took place, it could strike chemical or nuclear facilities, etc., which would also mean the presence of hazardous material in the plume. However, the location of homeland critical infrastructure is supposedly well tracked and characterized by DHS and state officials through a program called HCIP.

Because both impacts might result in a water impact, tsunami effects were considered.

The following images were taken from a simulation supplied by Steve Ward at University of California, Santa Cruz[xxx] to help participants better understand the effect of a water impact. Note that both the terrain and wave height are greatly exaggerated for display purposes, and wave heights greatly exaggerated over terrain. The numbers in yellow are the height of the wave in meters when they meet the shore, which is up to several hours after impact and related to its distance from shore.

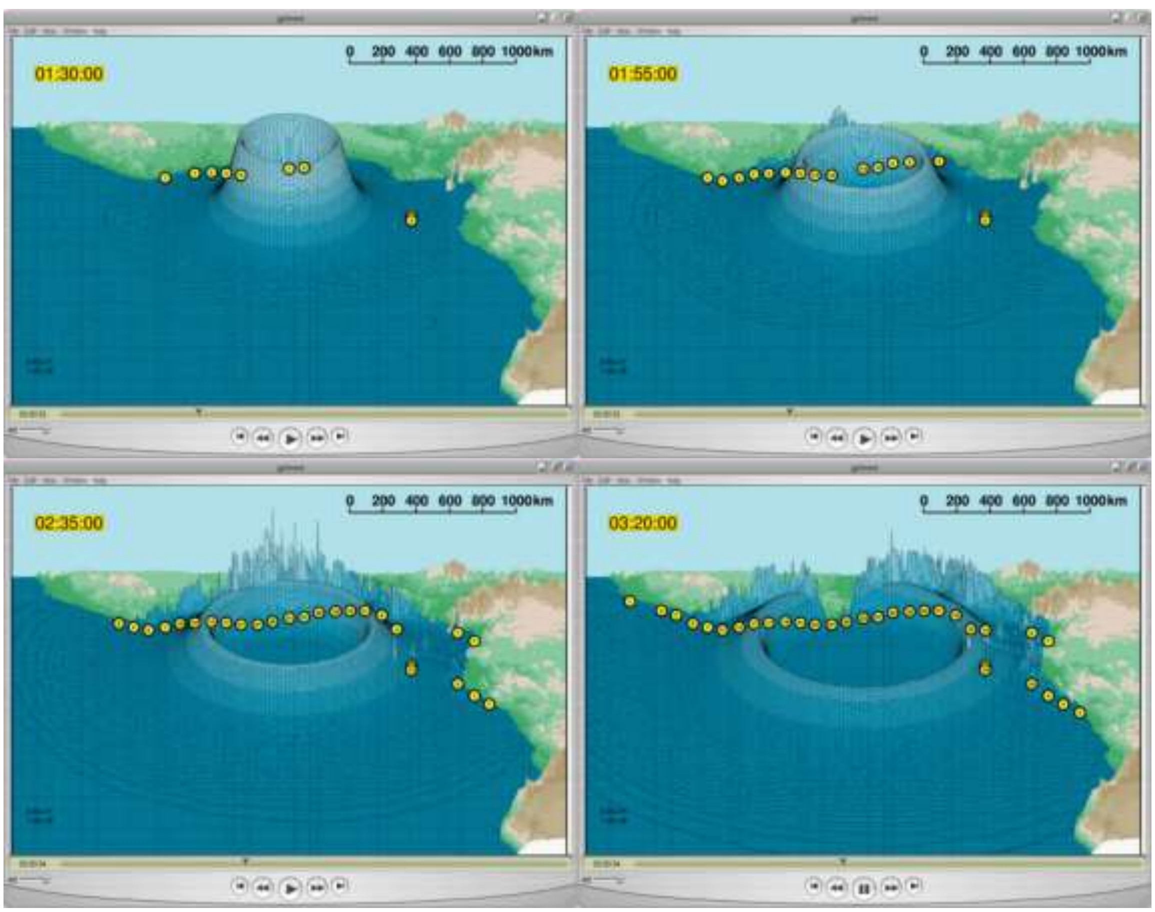


This simulation shows the progression of an impact-driven tsunami off the East Coast

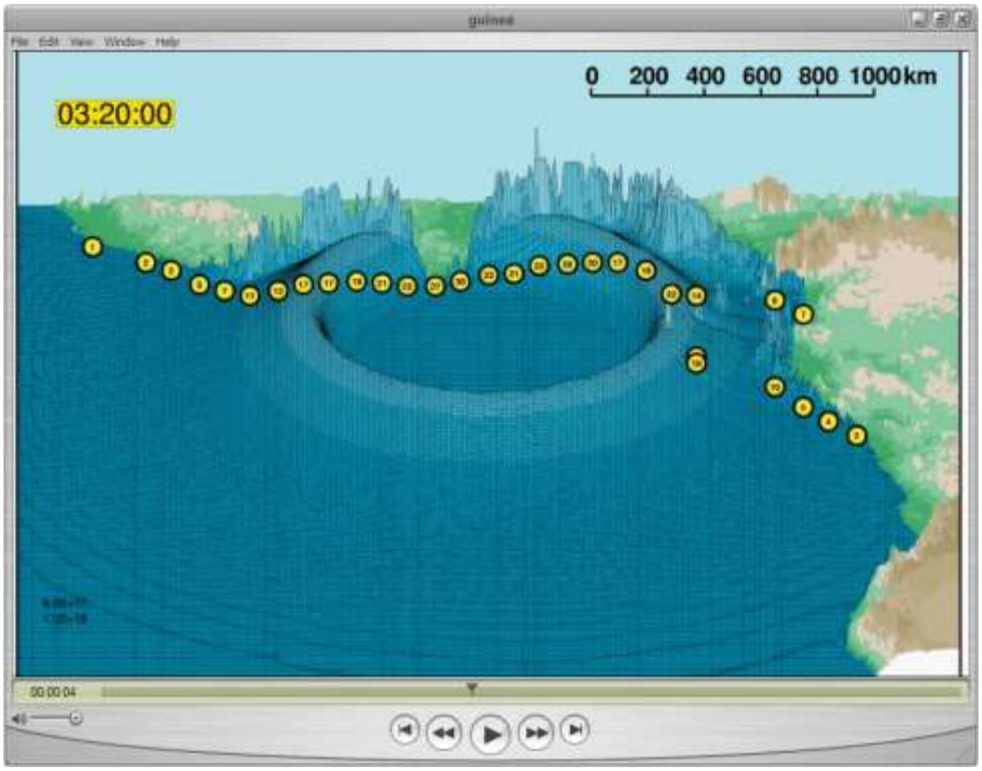


Note that even for a small 50m impactor off the DelMarVa Peninsula; it would have significant effects for a significant portion of the US East Coast.

The larger body, approximating the size of Apophis, would have much more significant effects.



This simulation shows the progression of an impact driven tsunami in the Gulf of Guinea



The devastation caused by an impactor of this size in an area of this population density would be truly horrific. Given the short timeframe and large number of nations to notify and high coastal population with limited infrastructure, evacuation would be very difficult. The region would also suffer a tremendous loss to coastal oil & gas infrastructure and sea ports.

Luckily the effect on the other continents is very small, with waves staying below 2 meters in Brazil and 1 meter in CONUS. Participants were concerned about Lajes and Azores, for which no data was provided.

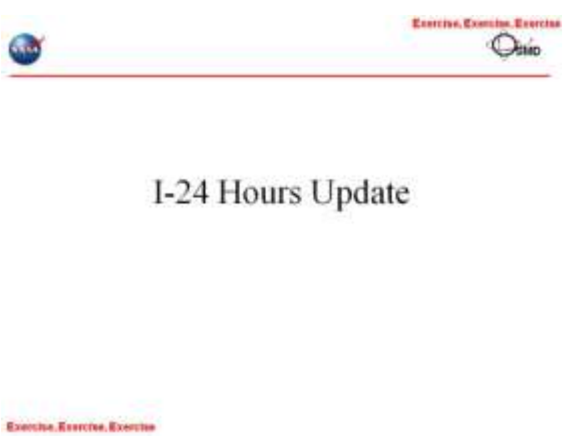
NOTE: Players felt NOAA might have additional capability to offer with regard to water impacts.

Participant discussion emphasized the following:

- **No Tools for Quick Assessments:** There is nothing like the above tools in any of our command centers for quick assessments.
    - DTRA reachback cannot do more at present than blast circles and plume forecasting
- **Unknown Global Threshold:** We do not know the threshold for global climate change, thought to be somewhere between 1/2km to 3km, but noted again by comparison that large volcanic eruptions can have very significant effects
- **Continuity of Government (COG):** A strike near the NCR carries with it very significant Continuity of Government (COG) concerns, and decision-makers would likely have to move
- **Alternate C2?**: Since FEMA, DTRA, NMCC, AFOG, and Space PCC are all in this area, what alternate command post would take over?
- **Value of HCIP Gold:** Existing database & geospatial tool not only contains information on potentially hazardous sites, but also on hospitals. Dept of Health & Human Services also has significant information, as does the TSOC at Hurlburt.

- **Each State make own decision:** States would not / could not wait on Federal government. States have authority in natural disaster response, and federal government is in supporting role, waiting for requests for assistance. The federal government must be invited in.
- **Self-Checked:** NSC noted that FEMA is further along than most think, but that our response is limited by Constitutional issues, and separated authorities in Titles 10, 32, 50, etc. Arguments fall into two camps: The first: This is a national emergency, and we will do what we need to protect America lives and property. The second: No you can't, there is this piece of paper called the Constitution that prohibits over-reach by the government.
- **Who is in charge?**: Trusted data would need to be disseminated from DHS, but the most significant conduit would be directly from POTUS to governors.
- **Consistent messaging:** The need for one "talking head" to support the states with trusted data
- **Airlift Posture:** With such a short timeline, would airlift might be one of the few options for evacuation?
- **AFRICOM just has phone #'s:** Players noted that at this point in time AFRICOM has no real forces, just phone numbers, and the most they could likely do is offer advice and pre-position response airlift in North Africa.
- **Nigerian Oil Refineries:** Players considered the economic and environmental effect of a tsunami on the Nigerian oil refinery infrastructure.
- **Tsunami Warning System:** Players noted that there does not appear to be a tsunami warning system in this area
- **Various levels of Planning:** States have very different levels of preparedness and planning for various contingencies
- **Conservative Worst Case:** There was a perceivable difference in how those in the science community and those in the defense-security community assessed risk, with those in the latter arguing that faced with uncertainty you take actions as if worst case.
- **Real-time software apps:** The requirements of strategic communication require software applications that can generate meaningful explanatory communication and decision aids in real time.

6.5 Update at I-24hrs



At I-24hrs, a real-time update was provided by Don Yeomans of the NASA JPL NEO Program Office. By this time, the impact projection had collapsed to a 1km x 2km error ellipse for the smaller body in a suburb of Washington DC.

6.6 Participant Discussion at I-24hrs

Impact modelers from Sandia and LLNL asked the following questions:

- Are you sure it is Iron and not stony, as sometimes have similar spectroscopic qualities? No, but 70% confidence.
- Can potential skipping on atmosphere be eliminated? Yes, entry far too steep for skipping.
- Could you tell total mass from binary or radar? Yes radar imagery and period allowed high confidence mass estimate, with bulk density of 8g/cc.

Evacuation: Evacuation was high consequence. If not handled correctly could have bottlenecks. Players thought that while actual movement might be able to wait for higher confidence, the plans must be in place immediately and communicated widely.

Confidence: Scientist argue for best estimates, engineers argue for worst seen. Decision-makers would likely wish to take error ellipse, and wrap it in the effects areas and evacuate based on the outer limits.

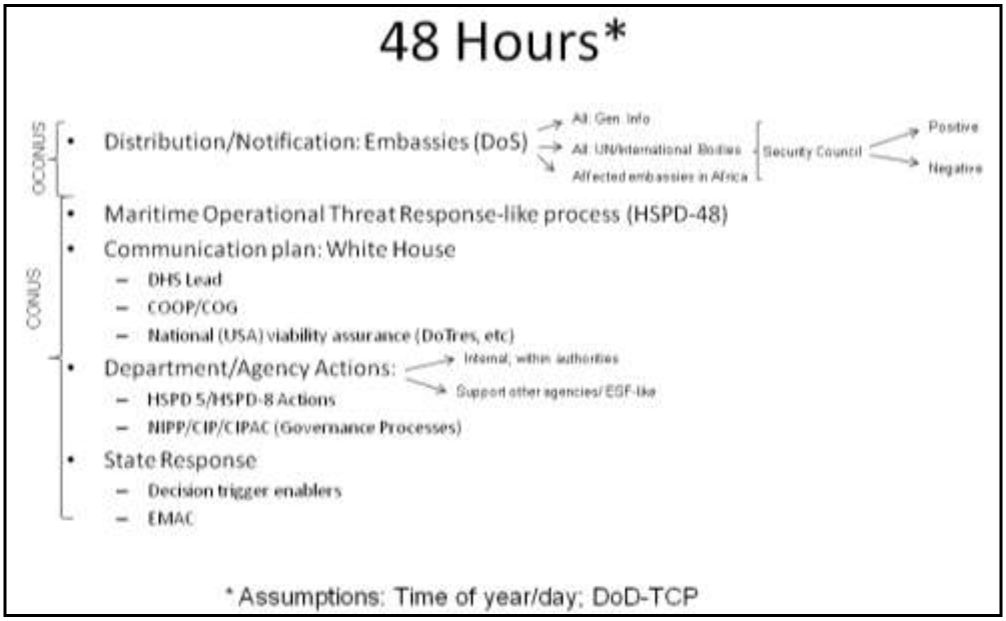
Power grid: Concern over electromagnetic effects potentially taking out Eastern power grid.

- Evidence of disruption from much smaller Tangus lake meteor in 2000.
- Nuclear Crater “P&E program” with 105 kt buried nuke “Sudan Crater” 1000ft deep saw no big Gamma pulse
- EM effects of plume: Very good antenna with high temp plasma.

LEO Sats: Concern about plume ejecta through ionosphere to affect satellites. Even in LEO, plume delivers 3km/sec particulate matter with condensation. Violence of the plume would last at least 15 minutes.

SCATANA: Should air evacuations be necessary, or hazards to air navigation (to include ash and EMP-type effects), NORAD may choose to put SECURITY CONTROL OF AIR TRAFFIC AND AIR NAVIGATION AIDS (SCATANA) into effect to control air traffic entering, departing and moving within the US areas and coastal approaches.

6.7 Disaster Response Team Outbrief:



Disaster Response / Notification Team Output Briefing Slide 1

The disaster response team divided their actions into CONUS and OCONUS.

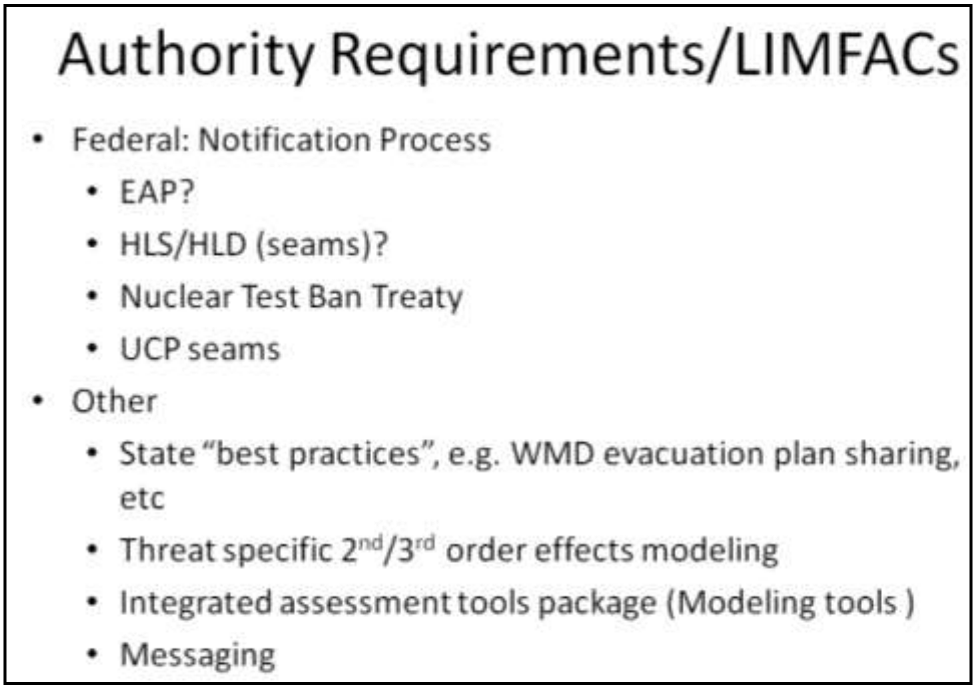
For OCONUS, the Department of State had lead, and would use existing methods ("All Gen Info" and "All UN/International Bodies") messaging system, as well as direct alert through messages of all affected embassies in Africa.

For CONUS, the team would use a Maritime Operational Threat Response (MOTR / HSPD-48) like process to minimize damage to maritime vessels and ports. They would establish a White House communications plan with DHS as lead, and ensure Continuity of Government (COG) and supporting plans (Continuity of Operations Plans (COOP) were implemented. United States viability assurance (including Department of Treasury) actions were also considered. They would task all departments and agencies to take appropriate internal action within their authorities and support other agencies. They would ensure readiness to assist States in their response, establishing decision triggers.

Particular Department/Agency Actions included relevant actions associated with:

- Homeland Security Presidential Directive 5 (HSPD 5), Management of Domestic Incidents[xxxi] which lays out the interagency process with respect to domestic response
- Homeland Security Presidential Directive 8 (HSPD 8), National Preparedness (to terrorism and "all-hazards")[xxxii] which specifies planning, preparedness, and training responsibilities
- National Infrastructure Protection Plan (NIPP)[xxxiii] which sets roles, responsibilities, goals and objectives with respect to Critical Infrastructure (CI) and Key Resources (KR)
- Critical Infrastructure Protection (CIP)
- An make use of / establish governance through the

- Critical Infrastructure Partnership Advisory Council (CIPAC) federally
- Emergency Management Assistance Compact (EMAC), which allows states to flow resources to other states (Fire, Police, Emergency Management, Comms, etc.) when hurricane, civil unrest, or other incidents arise



Disaster Response / Notification Team Output Briefing Slide 2

The disaster response team was concerned with what Emergency Action Plans (EAP) would be run, and where there might be seams in Homeland Security / Homeland Defense, as well as seams in the Unified Command Plan.

They further suggested that states & cities could share their best practices, such as WMD evacuation plans. They felt there was a need for 2nd & 3rd order effect modeling, and a definite need for an integrated assessment package of modeling tools, with a practiced and clear ability to conduct messaging almost immediately after notification.

7 MITIGATION / DEFLECTION TEAM:

The intent was to develop a full mission profile for deflection of both the larger (270m) and smaller object (50m) to serve as a comparison template. This turned out to be too ambitious. Restrictions on NASA travel to conferences meant that certain expertise and mission planning capability was not on hand, and half-a-day proved far too short a time to fully work both problems. Given the short time, the team chose to focus on the more challenging problem of the large object.

However, the Mitigation / Deflection portion was very successful in capturing the major considerations and type of thinking of scientific and national security personnel likely to actually be involved in the process, and in selecting the overall approach. With the approach selected, there are several individuals (Dr. Bong Wie, Dr. Brent Barbee, Warren Greczyn, Robert Adams) with the requisite skills to flesh out the actual plan with timing, system mass, launch dates, launch vehicles, etc. Future scenario planners might consider doing this in advance.

The Deflection team was told that 2008 Innoculatus had identical orbital elements to Apophis, with a 7 year synodic period (period between closest approaches with Earth).

7.1 Participant Discussion:

Summary notes from the deflection team, courtesy of 1Lt Christopher Engelhardt

- **Exo-atmospheric Fusing:** It was noted that there is a need to develop an appropriate fusing system pertaining to nuclear mitigation systems. Current fusing mechanisms are designed for use in the atmosphere and will need modification and testing for use in space.
- **Determine Launch Windows:** Discussed was the need to determine the number and frequency of launch windows that are available for mitigation options. The point was made to utilize each available launch window for multiple missions.
- **Treaties and Timely Notification:** It was mentioned that international treaties become important as well as the need to inform the international community in a timely and efficient manner of potential hazards.
- **Avoiding rubble dispersal:** There was a large discussion on mitigating a rubble pile threat and not causing it to disperse. This information came mostly from the test cases performed by Dr. Dearborn. In his test cases, a momentum change greater than a critical value caused some pieces of the rubble to gain escape velocity which dispersed some of the mass but left other parts with an unchanged velocity. In this situation, it was recommended to use small velocity changes (on the order of 1 cm/s) to keep the rubble pile intact. X-ray irradiation standoff bursts are able to impart this momentum change effectively. It was also noted that the velocity change must be applied along the direction of motion to have the most desired effect. The dispersing of a rubble pile body is still a needed area of research.
- **Multiple Options:** The need to produce a large variety of impact simulations was noted. It was agreed that there would not be a single chosen mitigation option of small velocity changes or fragmentation, but rather several plans needed to be delegated to specific organizations simultaneously.
- **Mass, Yield, Orbital Mechanics & Launch Opportunities:** The need for further research on the launch mass to energy yield of certain mitigation options was mentioned. In a real time scenario, this would need to be compared to the orbital mechanics of the specific threat and launch window opportunities.
- **Largest possible yield**: A question was asked: Why not simply design a mission with the largest possible yield that could be applied to any scenario? This was asked in the general

case as well as pertaining to the specific 270 m role-playing scenario. Again, the concept of dispersing a rubble pile versus changing its velocity while keeping it entirely intact was discussed.

- **Need for Orbital and Composition Data:** Noted was the need for orbital parameters as well as composition parameters to give a better probability of mission success. However, orbital parameters are much easier to determine than composition parameters. It may not be possible to determine composition until much later after the asteroid's discovery.
- **Pre-cursor sensor missions:** A critical mission piece is to obtain compositional data. Thus, a sensor mission is a required tool but at a high cost. Flyby versus rendezvous sensor missions were discussed in the context of penetrator impact effects. There is also a redundancy need for a sensor mission. Orbiting around the Near Earth Object (NEO) can give fairly reliable density information due to measurements of its gravity field.
- **Who will lead effort?:** In reference to the XCON process, the question was asked: Who will lead the process of giving a recommendation to the president? Who in our own government (international cooperation would likely be addressed later) do we need to have fluid continuity of government? Best candidates were the National Aeronautics and Space Administration (NASA) or the Defense Threat Reduction Agency (DTRA).
- **Multiple plans in parallel:** When working on the scenario tasks, it was noted to be important to develop multiple plans over a timeframe. This allows for parallel options with flexibility to change as information is gained.
- When working on the system architecture portion of the scenario tasks, two important aspects were to send out an ISR scout as a parallel discovery effort.
- **Who has authority to pull launches?:** Relevant questions that did not have clear answers were: Who has the authority to pull space launches? Possible candidates were the Secretary of Defense or the Space Policy Council. How can we stock pile nuclear options? Possible answer is simply to use those in the inventory. This brings up the need to develop fusing systems that can work in deep space as well as correct current design flaws considering operation in deep space.
- **Manhattan Project as the Model:** It was brought up by Dr. Boslough that the historical precedent for national effort of this magnitude would be the Manhattan Project. An effort of this size would require immediate use of many national assets, and likely a body would be conjured into existence by the President of the United States for this sole purpose. Until that point in time, the most appropriate technological development is probably that of fuses and modification of off the shelf technology.
- **Mitigation Affects Other Parties:** The international relations discussion was brought up again in reference to the sharing of astronomical information. It was noted that the location of an impact, even though susceptible to a large prediction error, could cause international conflict. Mitigation needs are not the same for all countries, depending on the location of impact. This is particularly important during "slow push" options or small, repeated momentum pulses where a mission error could change the impact location but not yet cause it to miss the Earth completely.
- **Best Candidates to Lead:** Discussed again was the need for a central lead agency, which could depend on the specifics of the threat. Best candidates are NASA and DTRA. It was also brought up that a completely new agency could be created for this purpose, historically similar to the Missile Defense Agency. For non-crisis timelines, encounter targeting and sensing capability development should most likely be delegated to NASA (note: NASA has no experience or capability in "fusing," but has capability for interplanetary encounter "targeting".

- **Strawman Plan:** We discussed more details to the scenario questions and the "Strawman" plan architecture.
  - **Precursor missions:** scout ISR missions, rendezvous and experimental impact missions
  - **Productions schedule:** depends on the results of the scout missions and number of kinetic impacts
  - **Launch windows**: East and West coasts sites can be used, launch intervals require 6-9 months for heavy and 3-6 months for medium launches
  - **Back-up and redundancy:** production must be modified to support spare lift vehicles and enhancement of their availability
  - Other "Strawman" details were using a scout ISR, low and high yield nuclear payloads

7.2 Nuclear Considerations

Because of the relatively short timeline available (less than seven years) to mount a mitigation response, most discussion necessarily focused on nuclear options. Only longer warning timelines would allow other mitigation options to become viable candidates.

Space Thermal Environment: While the participating nuclear device designers had high confidence in their suitability, it was noted that current stockpile devices are neither tested or qualified to travel for a significant period through deep space with its various thermal cycles, and this might require some on-ground testing, construction of a specialized cocoon, or design of a new simple device specific to this purpose.

Seekers & Fusing: While participating sensor & fusing experts had high confidence in high-velocity impacts, other engineers still felt this was a very challenging speed for terminal guidance and fusing, and noted that terminal fusing against a comparatively small object against the background of space may have important differences with fusing with respect to Earth re-entry.

Retaining the Nuclear Option: DOE HQ suggested that to retain the nuclear option require the following "no cost" efforts:

- A Memorandum of Understanding (MOU) with the State Dept ensuring that the large nuclear devices are not negotiated away.
- A MOU with the National Nuclear Security Admin (NNSA) to ensure that the large nuclear devices are not dismantled and the equipment need to maintain them is retained (e.g., the Kansas City Plant is eliminating about ½ of their job shops).

Treaty and Legal Considerations: This workshop did not have the benefit of legal expertise. Review of the language in the Outer Space Treaty generated discussion. Some players felt that the use of a nuclear device for propulsive means could not be construed to be stationing weapons of mass destruction in space, and rather constituted a form of nuclear space propulsion. Review of the Limited Test Ban Treaty was more problematic. While it might not prohibit actual use, it apparently would prohibit testing. Players felt this would likely require an exemption or withdrawal. Any use would also require a Presidential waiver for launching nuclear material.

Advance Testing: While the Limited Test Ban Treaty prohibits testing of a nuclear device in space, it might still be valuable to identify several test candidate asteroids on which equipment could be practiced. The selection should mirror the diversity of the asteroid threat (rubble, solid, metallic, etc.), and should be selected based on orbital characteristics that are inside Earth's orbit and a deflection could not result in danger to Earth or satellites, where detonation was far from Earth but could be usefully observed, and which could be reached using the smallest possible spacecraft and mass budget.

Expect Opposition: Some players felt additional political input was needed as not everyone is likely to be supportive of the nuclear option.

Disruption: Players discussed the option of fragmenting the asteroid. If the intent is to keep a rubble pile fairly intact, then the net force on the asteroid must be kept within certain structural limits which can be accomplished by adjusting fusing and distance. If however the time span will not allow full deflection, disruption is an option. The escape velocity is very low, perhaps 10cm/sec for a 270m body according to Dr. Dearborn from LLNL. In that case, the approach would be to shatter the asteroid via a surface detonation using the largest nuclear device. That would ensure that only a fraction of the remaining mass impacted the disk of the Earth, minimizing damage to Earth, but likely impacting our satellites. Mark Boslough from SNL expressed concern of a large number of small fragments striking the atmosphere and causing flash heating.

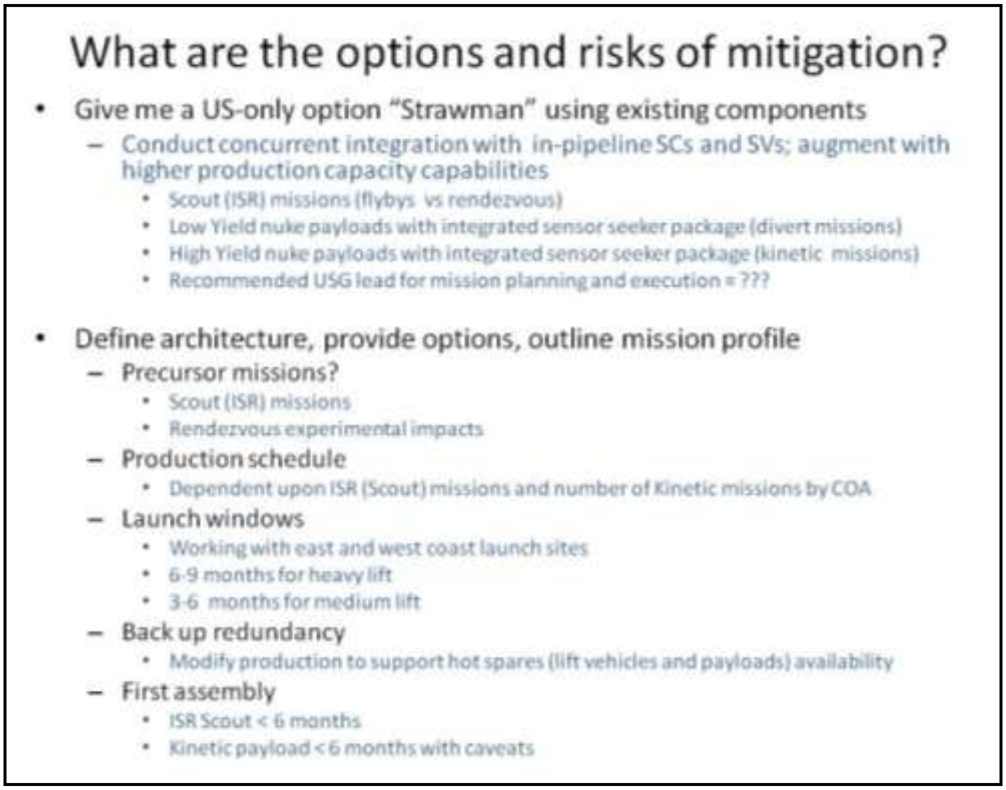
Studies and Simulations: Some DOE players expressed that for the nuclear option, several studies and simulations would be useful, including:

- **Nuclear Option Capabilities & Required Characterization**: A study to confirm the nuclear option capabilities; e. g., standoff 10 to 100 times more effective than Kinetic Impactors, surface and penetrators 10 to 100 times more effective than standoff, no characterization mission required (i.e., only ground-based observations of orbit and approximate mass required), etc.
- **Readiness:** A study to confirm the readiness of the large nuclear devices; e.g., not boosted (i.e., cheap to keep), can survive launch, can operate in vacuum, can be modified for surface or penetrator modes, etc.
- **Refurbishment:** A study on refurbishment of the aging large nuclear devices.
- **Modifications/Upgrades:** A study on modifications/upgrades for the large nuclear devices; e.g., new aeroshells (for standoff, surface, and penetration), enhanced radiation pressure, etc.
- **Impact Simulations:** Computer simulations; e.g., 140 meter diameter impacts, 1 km diameter impacts, Apophis impact, Tsunamis, minimum diameter of concern, standoff, surface, penetration, etc.
- **Declassifications:** e.g., large nuclear device yield, number, mass, age, size (with and with aeroshell), etc.

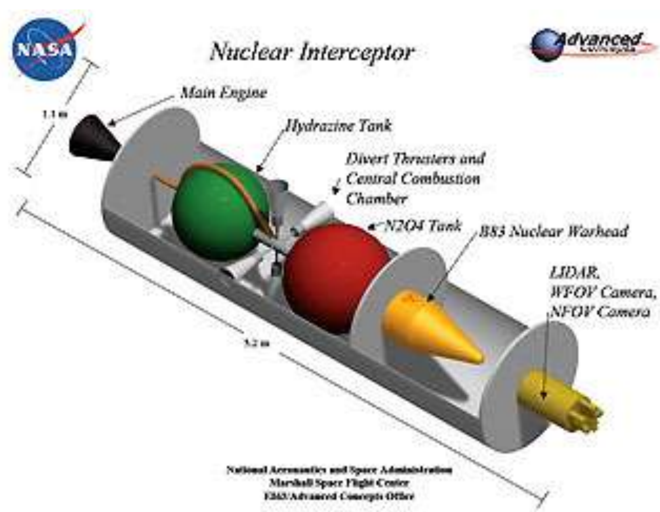
Funded Effort: One player suggested that a useful FY11 budget could consider a $20 million total effort broken up along the following lines:

- $5M for NASA to focus on analysis and publication of data
- $5M for USAF to focus on providing Pan-STARRS-4 data, and more radar capability
- $5M for NSF to focus on providing IT support and part time access for follow-up observations using instruments such as the Dark Energy Survey observatory in Chile (4m diameter primary, ½ gigapixel camera) and a similar facility in the Northern Hemisphere
- $5M for DOE to focus on providing mitigation R&D

7.3 Deflection Team Outbrief:

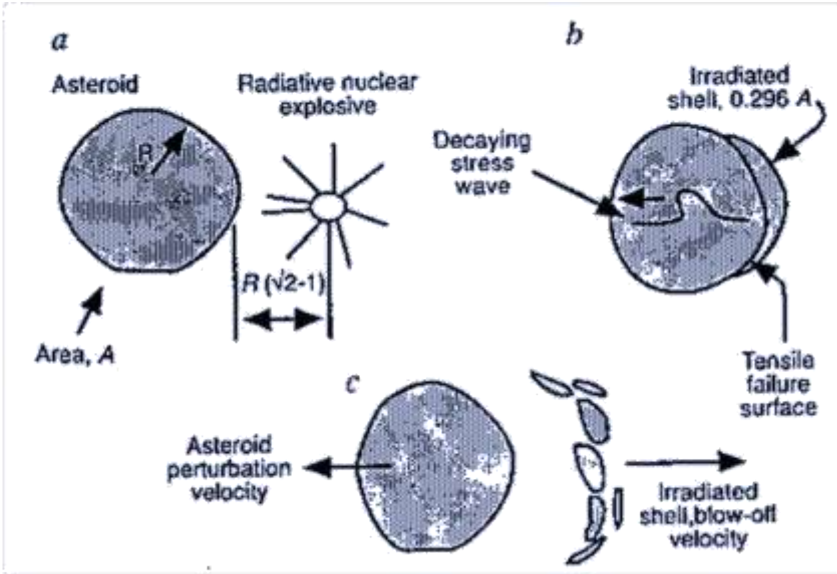


Mitigation / Deflection Team Output Briefing Slide



[xxxiv]

Nuclear Standoff on EELV Preferred: The Mitigation/Deflection team selected as their primary option a stockpile-based nuclear stand-off device launched on an EELV using existing MDA or NASA seeker / guidance. A stand-off explosion is very different than a surface or subsurface disruption which aims to blow the asteroid apart early enough that a significant portion of the asteroid misses the Earth and much of the remaining debris is hopefully small enough to burn up in the atmosphere.



xxxv

Many people misunderstand how "nuclear stand-off" works. In space there is no atmosphere to create a blast pressure wave, so a nuclear device works by depositing x-rays and neutrons on the surface of the asteroid, flash-heating a thin layer into a gas which blows away a thin layer of the surface and pushes the remainder of the asteroid in the opposite direction.

The rationale for selecting this approach is as follows:

- **Short Timeline:** Seven years is a very short time to design, manufacture, integrate, launch, cruise to the interplanetary target, implement the mitigation event, and then have sufficient time for the deflection action to modify the trajectory enough for it to miss the Earth. All components above have a high technological readiness level (TRL) at the component level and can be quickly adapted to the mission.
- **High Energy Requirement:** This was a fairly large object requiring a large push, and a nuclear device has the highest energy content per unit mass. Other methods would require significantly more mass and expense and were at lower TRL and higher risk.
  - **Slow push** methods might be very attractive, but require extensive development.
- **Loose Composition:** The object was thought to be a rubble pile rather than a consistent solid object. This limits the options available. A stand-off explosion allows the force to be distributed across the entire surface and if properly fused, minimizes the disruption.
- **Mission Simplicity**: Standoff nuclear greatly simplifies mission planning because the spacecraft need never touch the asteroid, or maintain precise position keeping

Concurrent Integration w/ In-Pipeline Products: The approach selected by the team was concurrent integration of in-pipeline spacecraft and space vehicles augmented with higher production, meaning that in-production spacecraft and vehicles would be diverted while industrial production would be increased.

NOTE TO FUTURE SCENARIO PLANNERS: Players did not have available to them the current pipeline information or relevant information to gauge how much our industrial base could be ramped up.

All Approaches in Parallel: Although the team preferred to use existing high-TRL components, there was significant discussion of custom devices and different employment concepts, and the team felt that it would be inappropriate to put all eggs in one basket. The Deflection team found that organization for this mission would / should follow a Manhattan Project paradigm, where multiple approaches were worked in parallel, some with ground testing and some tested for the first time at the asteroid (Little Boy & Fat Man analogy).

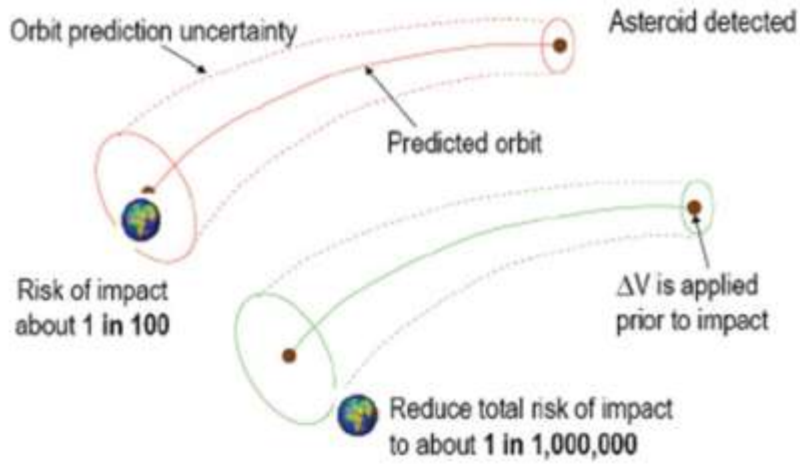
Prepare the Biggest Possible & adjust using Fusing and distance from target: Players were sympathetic to the idea of conservative engineering, of getting the largest warhead on the largest rocket, and adjusting with fusing.

'Tap...Look…Tap": Players did not feel that it needed to be an "all or nothing" single shot, but that we could and should allow ourselves time to examine our progress and make adjustments as necessary. One complication is that after the first tap (to include a small kinetic impactor to characterize); the asteroid would likely be surrounded by a cloud of gas/dust/particles which could complicate future missions.

Need for an Integrated Mission Planning Tool: Players expressed the need for an integrated mission planning tool. Such a tool should bring together launch vehicle capabilities, launch windows, astrodynamic mission planning and optimization, mass staging, deflection modeling, and Earth-miss criteria, more easily allowing movement between independent variables such as space vehicle mass, time of launch, launch vehicle payload, time of rendezvous, Earth miss distance, etc.

8 DEFLECTION PLANNING CONSIDERATION PRIMER

The following information was shared knowledge of many of the participants, but may not be to policymakers, national decision-makers, or exercise scenario builders.



[xxxvi]

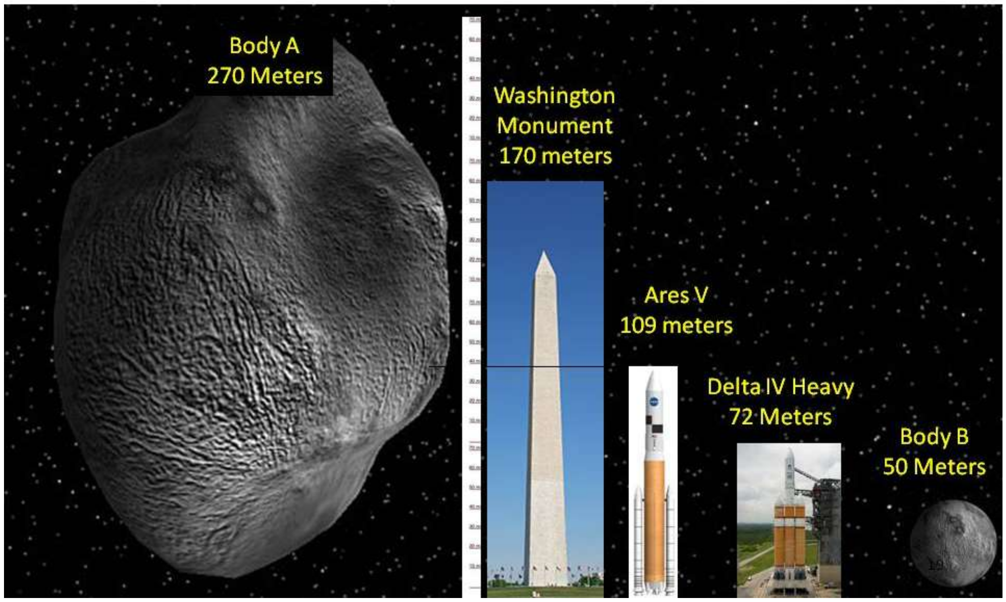
In layman's terms:

- **Not a small rock:** These are really massive objects with a lot of kinetic energy
    - The larger body in this scenario would have a mass on the order of 100,000 Boeing 747's travelling at 17km/sec and would create impact damage 10 million times worse than 9/11.
    - 17km sec is Mach 28, or about 38,028 Mph[xxxvii]
- **It takes a lot of energy to move one:** It takes a lot of energy to deflect that much mass moving that fast, even just a little.
- **It takes a lot of time to get there:** Typically at least one to several years. Add to that the time it takes to build the spacecraft, rocket, integrate the two together, and complete launch operations.
- **Timing Matters:**
    - **Sooner is better:** Generally, the farther out in time before impact you deflect them the easier it is, and the longer you wait (closer to impact) the more energy it takes
    - **It only makes sense to push at certain points in the orbit:** Not all "nudges" are equal, in most cases you want to hit it along the direction it is going (speed it up or slow it down), and hit it when it is closest to the Sun (perihelion)
    - **It only makes sense to launch at particular times of the year**: You (the Earth) and the Asteroid are both circling around the Sun, at times closer together and at times farther apart, and you have to time it right to get there in the minimum amount of time with the amount of energy available with our current launch systems.
    - **It only makes sense to launch at particular times of the day**: It takes a huge amount of energy and fuel to change direction in space, so you need to be pointed the right way. The Earth is spinning on an axis and is only pointed in the right direction once a day. Interplanetary launch windows are short, on the order seconds.
- **Our rockets only get so big:** It takes a lot of fuel to speed up and slow down to get there. The heavier your deflection package, the more fuel you need. The less efficient your flight path, the more energy you must expend to change speed & direction, the more fuel you need. The more fuel you need, the heavier your rocket. The heavier your rocket, the bigger your rocket. Our biggest rockets right now can only lift between 8,000 and 10,000 kg to interplanetary destinations.

The charts below illustrate these considerations:

Not a small rock: The size and mass of even "small" impactors are impressive when compared to human constructed objects, and they strike at speeds much faster than Earth orbiting satellites or ballistic missiles.

Size Appreciation

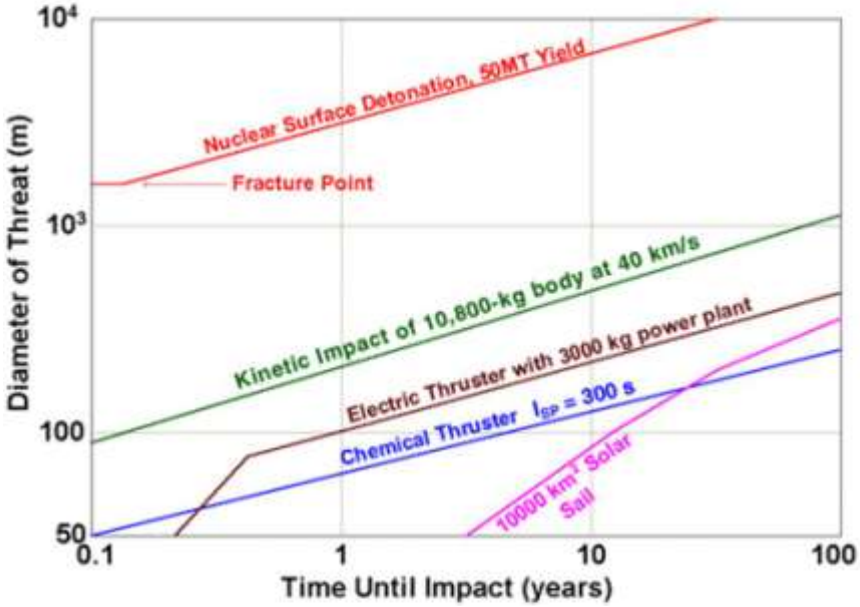


There are a number of ideas about how such objects might be deflected. The following chart taken from the NASA report to Congress and analysis[xxxviii] lists some of the possible impulsive and "slow push/pull" ideas, and what properties of the target object must be known for it to be effective:

	Mass	Spin	Density	Material Properties	Size & Shape	Surface Properties
Conventional Expl. Surface - Contact	Yes	No	Helpful	Helpful	Helpful	Helpful
Conventional Expl. Subsurface	Yes	No	Helpful	Helpful	No	No
Kinetic Impactor	Yes	No	Helpful	Helpful	Helpful	No
Nuclear (Contact)	Yes	No	Helpful	Helpful	Helpful	No
Nuclear (Standoff)	Yes	No	No	No	No	No
Nuclear Explosive (Sub-Surface)	Yes	No	Helpful	Helpful	No	No
Nuclear Explosive (Surface Delayed)	Yes	Yes	Helpful	Helpful	No	Helpful

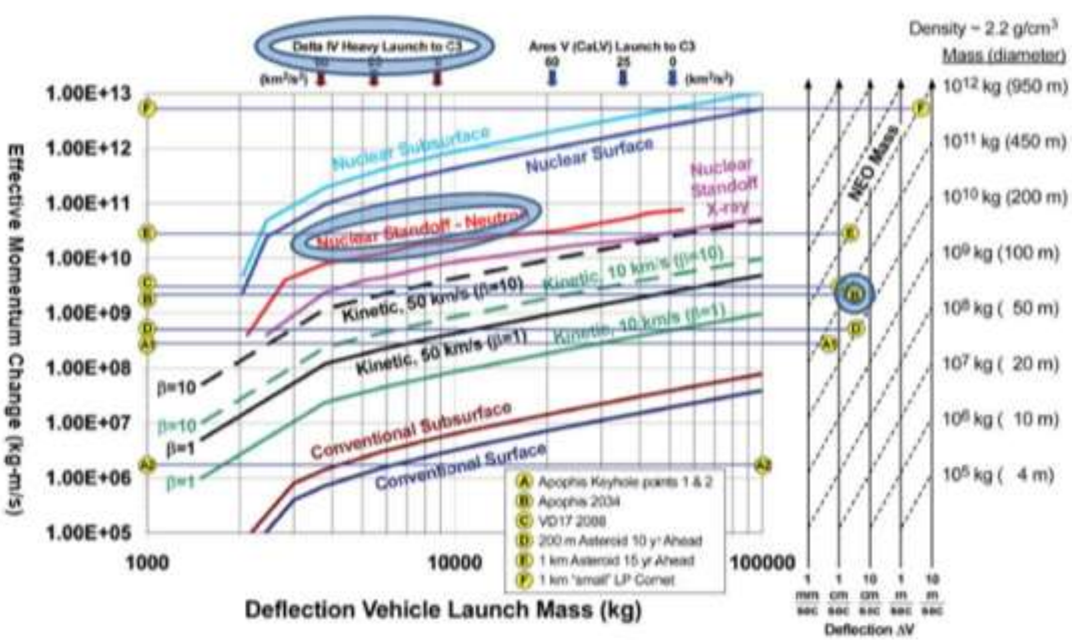
	Mass	Spin	Density	Material Properties	Size & Shape	Surface Properties
Yarkovsky	Yes	Yes	No	No	Yes	Yes
Focused Solar	Yes	Helpful	No	No	No	Yes
Gravity Tractor	Yes	Yes	No	No	Yes	No
Mass Driver	Yes	Yes	Yes	Yes	Helpful	Helpful
Pulsed Laser	Yes	Helpful	No	No	No	Yes
Space Tug	Yes	Yes	No	No	Yes	Yes

It takes a lot of energy to move one: This chart by Dr. Gold (NIAC report, available at NSS Planetary Defense Library)[xxxix] illustrates how time and size of threat can affect the selection of a mitigation method. Note that as the diameter gets larger and time to impact decreases, few options remain except nuclear.



The chart below is taken from NASA's report to Congress[xl]. On its vertical axis it shows how comparatively effective various deflection techniques might be. It is important to note this is a logarithmic scale, meaning each line is 10x as much change in momentum as the line below it. It likewise highlights the effectiveness of nuclear options.

Figure 43. Momentum Capability of Impulsive Alternatives Applied to Scenarios



It takes a lot of time to get there: The chart below is taken from Dr. Brent Barbee's thesis[xli] on NEO deflection and gives a sense of the timeline needed from detection to Earth impact to implement a deflection mission, and the actions that must take place within that timeframe:

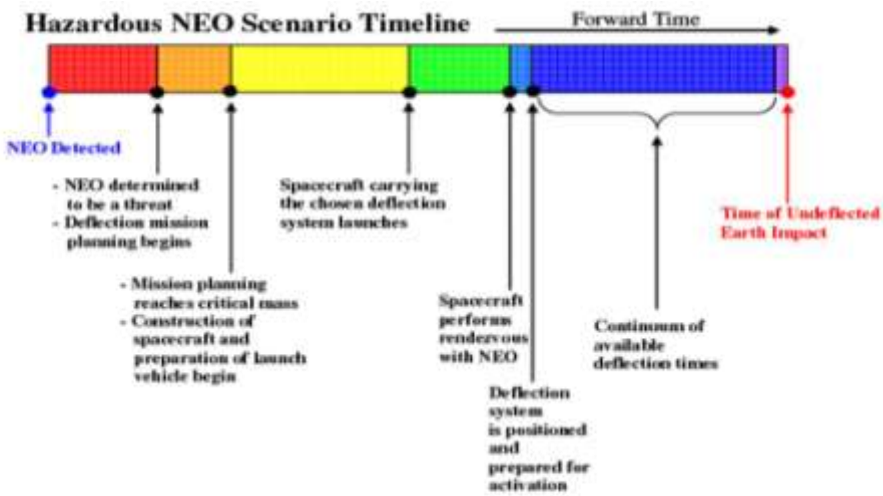


Figure 1. Hazardous NEO scenario timeline.

The chart below gives a sense of the total mission time needed to get to and deflect an asteroid. Mission times for a scenario comparable to this exercise scenario run approximately 1,500 days, or slightly over <u>four years</u> from actual launch.

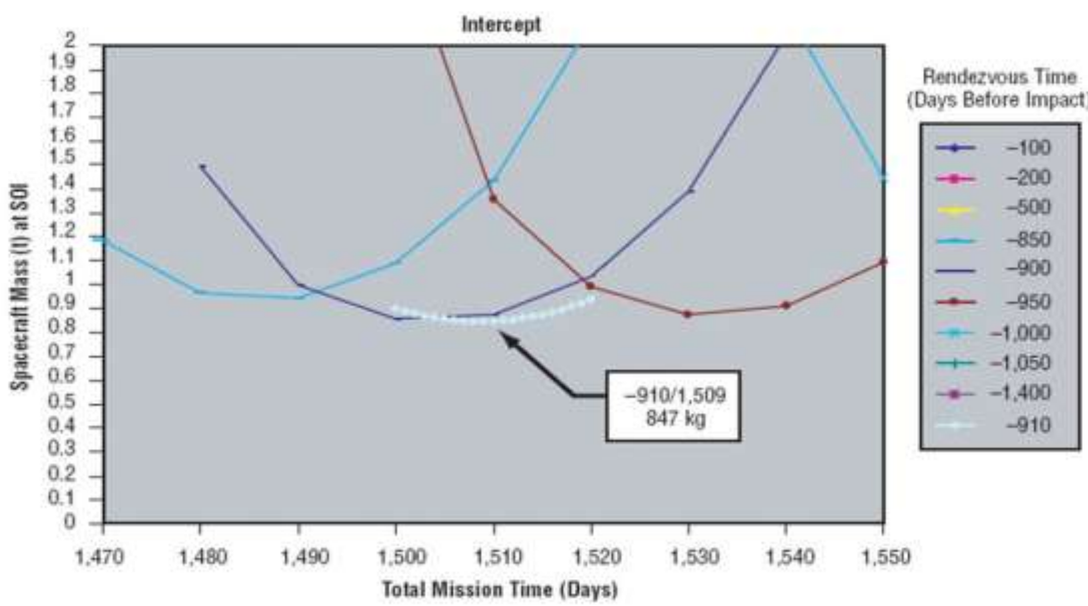


Figure 92. Minimum total system mass for the staged chemical/nuclear blast option, showing the optimum rendezvous and total mission times for intercept.

[xlii]

Timing Matters, & Sooner is better: The charts below illustrates that it is comparatively harder to deflect an asteroid as it gets closer to impact, but that when you apply the deflection (preferably at perihelion—its closest point in orbit to the Sun) makes a tremendous difference in how effective a given "push" can be.

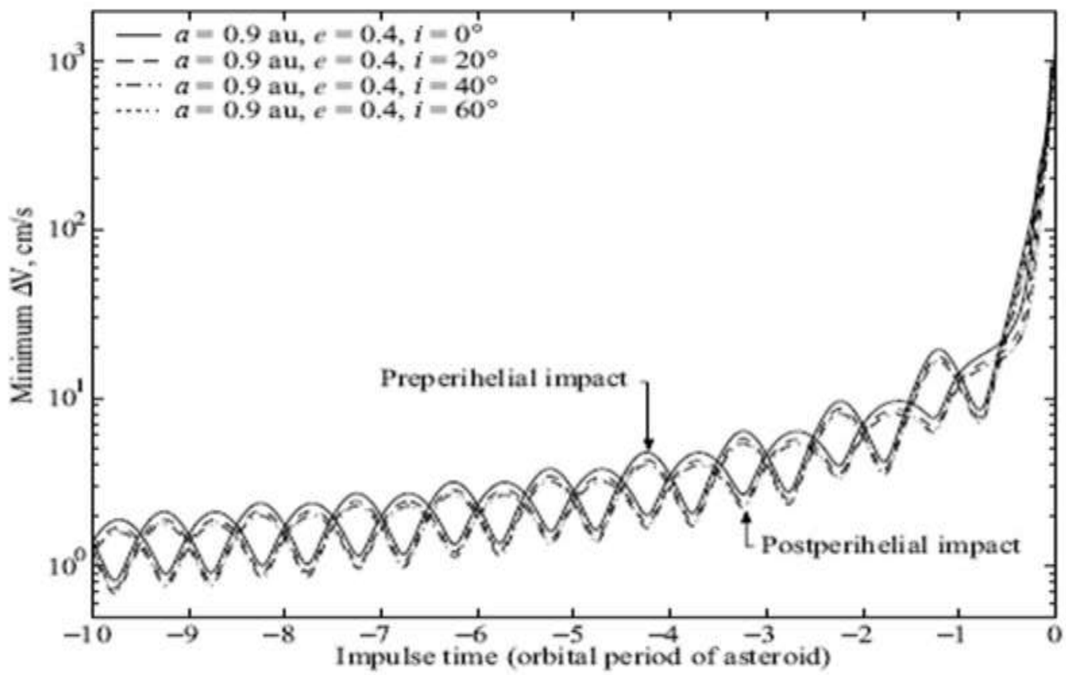


Figure 9. Minimum ΔV: Aten-type asteroids with a = 0.9 au, e = 0.4, i = 0°, 20°, 40°, 60°.

Taken from [xliii]

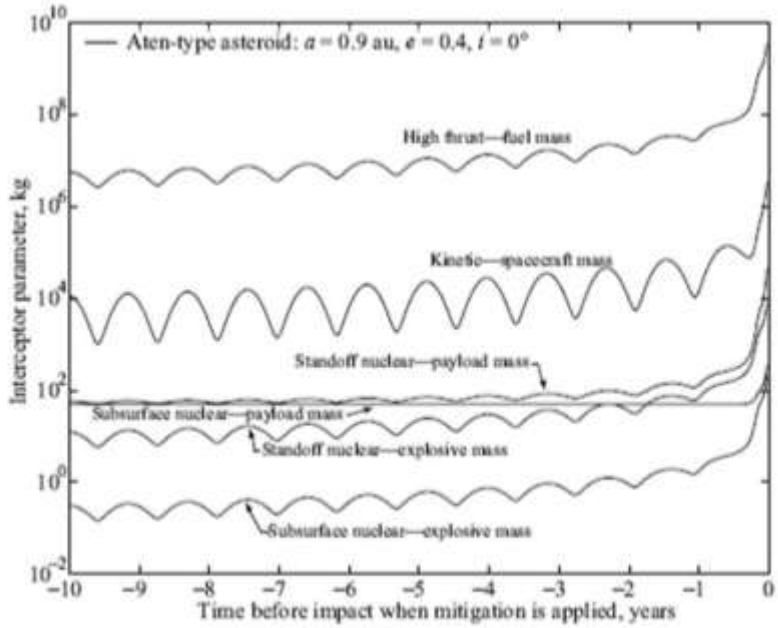
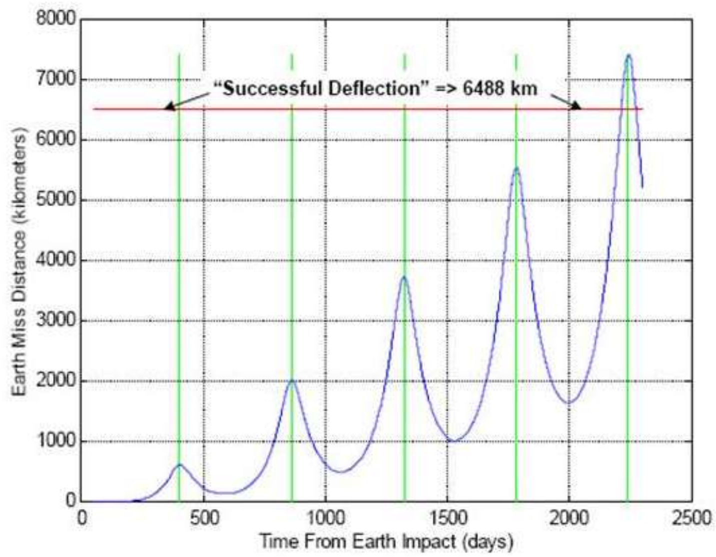


Figure 22. Various interceptor masses for 1-km stony Aten-type asteroid. [xliv]

Figure 4-10: First Successful Mitigation for Example Threat Case



The plot shows that in order to achieve a zero-margin Earth miss against the example threat, the 1-cm/s deflection must be applied approximately 6 years and 21 days before Earth impact. If displacement margin is desired, the deflection would have to take place about 30 days earlier at the local deflection peak. The largest margin available in this timeframe, however, is only about 1000 km. It should also be noted that the offset xlv

It only makes sense to push at certain points in the orbit: As shown above, it only makes sense to push an asteroid at a certain point in its orbit. This is illustrated graphically below.

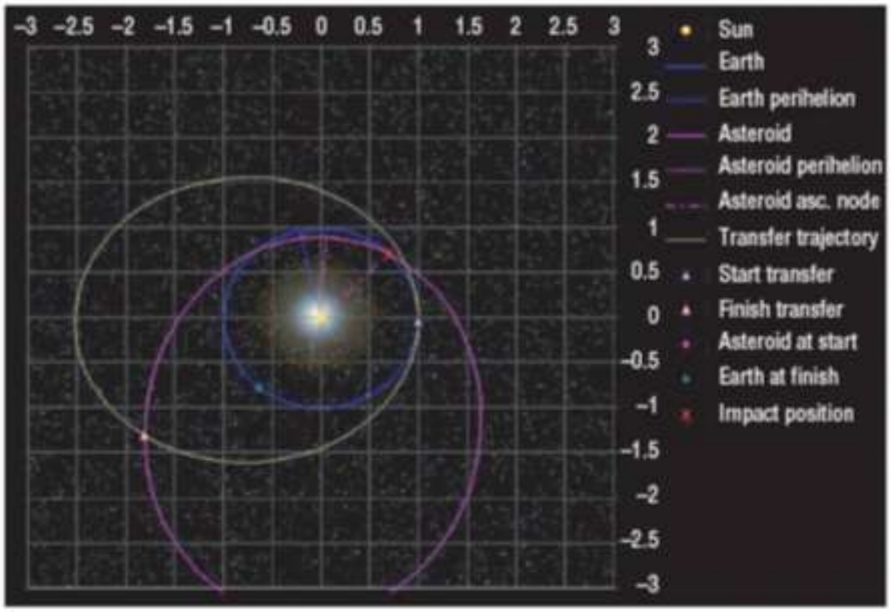
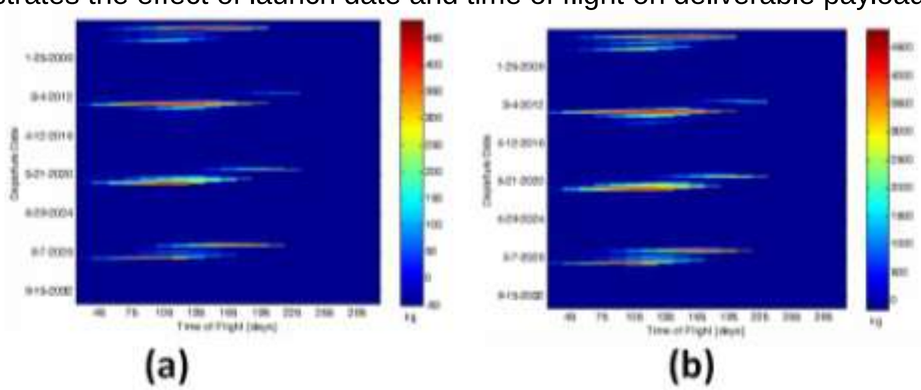


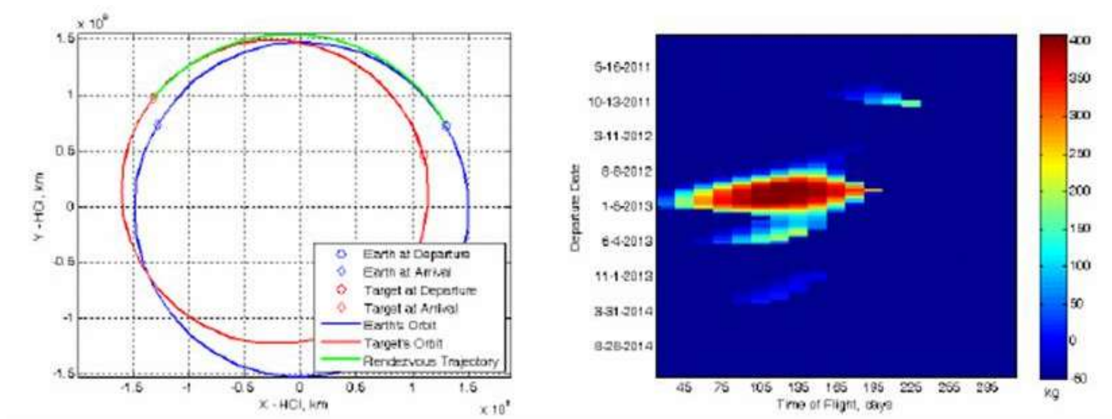
Figure 94. Optimum intercept trajectory for the staged chemical/nuclear deflection option. xlvi

The effects of timing the push matter substantially. But timing also matters in order to minimize mission time. Rendezvous must be planned for when both the Earth and the NEO are in a place in their orbit to minimize the transit time and/or energy & fuel required to get from Earth to the NEO.

Such conjunctions only happen every so often, and so launch windows must be planned carefully. Launching outside the optimal window requires significantly more fuel and also significantly decreases the mass of the spacecraft which can arrive at the NEO. The chart below from Dr. Barbee[xlvii] illustrates the effect of launch date and time of flight on deliverable payload mass.



- **Figure 11. Deliverable payload mass for (a) Discovery Class configuration and (b) Heavy Lift configuration.**

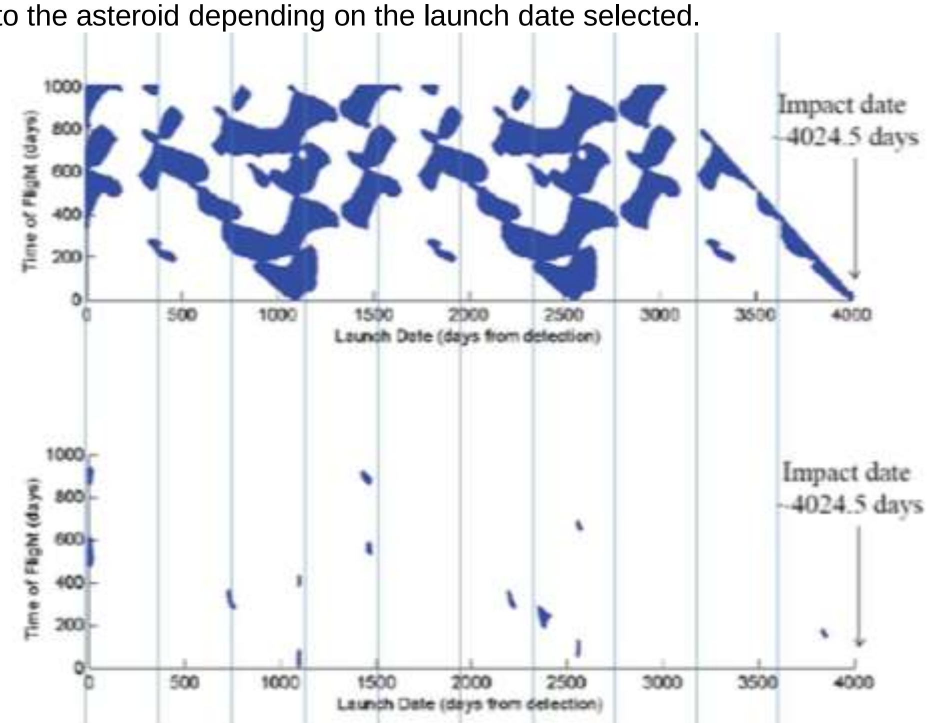


(a) (b)

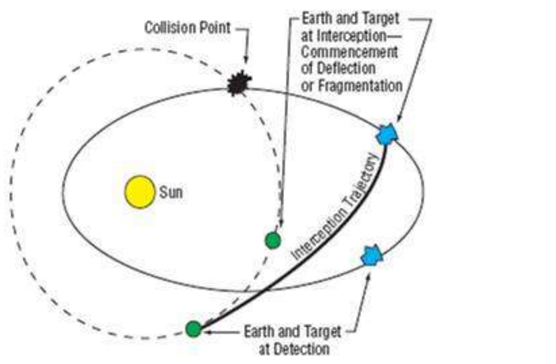
Figure 12. (a) Maximum mass rendezvous with Apophis in 2012 and (b) delivered payload mass to Apophis in the 2012 timeframe as a function of departure date and flight time.

A logical sequence of events is to reconnoiter Apophis in the 2012 timeframe, gathering precise orbit determination data and conducting a thorough scientific characterization of the asteroid. The delivered payload mass numbers in Table 5 for the Discovery Class configuration suggest that such a mission could be performed at or below the cost of the 2001 NEAR-Shoemaker mission, which characterized the asteroid Eros for a Discovery Class budget of approximately $300 million dollars. The 2012 Apophis mission obtains a valuable science data product regardless of whether the asteroid will in fact strike Earth in 2036. The orbit determination segment of the mission would provide sufficient information to determine whether a 2036 impact would actually occur. If a 2036 impact is found to be certain, the 2021 launch window can be used to launch one or more deflectors. If no impact impends, our attention can be focused elsewhere.

It only makes sense to launch at particular times of the year: Because the Earth and the NEO are moving in orbits that weave in and out, we cannot just launch at any time we want, but are constrained to launch in particular windows. The charts below illustrate go & no go times, and the time of flight to the asteroid depending on the launch date selected.



If the mission concept requires rendezvous (must slow down and match speed) vs. intercept (run into it at high speed), it requires substantially more DeltaV or fuel, and so timing the spacecraft outbound trajectory becomes even more critical.



: 26. Delivering deflection or fragmentation energy by the interception mode.

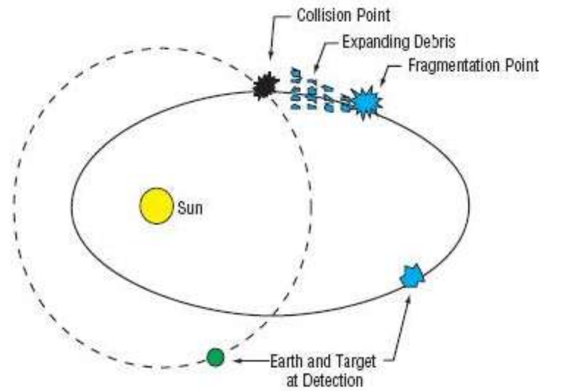


Figure 24. Illustration of fragmentation method of threat mitigation. [xlviii]

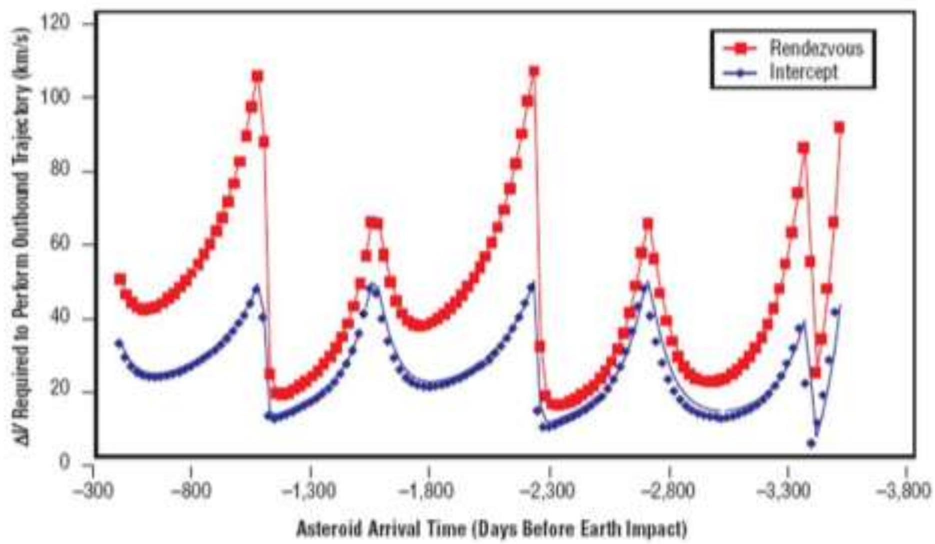


Figure 70. Outbound trajectory ΔVs for 3,600-day total mission duration. [xlix]

It only makes sense to launch at particular times of the day: Because the Earth's axis is inclined, and because the Earth is constantly turning, mission planning is not just limited by a particular day in the year, but is also limited by when the launch site (Cape Kennedy or Vandenberg AFB, for instance), is aligned with the direction of launch. Interplanetary launch windows can be as narrow as seconds.

It matters very much which direction you push: Generally, the lowest energy to deflect an asteroid from striking the Earth is to speed it up or slow it down, but the relative effectiveness of the direction of push varies according to its location in orbit and proximity to impact. A lateral push only becomes attractive in the final days to impact, and is likely to present additional mission challenges and need much, much higher energies than a push along the line of motion years in advance.

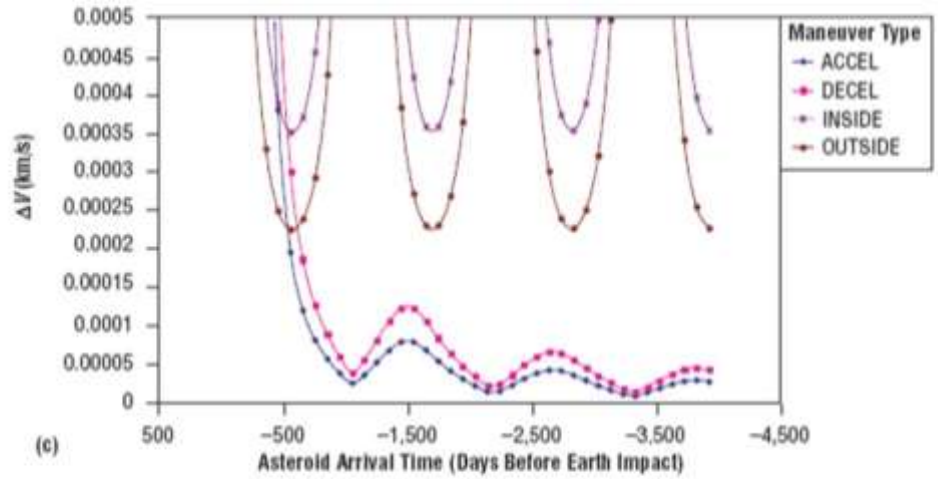


Figure 81. (a) Optimal deflection direction, (b) optimal deflection direction—detailed view, and (c) optimal deflection direction —detailed view—minimal deflection ΔV.

Our rockets only get so big: At present, the largest launch vehicle our nation is able to produce is the Delta IV Heavy, which can only carry approximately 8-10,000 kg of useful payload for interplanetary missions, and also limits the dimensions to under 19.8x5m. That severely limits the "size of the hammer" you can bring to the asteroid.

Forewarning helps, but requires better instrumentation: A ground-based system is limited by weather, Moon brightness washout, and because it can only observe at night, seeing only on the side of the Earth away from the Sun. The following chart[li] illustrates the limited viewing opportunities available to observe a given threat and provide warning:

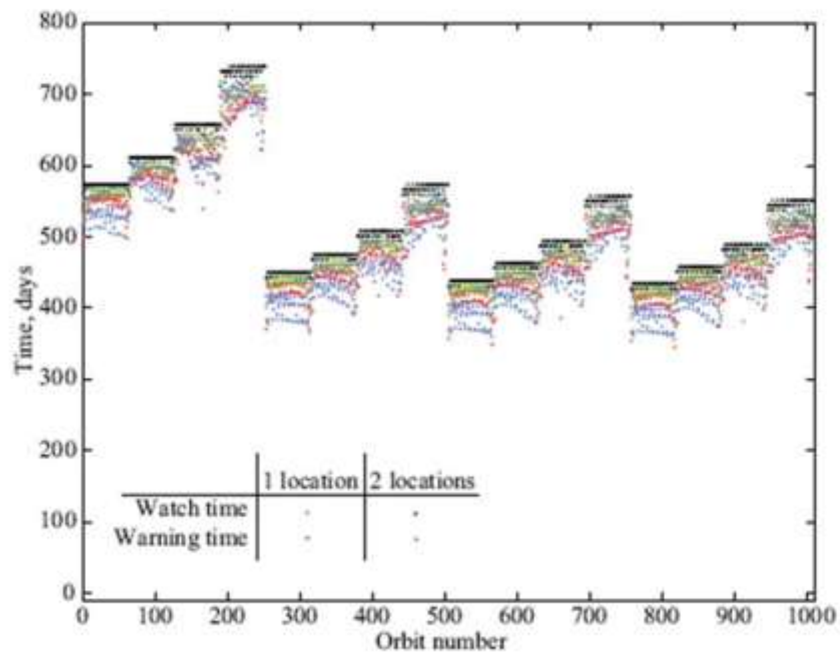


Figure 19. Watch and warning times.

A notional space-based architecture proposed by Dr. Gold in his NIAC report[lii] places three sentries in a Venus-like orbit for NEOs, and a later iteration in a Jupiter-like orbit to watch for long-period comets.

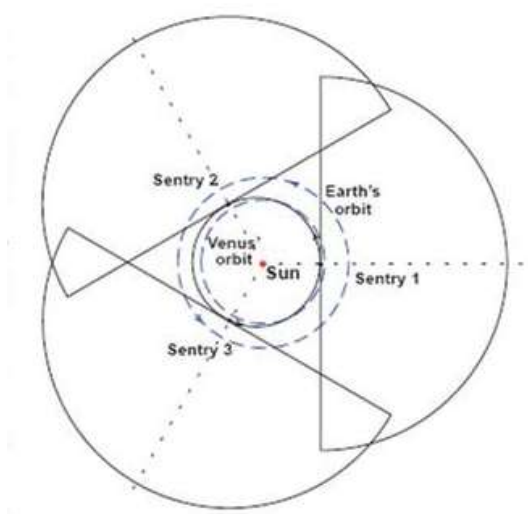


Figure 9. Sentry coverage with three Sentry spacecraft near the heliocentric distance of Venus observing 90° from the opposition direction.

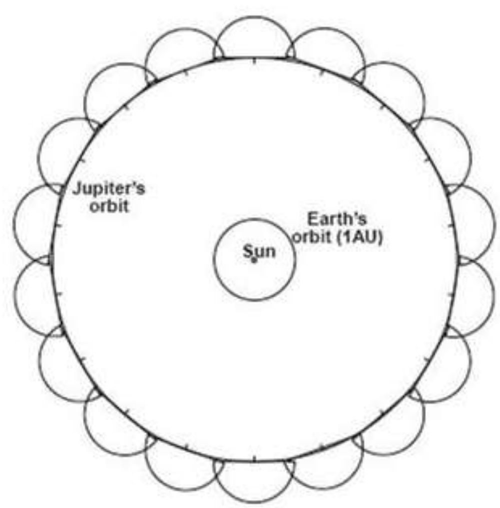


Figure 10. Long period comet distant early warning system. Ecliptic-plane coverage for long period comets 1km in diameter can be provided by 18 Sentry spacecraft observing 90° from the opposition direction from Jupiter's orbit. The Sentries could be placed there with Jupiter swingbys. Many out-of-plane Sentries would also be needed to give full-sky coverage.

[redacted]

9 MAJOR EXERCISE INSIGHTS AND RECOMMENDATIONS

9.1 The NEO impact scenario is not captured in existing plans

While a number of useful analogs exist, as well as procedures that could be used or adapted, at the present time they have not been so adapted, and attempts to do so in the moment are likely to be much less successful than advance preparation. NASA has an existing contingency process that terminates in notification, but downstream agencies do not. Players felt that downstream agencies (NMCC, STATE, DHS, COCOMs) should develop and have on hand checklists for specific actions. Players suggested that an impact emergency scenario must be incorporated into the Emergency Response Plan list of scenarios so that some advance planning can be initiated. Some players suggested establishing an advisory board of experts in affected agencies to be called in the event of a high-risk PHO discovery. Another recommendation was to charter the development of a document for national leadership which, in an actual event, would instruct the various agencies what to do, and could be kept on the shelf and continuously refreshed. Some players suggested the development of a scenario flowchart to inform mission preparation, planning, execution and assessments by capturing data collection, mission options, and factors influencing mission decision.

9.2 The NEO impact scenario should be elevated to higher level exercises with more senior players

Players suggested that the scenario was mature enough, interesting and compelling enough for elevation to higher levels of visibility and increased levels of detailed examination. Players suggested that National Planning Scenarios needs to include a NEO impact as one of its scenarios. Players recommended incorporation of a NEO impact scenario into a number of formal planning exercises, including: National Level Exercises (NLE), NORTHCOM exercises, DHS Multi-hazard scenario exercises, TOPOFF (Top Officials) exercises, and the annual interagency Continuity of Government (COG) exercises at Mount Weather. Players suggested future exercises should seek increased participation from: FEMA, USNORTHCOM, USSTRATCOM, NNSA, NOAA, Justice Department and DoD/AF General Council, State Department, HSC Staff, National Guard, DOE Emergency Preparedness (COG), and include one or more state emergency managers. Include more senior Policy individuals and OSTP. Future exercises should consider inclusion of International actors (even if simulated), Press & Media, interested and expert non-governmental organizations (NGOs) such as B-612, Association of Space Explorers (ASE), Planetary Society, and civilian expertise external to the government and perhaps international.

9.3 Proper planning and response to a NEO emergency requires delineation of organizational responsibilities including lead agency & notification standards.

Players consistently remarked that the complexities and overlapping nature of this contingency required advance delineation of responsibilities, formalization of the notification process, and clarification of authorities and chains of command, including authorities for delegation and supported/supporting relationships. Players thought it was important to think through and document this prior to any actual NEO emergency. Players felt the appropriate level for decision was the NSC/HSC-level National Response Framework and the formal interagency Policy Development and Modification Process, and might find its expression in a formal policy on lead/supporting relationships such as a Presidential Decision Directive or Memorandum, perhaps including a new National Space Policy. Some players suggested a useful first step would be to require relevant agencies/departments to conduct scenario studies, risk assessments and mitigation strategies terminating in the submission of formal agency/department position papers.

While players did not arrive at a consensus on lead agency for deflection/mitigation, disaster response was non-controversial, and players felt DHS should be formally recognized as lead for domestic impacts. Players consistently remarked on the need to formalize notification standards (to include message templates) and tighten up the federated nature of warning and prediction. Some participants felt there was a need to formally address the mission in existing documents, plans and mission statements, and variously recommended a re-examination of NASA Charter, AF Functions, STRATCOM mission statement, National Space Policy, National Defense Strategy (NDS), National Security Strategy (NSS), Guidance for Employment of the Force (GEF), Joint Strategic Capabilities Plan (JSCP), Unified Command Plan, as well as COCOM CONPLANS and OPLANS, none of which reflect a concern or readiness to protect against or respond to a natural catastrophe that emerges from space and may require a coordinated whole of government approach to address.

9.4 Players were not able to achieve consensus on which agency should lead the NEO deflection/mitigation effort

No obvious consensus emerged on which agency should have lead for a deflection effort. Expertise is widely distributed across US government agencies. Players held widely divergent views in terms of organizational equities will require a policy decision at a higher level. Players felt an actual deflection in the absence of policy guidance would likely mirror the Manhattan Project, where expertise was drawn from many locations under a single organization. The disadvantage of such an approach is the lack of preparation until confronted with a particular threat.

9.5 There is a deficit in software tools to support senior decision-making and strategic communication for disaster response & mitigation for a NEO scenario.

None of our command centers have the necessary tools to make quick assessments. Players expressed a need for a National Decision Support System for natural impact scenarios and events. Such a system would tighten up the federated nature of impact prediction and impact effects prediction, integrating models for impact location & uncertainty prediction, kinetic effects prediction, plume, and tsunami effects, and feed evacuation planning models. The desired end state would be a “turn-key” model that accepts the best data from astronomical observations and generates predicted impact location and effects and recommended actions, and well as captures the capabilities of observation instruments and predicts when updates are to be expected. There is a corresponding need for an integrated suite of planning tools to allow end-to-end mission planning and decision support for deflection. Such a model should integrate astronautical navigation models, deflection modeling, launch windows, spacecraft & launch vehicle production capabilities and schedule to clearly present to national leaders what options exist for deflection. Players felt that both ground and space-based National Security Assets should receive software upgrades to allow them to participate in the orbital refinement process.

9.6 There are significant effects a NEO impact would generate that are not adequately captured in existing models.

Players highlighted the fact that current models inadequately address several effects likely to significantly affect accurate damage / effect estimates. These include the effect of blast plumes on Low Earth Orbit (LEO) satellites, electromagnetic effects that could affect electrical power infrastructure, seismic effects, effect of terrain on blast dissipation and focusing, coupling of air-blast to tsunami response, and atmospheric distribution/dispersion of hazardous materials.

9.7 The public may be aware of an impending NEO impact before senior decision-makers.

The NEO detection community conducts its work openly using Internet communications and Web-based datasets, so it is very likely that information on a new discovery of high interest will be available to the public before NASA can complete adequate verification and validation of the potential for impact and provide a news release, or even speed notification to the POTUS and appropriate agencies. The POTUS will either know from NASA or from the media, but even if the POTUS hears it first from NASA, the time delay before it is widely known in the media is likely to be exceptionally short.

9.8 Lead time for evacuation requires decisions be made before best information is available

States and local authorities require a certain lead time in order to plan and implement evacuation, and the error ellipse under current capabilities is not likely to adequately constrain the possibilities to allow effective decisions. Current NASA efforts seek to provide decades of advance warning time of a general impact, but there is no concept for a program to discover and refine a short warning impact position within the timeframe (approximately 72 hrs) to support evacuation decisions.

9.9 Public safety and tranquility require that the federal government be able to rapidly establish a single authoritative voice & tools to present critical information

Given the concern of what the public might know before it even gets to leadership, there needs to be a plan to put forward a single authoritative voice backed up with tools that clearly present information to support state and local authorities and reduce the chance of panic and counter-productive movement. A pre-drafted communications plan would be helpful. The National Decision Support System discussed above must support this need to clearly communicate to the public information about uncertainty, expected effects, and evacuation recommendations. Players struggled with the lack of information available to them about when they would know more, and suggested NASA develop tools to predict when observations are predicted for various sensors, when orbital refinement will take place, when the error ellipse could be collapsed and to what areas, and to be able to display this information graphically.

9.10 The preferred approach for short-notice NEO deflection was stand-off nuclear

In this scenario, given the short lead time (less than a decade), players chose to go with a solution they felt was low mass, provided high energy density for deflection, leveraged existing national capabilities, and had comparatively high technological readiness level (TRL). Even given its high TRL, players felt there was significant maturation and additional study needed to be confident in this option. A very different solution might be selected if there were multiple decades of warning, but then there would also be more time available to react after detection of the threat. The use of nuclear devices for this purpose would require significant international preparation or participation by other nuclear or spacefaring powers. Some players were skeptical of the degree of political support for the nuclear option and suggested more political input in future exercises. Players felt the Nuclear Test Ban Treaty must be addressed, and suggested the need for a prepared legal opinion. Some players suggested a Memorandum of Understanding (MOU) between NASA, DOE and DOS may be necessary to preserve the required capabilities and infrastructure to execute the nuclear option.

10 CONCLUSION

This exercise represents the first official US Government look at a possible response to what is a rare, but inevitable event. Given the uncertainties at the time of writing, it is quite possible that such a response might actually need to be carried out in 2029 should Apophis pass through the gravitational keyhole, or for some other object as our search abilities increase. A one-day event can only serve as a starting point. Much more detailed planning and exercise is required.

APPENDIX A: A NOTIONAL CHECKLIST FOR NATURAL IMPACTOR

Disaster Response & Notification (Domestic)

- ☐ Pre-plan Actions
  - ☐ Establish call-in list of subject matter experts (SMEs)
- ☐ Establish a Communications Plan
  - ☐ Establish a Single Public Authoritative Figure
  - ☐ Give authorization to use additional assets to refine observations & predictions (NSF, NASA, JSPOC, NRO, DOE) & request international assistance as applicable
  - ☐ Place military on alert for evacuation support, and post-impact hazmat and rescue
  - ☐ Task national assets to provide impact & post-impact imagery
  - ☐ Call in all technical experts and establish ground rules for engagement with media
  - ☐ Establish timeline with Media, State and Local authorities for when significant updates for decision-making will be available (when new observations are possible, when error ellipse will collapse, when models/simulations will be ready)
  - ☐ Request and select products that clearly communicate public information that increases confidence, reduces panic, and minimizes unnecessary evacuation traffic
  - ☐ Make evacuation plan recommendation / decision considering the following:
    - Blast / Cratering Radius effects (University of Arizona)
    - Tsunami effects (University of Santa Cruz)
    - High Altitude Air Blast effects (Sandia National Labs)
    - Blast Plume effects (FEMA HPAC)
    - Hazardous materials from homeland critical infrastructure damage
    - Impact uncertainty ellipse (NASA JPL)
  - ☐ Decide appropriate actions for maritime vessels
  - ☐ Decide appropriate actions for non-evacuation supporting aircraft

Mitigation / Deflection

- ☐ Pre-plan Actions
  - ☐ Establish call-in list of subject matter experts (SMEs)

APPENDIX B: PLAYER SURVEY RESULTS

Natural Impact Interagency Deliberate Planning Workshop
Player Survey Results

1) Did this event inspire confidence in our ability to handle such a scenario?
   a. ---
   b. **Yes**, but more work is needed
   c. **Yes**
   d. **No**
   e. Somewhat
   f. **Yes**, but much more needs to be done
   g. I have mixed opinions; I feel the DHS/Conseq mgmt side is able but I believe the Homeland security +homeland defense + NASA/DOD Seams leave me w/ less confidence
   h. **Yes** → Moving in right direction
   i. **Definitely** to plan for…to a great degree; **yes** to our ability to handle
   j. **Yes**
   k. **Yes,** on response on the ground. **No** on response in space.
   l. **Yes,** but showed we still have considerable seams.
   m. **Yes,** assuming right people (Fed, State, International) were notified
   n. **No** (but not because it wasn't an excellent and productive meeting)
   o. A good start
   p. **No.** But it inspired confidence we'll get there
   q. **No.** Actual policy team dealing with the problem is likely to be less informed and spend more time considering rejected options while the hours burn. It would take significant time to assemble the right expertise, and the tools are nowhere close to good decision-making and communication support. Official NASA and OSD representatives clearly thought it should be the other guy's problem.
   r. Some. Providing the participants involved in such a scenario are astute and creative enough, there are several existing emergency response processes that could be adapted to cope with an impact emergency.

2) What **tools** need to be developed to properly cope with this situation?
   a. **Impact damage models** which account for **topography, Tsunami models** in USG which include inundation, **Modify GOEDSS & NRO sats software** to help refine orbits of heliocentric objects
   b. **Interagency Long-Tem & Crisis Action planning resources**
   c. Mainly **interagency planning tools**
   d. Development of **software for on-demand supercomputer simulations**
   e. Better **SA of previous events**. More focused on **analysis products**
   f. Interagency coordination. **Comms plans (international +domestic). C2.**
   g. **More seam-splitting exercise scenarios**. Multistate not hurricane/WMD tied. National framework vs NORTHCOM DoD plan, scenarios
   h. **Models, both space (pre-impact) and Earth (post-impact)**
   i. Develop **scenario – dependent detailed plan / mission exemplars**. **End-to-end sim** allowing the above to be accomplished: **Tradeoff launch vehicles, payloads, launch timing, target acquisition, / closing, and end game guidance**. From the above, develop **the generalized planning / mission descriptions** sought in this.
   j. 1) **Orbital Mechanics algorithms** which are coupled to astronomical and statistical data. 2) **Integration of launch capability with current deflection technology**
   k. **Incorporate scenario into multiple hazard exercises/training**. Integrate effects models into fast running tools.

l. **Integrated robust modeling tools** to best establish **impact location, effect of impact, fallout tools (DTRA Plume)**
m. **Perfect [the] tools available now, first**. Then examine gaps.
n. More research, S&T, dual – use missions by NASA. **Modeling of impacts.** We have a lot of work to do.
o. --
p. **PanSTARRS like scopes. Space Based Detection**.
q. We need **end-to-end modeling tools in Ops Centers (DHS/FEMA) / NMCC, or DTRA Reachback**. Tool needs to take **error ellipse and wrap around it the blast and plume effects model including terrain and tsunami effects**. We need **comprehensive deflection mission modeling tools**. We need clear presentation charts to illustrate for leadership why one option is preferred over another. We need to **include NEOs/PHOs in our formal definition of Space Situational Awareness**, and create requirements to survey down to 30m (including in-space "**NeoStar" IR telescope in Venus-like orbit**), and to have in-space **SSA to provide continual warning to ensure at least 48hrs** for evacuation.
r. More properly **adapted and vetted software simulations to be used to inform decisions makers of the nature and severity of the expected impact** so that they can more **confidently speak to the response teams and public** on what must be done to prepare for the event.

3) What **processes** need to be amended to accommodate response to the presented scenario?

a. Reduce sharing of threat data from NASA/MPC to rest of world
b. Interagency Planning Process. **Policy development & Modification Process**
c. Government **planning for very infrequent catastrophic events**
d. Suggest utilize the **FEMA Emergency Ops Center at Mount Weather in Virginia used for Continuity of Government (COG) exercises**.
e. More political input needed. Not everyone will be supportive of Nuclear option
f. Integration of scientific + other agencies. **Notification standards**. **Clear delineation of responsibilities**
g. **Interagency process @ NSC / HSC level**. Space Authority and responsibility – mapping vs kinetic. **Modeling – kinetic, plume, tsunami – integrated approaches**. **Notification** process
h. Chains of Command for notification
i. At Least—tighten up **the federated nature of the warning / prediction and effects prediction process**
j. Chain of command and responsibility delegation are needed
k. **Formalize communication process out of NASA**. **Formally recognize DHS lead role**—domestic. **Alter NTBT if nukes to be used in space**.
l. **Clarify who has authorities for engagement** of the comet [asteroid] and what needs to be modified (nuclear weapons in space). **Establish a National Decision Support System**.
m. **Notification** (who, what, when, how)
n. Need to **create an advisory board that would be called in event** of a high-risk PHO discovery. Board should consist of experts in affected agencies.
o. --
p. --
q. **NMCC, COCOM, and STATE notification should have a special checklist** of action. **Coast Guard should have pre-developed specific actions. FEMA should have specific pre-planned actions**. Given the concern that the public will know before it even gets to leadership, we need **to have a single authoritative voice with tools that clearly present information**. **NASA must formalize notification process** and develop tools to predict when: orbital refinement will take place, when error ellipse will collapse and to what, when observations are predicted for various sensors.

National Security Assets need to get software upgrades to allow them to participate in orbital refinement.

r. An impact emergency scenario must be incorporated into the Emergency Response Plan list of scenarios so that some advanced planning can be initiated.

4) What **documents / guidance** need to be amended to accommodate response to the presented scenario?

a. --

b. NDS, NSS, Outer Space Treaty, Nuclear Test Ban Treaty, GEF, JSCP, UCP, COCOM CONPLANS / OPLANS

c. Many, particularly **mission statements**

d. Prepare a **COG Presidential Decision Directive (PDD)**

e. None

f. **Authorization requirements**. **Comms / message templates**

g. National Response Framework? NSC / HSC framework

h. The **national planning scenarios** need to have this thing as one of the scenarios

i. Can we get charter to **develop a <u>document</u> that is available on a shelf that, given an event, tells leadership what to tell <u>US</u> to do**? This would be refreshed continuously –and it would be derived from the article in item #2.

j. A general **scenario flowchart to include data gathering**, mission options available, factors for **mission decision, mission preparation, mission planning, mission execution, and assessments**.

k. Present **official letter with recommendations to NASA + DHS decision policymakers**.

l. First start with **clarity of existing authorities/guidance**, much of which was discussed.

m. **Use existing documents / guidance first**. **Exception is deflecting options**.

n. Position papers on scenario studies, risk assessments, mitigation strategies

o. --

p. Need to amend **UCP, GEF + JSCP**

q. **National Space Policy to specify responsibilities for deflection**. **Air Force roles and missions or NASA charter (or new agency) and/or STRATCOM responsibilities**.

r. Some **policy on lead/supporting relationships** among government agencies needs to be thought through and **documented** for an impact scenario.

Congress has tasked the director of the Office of Science and Technology Policy (OSTP) to:
(1) develop a <u>policy for notifying Federal</u> agencies and relevant emergency response institutions of an impending near-Earth object threat, if near-term public safety is at risk; and
(2) <u>recommend a Federal agency or agencies to be responsible</u> for--
(A) protecting the United States from a near-Earth object that is expected to collide with Earth; and
(B) <u>implementing a deflection campaign</u>, in consultation with international bodies, should one be necessary.

5) Do you have **any insights / recommendations from this workshop that might assist them**?

a. --

b. --

c. The **development of interagency teaming and budgets**

d. **NASA focus on Data analysis and publication**. Defense **provide NEO survey to 140M** with PANSTARS 4+MAPAR[?]. NSF provide follow up observations with 4M primaries. DOE provide mitigation studies and also development of nuclear option. DHS provide emergency response coordination

e. **Split the space vs. Terrestrial aspects** of the possible event

f. NTSR

g. 1) **MOTR Plan or HSPD 48, port security PD**. Process to handle exigent interagency issues inteiajsn. 2) **DoD – Prob USAF**. **Protect = DoD, deflect DoD**. LFO – DHS **HLS = Consequence management**

h. Have **specific states that have expertise** [eg. California Earthquakes; Florida + Hurricanes] and have them help other states prepare for these events that they aren't used to.
i. Again, such insight better be in the product of #2 & #4.
j. Currently **NASA NEO program manger should inform federal agencies and international players**. If CONUS impact unavoidable, then **information must be passed to local governments**. For **deflection campaign, DTRA or NASA should lead**.
k. See #3. **NASA has responsibility to improve detection and tracking**. **DoD for deflection. DHS has responsibility for response – CONUS**.
l. Need to do **more international engagement**! If we're running analysis 12-hours/day only, why not ask **the Australians to run opposite 12 hours**.
m. Model of existing paradigms vs. re-creating the wheel.
n. **New org. (akin to Manhattan Project)** would need to be stood up for deflection once PHO is determined to have ~100% impact probability
o. To date the research **using nuclear explosives to divert or disperse asteroids has been limited to uncoordinated** small studies. The **DOE labs have the correct expertise** for this work and should be **encouraged to develop a more comprehensive set up studies** on the asteroid response for different bomb types.
p. --
q. **Run a higher-level event with missing players**. **NSC participation essential**. Recommend a **Defense Science Board and AF Scientific Advisory Board** also consider the problem. Consider carefully the **risks of international involvement** on the critical path or critical decisionmaking. Make a strong recommendation—**neither DoD or NASA appear to want the mission as it competes for resources with other priorities**. DoD makes the case it only worries about manmade problems. NASA makes the case it is human and robotic exploration, not defense, with no nuclear authority.
r. **Do not start from scratch**. **Review existing emergency response plans** to see what already exists and can be adapted to respond to this scenario. The closer the policies and procedures are to already existing and somewhat familiar plans there are, the greater chance there is for a realistic and successful response.

6) How do you see the **proper division of responsibilities** and **supported / supporting** relationship?

a. **STRATCOM should execute** overall. **DTRA should lead weapon tech** effort. **NASA should NOT lead!** (**No quick reaction skills** for complex projects and consistently lousy schedule performances.) **Possibly put JHU-APL in charge of space effort** (or at least spacecraft development). **Deflection campaign must be preceded (pre-crisis) by development and test program**, including in-space intercepts and nuclear experiments.
b. **Within DoD. USSTRATCOM** – Supporting CC. Appropriate GCC – Supported CC
c. To be determined
d. See above. **Suggest $5 million per year for NASA, DEFENSE, NSF, and DOE**. PANSTARS4 could detect 70% of >=140m PHOs in 20 years (~14,000 PHOs)
e. There **is <u>no</u> clear division**. There is **expertise spread** throughout government.
f. **Depends on where** the event is to occur. **DHS – Domestic event**. **DoS – International** event
g. I see **DoD as lead for protect NEO/ Implement deflection campaign**. I see **DHS as supported for consequence managemen**t as this would be a support to state/ local scenario via our constitutional / federalist organization.
h. There is **no defined leader** in such an event. There **needs to be in place a leader** for a CONUS event and for a O-CONUS event.
i. Lt Col Nolan's outbrief should cover this…or more precisely the problem we had in coming to a conclusion on this.
j. **NASA or DTRA should be sole responsibilities** and **all others be supporting**.

k. **Space / interception / deflection goes to DOD/NASA**. **Domestic on the ground goes to DHS w/ support from all others. International event goes to State Dept.**
l. Not sure – **it's not clear** – which is why we love a problem.
m. There, but confused and **lack of broad understanding of existing authorities**.
n. **NASA: Data collection**, Info dissemination; **DOE: Weapons development**; **DoD: Implementation**
o. --
p. **NASA – Lead**. **DOE – Deflection alternatives**. **MDA – Terminal Guidance and Fuzing**. **DoD – Support SSA, post impact support to civil authority**
q. For **domestic response – DHS supported by all others.** For **abroad response State** supported by all others (with specific COCOM notification / advice plans). For **deflection effort, STRATCOM should run overall project C2** with direct support from DTRA & DOE for nuclear deflection, AFRL & NASA for non-nuclear deflection, NASA and DoD Space Labs for spacecraft design and mission planning, AF and NASA for launch, and NSF, NASA & NRO support for SSA. DoD should be given the mission for NEO Space Situational Awareness and survey.
r. It is very dependent on the actual impact scenario. If predicted to be a near term **domestic impact, DHS has the lead**. If **foreign, DOS**. If longer term with some possibility of **mitigation actions, perhaps NASA or DoD, or perhaps a specially instituted impact emergency response agency**. Regardless, support must come from many different government agencies.

7) Were you **previously aware** of this scenario? Never / Barely / Quite familiar
a. **Quite Familiar**
b. Barely
c. Between barely and quite familiar
d. **Quite Familiar**
e. **Quite Familiar**
f. Never
g. Barely
h. Never
i. **Quite Familiar**
j. **Quite Familiar**
k. **Barely**
l. **Barely**
m. **Barely**
n. **Never** (not these specific scenarios)
o. **Quite Familiar**
p. --
q. **Quite Familiar.**
r. **Yes, very familiar**.

8) What might you change **in a future Natural Impactor Scenario**?
a. Create **matrix of (top-level) descriptions of preferred responses** for given responses
b. **Scope** and evolution of **particular objectives** dealing **with interagency proposed roles and responsibilities**
c. **Large impactor**
d. Have it as one of the **annual Interagency COG Exercises at Mount Weather**
e. I might have an **international element** (even if it was simulated)
f. Make it **real time, multiple day** event
g. **Capture the critical paths WRT decision-making critical** paths (Eval Deflection). Even greater **highlight of HLSEC/HLDef Seams + intnl planning risks**

h. Have **more involvement from NASA + NOAA**
i. This is twist…the general nature of today's threat orbits helped us make sure we didn't skip over anything important…But it **left many unknowns** that prevented any satisfying consequences. Perhaps **a directly-tasked tiger team that develops response exemplars ahead of the time that an exercise event validates / corrects** (it's tough to attack this problem by Ad-Hoc committee)
j. Should require **more organizational specific and less technical details**.
k. Make it **part of multi-hazard scenario**
l. Fewer **movies/gee whiz stuff which created too much discussion + not enough time to actually work** issue
m. **Scenario read ahead** w/ **existing authorities documents as references**
n. I didn't think the "binary" impact separated by 1000's of miles was realistic
o. --
p. --
q. **Multi-day event. Start with Policy Coordinating Committee. Model ground truth in a Sim** to include **all data about asteroid and orbital elements** to allow true mission planning. Model weather, Moon, and instruments to **know when actual observation opportunities occu**r. Bring in **State and local officials**.
r. Multiple objects and timeframes confused the players some. Concentrate on a more specific , single object scenario.

9) **Who needed to be at this workshop** and wasn't?
a. **USSTRATCOM, JHU-APL, NASA Ames**
b. **USSTRATCOM, USNORTHCOM**
c. **USSTRATCOM**
d. **NSF, NNSA, DOE Emergency Preparedness (COG)**
e. **More State Dept**
f. **FEMA? Army? Int'l reps**
g. **A state emergency manager –** would offer very different perspective. **NOAA-** they do a lot. **NORTHCOM + FEMA response personnel**
h. **NOAA, FEMA**
i. Others had recommendations; I had none-yet.
j. Do not know. **Gen Smith and Gil Siegert were particularly important for senior visioning**
k. **--**
l. **More experienced DHS, DoS, Policy individuals with better insights.**
m. **HSC Staff.**
n. **FEMA**
o. **Justice Dept Advisor** on how to legally make all resources available in short term
p. **--**
q. **USSTRATCOM, NORTHCOM, NSSA, FEMA, NOAA, B612, Civilian expertise outside government, British researchers** for international perspective
r. **FEMA, OSTP**.

10) Was this scenario useful in general to **facilitate interagency deliberate planning**?
a. Somewhat
b. Yes
c. Yes
d. Yes
e. Partly, members would have to **go back to their agency** and do some research/homework, get buy-in, then **return for a second session**

- **f. Yes**
- g. **Yes** – A unique planning scenario that **cuts across traditional planning elements** while also being **a realistic/probabilistic event**
- **h. YES**
- i. See #8
- j. **Yes. Interagency planning was useful**.
- **k. Not unless raised to a higher level.**
- l. **Yes** – recommend **continuing to run TTX, until fine-tuned + then take to NORTHCOM or STRATCOM to do a TTX.**
- **m. Yes**
- **n. Yes**
- o. --
- p. --
- **q. Yes.**
- r. **Yes,** but it needs to be taken to a higher level to expose agency decision makers to the scenario.

11) Was this event **useful for you** and/or your organization?
- a. Somewhat, especially if there is follow up and POC's remain in touch
- **b. Yes**
- **c. Yes**
- **d. Yes**
- **e. Yes**
- f. Marginally for this type of event. Better from **networking** perspective
- **g. Yes** – feeds into the existing debates over whether national security organization needs to be modernized. Also feeds into needs to **address vice postpone discussions about HLS/HLD seams**
- **h. Yes**
- **i. Very**
- j. **Yes.** There was good information presented.
- k. **Yes** – It helped me **identify potential areas for DHS/S+T future investment**
- l. **Yes** – good **cross talk** and greater awareness for all participants
- **m. Yes (moderately)**
- **n. Yes**
- o. --
- p. --
- **q. Yes**
- **r. Yes,** it **allowed us to inform other agencies** about the potential for such an event and how it might unfold, what current capabilities there are to deal with it, but **mostly what doesn't exist to deal with it.**

12) What **additional information** or support would be of use **to improve understanding and planning in your organization** to prepare for response to a natural impact?
- a. Formal request/**requirement to gather data (conduct tests) supporting models** and **understanding for weapons effects on Ni-Fe Materials and "Rubble Piles" – warhead penetration data and design. Funding**, etc.
- b. --
- c. To be determined
- d. **Briefing of the incoming senior management (DOE Secretary and Undersecretaries**)
- e. Honestly, the Probability is so low that planning, (deliberate planning) can only go so far. Unless it was a **whole-of-gov plan**, the structure + organization as well as leadership will be so different that

individual agency plans are of limited utility. This working group **didn't address the detection issues**. This should be the largest effort today.

f. An **understanding of the C2 and Command center architecture**. Request you send out and e-mail w/ all participants contact info included. Also request to be sent the **formal AAR** from the event. Thank You. Thanks to your wife for the great food! Nice Touch! Room was uncomfortably warm + a bit overcrowded. Recommend change venue for future events.

g. Better understanding of **tsunami modeling + probability**

h. An **all encompassing planning event for Earthquakes, hurricanes, and Nuke** (minus the radiation)

i. I need to defer to Mr. Myrick from an official answer..My personal answer is that a **letter of information** might be sent to the proper level from the proper level at MDA. Might not generate anything except cognizance, but that's a start.

j. It would be useful to have a **pre-brief** to get all players and the same knowledge level before the scenario.

k. Clearer, **more definitive discussion of effects modeling from a scientific perspective**; presence of more **players from decision support system scientific community** – for my personal take-aways from this day.

l. See#4. Provide a **ref to all of the existing DoD, etc. Guidance** and a short exec sum of each to clarify/speed process.

m. Threat understanding opportunities / **briefs to leadership**.

n. Funding to **model realistic scenarios** so if impact object is discovered we will have a **better basis to advise decision-makers**

o. --

p. --

q. Understanding **limits and capabilities of sensing instruments**. Information about on-**spacecraft survey capabilities** (and mass) and what they add to modeling.

r. **Documentation of official positions** from other government agencies on the roles and **responsibilities each believes they have for such a scenario**.

APPENDIX C: PARTICIPATING ORGANIZATIONS

The following Organizations were represented at this seminar:

National Security Council (NSC) Defense	(played POTUS round 1)
OSD Strategic Policy	(played POTUS round 2)
Joint Staff/J5 United Command Plan	(played AFRICOM)
Joint Staff/J5 National Military Strategy	(played STRATCOM)
Joint Staff/J5 Space Situational Awareness	(played NORTHCOM)
National Security Space Office (NSSO) Policy	(played Space Executive Agent)
Department of Homeland Security (DHS/S&T)	(played DHS)
Department of State S&T	(played State)
National Aviation and Space Administration (NASA) HQ	(played NASA)
Department of Energy (DOE) HQ	(played DOE)
OSD Homeland Defense	
National Military Command Center (NMCC) / J4	
Air Force Operations Group (AFOG)	
Missile Defense Agency (MDA)	
Defense Threat Reduction Agency (DTRA) Reach-back	
Air Force Checkmate (HAF/CK) & Coast Guard	
US Navy USN/N51 Strategic Concepts	
Defense Threat Reduction Agency (DTRA) Weapons Effects	
Lawrence Livermore National Lab (LLNL)	
Sandia National Lab (SNL)	
Air Force Research Laboratory (AFRL) Munitions	
Air Force Air Armaments Center (AAC/XRX)	
OSD Policy Planning	
Air Force Future Concepts (AF/A8XC)	

APPENDIX D: EXERCISE PLAYERS AND PARTICIPANTS

On-site participants & players:

Smith, Brig Gen, National Security Council

Boslough, Mark, Sandia National Laboratory (SNL)
Bucknam, Mark, Col (USAF), OSD-POLICY
Charlie Broadwater, DTRA
Coyne, Kevin M CDR JCS J5 S&P
Cserep, John D Mr CIV USAF AFMC AAC/XR
Dave Dearborn, LLNL
DeLaMater, Douglas C LT Col JCS J5
Desmond, Michael P LCDR CNO, N5SP;
Dockery, David Col (USAF) OSD POLICY
Earle, Stephen M LtCol JCS J 5 S&P SPOL
Engelhardt, Christopher M 1stLt USAF AFMC AFRL/RWAC
Fazenbaker, David Maj AF/A30-AOBC;
Garretson, Peter Lt Col AF/A8XC
Goodwin, Dave, DOE HQ
Greczyn, Warren CTR MDA/DEEC
Hiss, Steven T Col AF/A8XC
Hynes, Mary Ellen, Department of Homeland Security S&T
Johnson, Lindley, NASA HQ
Keeports, Timothy L LtCol Joint Staff J4/Readiness Division
Myrick, Erwin CIV MDA/SN/DV
Nolan, Jeffrey R LT Col JCS J5
Parete-Koon, Suzanne T, Department of State (OES)
Schaffer, Audrey M Ms OSD ATL NSSO
Servidio, Joseph A CAPT HAF/CK
Siegert, Gil, CIV, OSD-POLICY
Ullrich, Gilbert Wayne CIV, DTRA

Off-site participation & support:
Adams, Robert B. (MSFC-ED04);
Cambier, Jean-Luc J Civ USAF AFMC AFRL/RZSA
Ward, Steven N., University of California, Santa Cruz
Yeomans, Don, NASA JPL

APPENDIX E: ACRONYM LIST

2008 Innoculatus – Mythical asteroid used in this scenario
2008 TC3 – A small asteroid, the first discovered and tracked to atmospheric impact

A8XC – Air Force Future Concepts
ADRC – Asteroid Deflection Research Center (Iowa State)
AFI – Air Force Instruction
AFOG – Air Force Operations Group
AFPD – Air Force Policy Directive
AFRL – Air Force Research Lab
AFRICOM – United States Africa Command
Albedo – The extent to which an object diffusely reflects light from the Sun
AO – Action Officer
Apophis – An asteroid that has a small chance of striking Earth in 2036
ASE – Association of Space Explorers
AFSPC – Air Force Space Command
AIAA – American Institute for Aeronautics and Astronautics
C2 – Command and Control
CI -- Critical Infrastructure
CIP -- Critical Infrastructure Protection
CIPAC -- Critical Infrastructure Partnership Advisory Council
COCOM – Combatant Command
COG -- Continuity of Government
CONOPS – Concept of Operations
CONUS -- Continental United States
COOP -- Continuity of Operations Plans
COPUOS – Committee on the Peaceful Uses of Outer Space (United Nations)
CSAF – Chief of Staff of Air Force
DeltaV – Change in Velocity
DelMarVa – Delaware Maryland Virginia Peninsula
DHS – Department of Homeland Security
DOD – Department of Defense
DOC – Department of Commerce
DOE – Department of Energy
DOS – Department of State
DTRA – Defense Threat Reduction Agency
EAP – Emergency Action Plan
ECO – Earth Crossing Object
EM -- Electro-Magnetic
EMAC -- Emergency Management Assistance Compact
EMP – Electro Magnetic Pulse
FEMA – Federal Emergency Management Agency
FG – Futures Game
GEF -- Guidance for Employment of the Force
HCIP – Homeland Critical Infrastructure Program
HLC -- Homeland Security Council
HLD -- Homeland Defense
HLS -- Homeland Security
HPAC – Hazard Prediction and Assessment Capability (DTRA)

HSC – Homeland Security Council
HSIP -- Homeland Security Infrastructure Program
HSPD -- Homeland Security Presidential Directive
Hrs - Hours
JHU/APL – John Hopkins University Applied Physics Laboratory
JPL – Jet Propulsion Laboratory
JS – Joint Staff
JSCP – Joint Strategic Capabilities Plan
JSPOC – Joint Space Operations Center
Kg -- Kilograms
KR -- Key Resources
LLNL – Lawrence Livermore National Laboratory
LANL – Los Alamos National Laboratory
LEO -- Low Earth Orbit
LINEAR -- Lincoln Near Earth Asteroid Research
LONEOS -- Lowell Observatory Near-Earth Object Search
m – Meters
MARE – Major Accident Response Exercise
MDA – Missile Defense Agency
mph – Miles per Hour
MOU – Memorandum of Understanding
MOTR -- Maritime Operational Threat Response
MPC – Minor Planet Center
MSFC – Marshall Space Flight Center
NASA – National Aeronautical and Space Agency
NIPP -- National Infrastructure Protection Plan
NCR – National Capital Region
NDS – National Defense Strategy
NEA – Near Earth Asteroid
NEC – Near Earth Comet
NEO – Near Earth Object
NEODyS – Near Earth Objects Dynamic Site
NEOO – Near Earth Object Observation program
NLE – National Level Exercises
NMCC – National Military Command Center
NNSA – National Nuclear Security Agency
NOAA – National Oceanic & Atmospheric Agency
NORAD – North American Air Defence Commande
NORTHCOM – US Northern Command
NRC – National Research Council
NRO – National Reconnaissance Office
NSF – National Science Foundation
NSP – National Security Plan
NPS – National Planning Scenarios
NRC – National Research Council
NRO – National Reconnaissance Organization
NSPD – National Security Presidential Directive
NSC – National Security Council
NSS – National Security Strategy
NSSO – National Security Space Organization
NNSA – National Nuclear Security Agency

NOAA – National Oceanic and Atmospheric Association
OCONUS -- Outside CONUS
OER – Office of External Relations (NASA)
OLIA – Office of Legislative and Intergovernmental Affairs (NASA)
OPREP – Operational Report
OSD – Office of the Secretary of Defense
OSTP – Office of Science and Technology Policy
PAO – Public Affairs Office
PDD – Presidential Decision Directive
PHA – Potentially Hazardous Asteroid
PHO – Potentially Hazardous Object
POC – Person of Charge
QDR – Quadrennial Defense Review
POTUS – President of the United States
RADAR – Radio Distance and Ranging
RFI – Request for Information
SCATANA -- Security Control of Air Traffic and Air Navigation Aids
SFF – Space Frontier Foundation
SME – Subject Matter Expert
SNL – Sandia National Laboratory
SORTR – Space Operational Threat Response
SPCC Space Policy Coordinating Committee
SSA – Space Situational Awareness
SMD – Science Mission Directorate (NASA)
SOP – Standard Operating Procedure
S&T – Science and Technology
TOPOFF – Top Officials Exercise
TNT – Trinitrotoluene (measure of explosive strength)
TRL – Technological Readiness Level
TSOC –Theater Special Operations Components [exist at sub-unified commands to provide special operations expertise to geographic commanders]
UCP -- Unified Command Plan
USAF – United States Air Force
USAFRICOM – United States Africa Command
USCG – US Coast Guard
USNORTHCOM – United States Northern Command
USSTRATCOM – United States Strategic Command
WMD -- Weapons of Mass Destruction
XCON – Executive Control

APPENDIX F: NASA REQUEST

National Aeronautics and
Space Administration

Headquarters
Washington, DC 20546-0001

Reply to
Attn of: SMD/Planetary Science Division

August 26, 2008

Director, Air Force Strategic Planning
HQ USAF/A8X
1070 Air Force Pentagon
Washington, DC 20330-1070

SUBJECT: Inclusion of Natural Impact Events in AF Strategic Planning Activities

NASA recognizes that the USAF Strategic Planning group broadly solicits ideas for future concept exploration and Air Force futures wargame activities. With that in mind, the Planetary Science Division of NASA recommends that you consider the situation of an approaching natural impact of a Near Earth Object that would create a devastating natural disaster as an upcoming USAF strategic planning effort. For background purposes let me elaborate.

Over the last 10 years NASA has made significant progress in our understanding of the real threat that asteroid and comet impacts could pose to life and human civilization here on Earth, implying - at some level - there are national security interests to be considered. Though our current space situational awareness capabilities are very modest we are now approaching our goal of finding 90% of the naturally occurring Near Earth Objects (NEOs) greater than 1 kilometer in size. These objects are capable of causing global devastation should they ever impact Earth. Of an estimated population approaching one thousand, 813 have been discovered and tracked to determine their obits. One hundred forty of these are in orbits that pose a potential hazard to Earth, though none are predicted to impact in the next 100 years.

However, we have also discovered 4,763 NEOs that are smaller than 1 kilometer and, because of their greater number, pose a more frequent impact hazard. Recent modeling at Sandia National Lab suggests that asteroids as small as 30 meters can penetrate the Earth's atmosphere and airburst at low altitude, devastating an area the size of the DC metropolitan area. Over 966 objects this size and larger have been found in potentially hazardous orbits. We estimate that there are probably 100,000 more to be discovered. Within this number there are likely several hundred on trajectories for future close encounters with Earth that will require close tracking, and a few could be candidates for potential orbit deflection activities. One such known asteroid, called "Apophis" (270 meters in estimated size), makes a close approach to Earth every six to seven years, and will come so close in 2029 that it will be within the distance of the geosynchronous satellite belt. Dependent on the post encounter trajectory, the next approach in 2036 may be even closer and is calculated to have a 1 in 45,000 potential for impacting the Earth. Additional observations and orbit analysis must be completed before this possibility can be completely eliminated.

It is estimated that a capability to deflect an asteroid on a predicted impact trajectory would require at least two decades of advanced notice to plan, develop and implement. Though there have been some academic studies of the scenario, we feel it is now time that such knowledge moves from the academic to the policy and security communities that have obligations under Executive Order 12656 (National Security Emergency Preparedness Policy), DoD Directive 3025.1 (Military Support to Civil Authorities), or DoD Directive 5100.46 (Foreign Disaster Relief) and NSPD 49 (National Space Policy). Whether in impact disaster response or proactive mitigation, the USAF is likely to have significant roles and equities that need significant advance planning and consideration.

As you consider what future studies you perform, NASA stands ready to work with you in this proposed effort. Please let me know if you would like our assistance to consider this concept further.

James L. Green
Director, Planetary Science Division

NASA simultaneously engaged the National Security Space Office (NSSO) on the Natural Impact topic. A8XC closely collaborated with NSSO, and became aware of the following letter from the Space Frontier Foundation (SFF) which arrived the following month. The SFF letter also influenced the agenda to move Natural Impactors from the halls of science to defense planning:

SPACE FRONTIER FOUNDATION

Advancing NewSpace

William Watson
Executive Director
16 First Avenue
Nyack, NY 10960
1.800.787.7223

September 5, 2008

Mr. Joseph Rouge
Director
National Security Space Office
1670 Air Force Pentagon
Washington, DC 20330-1670

Dear Mr. Rouge:

This past June 30th marked a momentous event: one hundred years earlier, the Tunguska region of Russia was rocked by an explosion of what was later determined to be a near-Earth object (NEO) striking our atmosphere. The impact of this object, estimated to have been only 30 meters in diameter, resulted in a blast equivalent to 10-15 megatons of TNT, 1000 times more powerful than the atomic bomb dropped on Hiroshima in 1945. While the effects of this impact were limited to a very remote and sparsely populated portion of the Earth, the energy from the blast was enough to level 80 million trees over 830 square miles. Had this event occurred over a more densely populated urban area, the human consequences would have been catastrophic: Had the impact occurred just a few hours later, it would have destroyed the Russian capital, Saint Petersburg.

The 1994 collision of Comet Shoemaker-Levy 9's fragments with Jupiter was our first modern glimpse of the destructive power of these collisions; one impact fireball was the size of the entire Earth.

Today the threat posed by these NEOs remains the same as in 1908. Unfortunately, our ability to prevent an impact from one of these objects also remains unchanged. While we have a much greater ability to detect, track, and calculate the chances of an object hitting the Earth, we have essentially no ability to take action once an impending impact is confirmed. With an ever-increasingly interdependent world community and economy, even a small NEO strike could have overwhelming consequences.

The subject of NEOs and our defense against them has gained renewed attention of late. The United States is beginning to recognize that the threat posed by Earth-crossing NEOs may be comparable to (if not greater than) that posed by the proliferation of weapons of mass destruction. While NEO impact events may be lower in likelihood, their destructive effect would be much greater, and so their net risk is unacceptably high. This calculus is further complicated by the uncertainty of when and where an impact might occur – potentially with no warning.

www.spacefrontierfoundation.org

We believe that, consistent with the Constitutional obligation of the U.S. Government to "provide for the common defense," the Department of Defense should lead the effort to develop a strategy for our planetary defense from NEOs with support from other federal agencies. In this effort, there will be roles for United States Strategic Command, U.S. Northern Command, U.S. Joint Forces Command, the U.S. Air Force, and the National Reconnaissance Office among many others. As the only office specifically focused on cross-space enterprise issues involving all of the national security space stakeholders, we feel it appropriate that the National Security Space Office become the vanguard in this effort.

Such a strategy should pursue the following core objectives:

1. Achieving consensus on a proper assignment of organizational responsibility for key aspects of the mission
2. Shepherding of formal requirements for mission capabilities that would inform architecture studies
3. An initial strategic plan to develop ever-increasing spirals of operational capability, which must include:
    - Maximization of our capability to track NEOs as part of our comprehensive space situational awareness and space protection capabilities; to accurately predict their trajectory and calculate the likelihood, time and likely location, and expected damage of possible Earth-impact;
    - Development and implementation of standardized procedures for dissemination of information about possible NEO impacts in a manner that maximizes the ability of other governments to take precautionary measures while minimizing unnecessary public concern and ensuring that high altitude NEO detonations—which occur routinely every year—are not mistaken for nuclear blasts;
    - Develop specific requirements that drive the development of ever-increasing technical capabilities for diverting the course of NEOs;
    - The creation of planning tools to inform decision-makers, including cost/benefit analysis by which the NEO risks can be compared with the expense of mitigation; and
    - The development of standard reference plans that may be implemented for the diversion of NEOs consistent with that cost/benefit analysis.

NSSO should also give special consideration as to how the U.S. government might be able to facilitate the development of technologies with capabilities for both NEO threat mitigation and commercial NEO mining. Through effective partnerships with the private sector and strategic investments, the U.S. government could leverage private investment in such technologies to achieve greater NEO capabilities while at the same time:

- Advancing American space-faring capabilities;
- Opening the vast mineral wealth of the inner solar system to incorporation within humanity's economic sphere; and
- Thereby enabling ambitious space construction projects such as space-based solar power.

In particular, opportunities may exist where a public-private partnership could characterize one or more dangerous NEOs for deflection using private funding and public indemnification and government oversight, while simultaneously providing a survey of mineral resources and protecting intellectual property for commercial mining consideration. Of course, any diversion of NEOs for commercial purposes will itself require U.S. Government supervision to minimize the potential risks involved.

We, the undersigned, urge you to lead your colleagues within DOD and the broader Executive Branch to recognize both the threat and the opportunity posed by NEOs and therefore to begin planning accordingly for the good of the United States and all humanity.

Very Truly Yours,

BERIN SZOKA

____

Berin Michael Szoka
Chairman of the Board
The Space Frontier Foundation

3

APPENDIX G: 2008 NASA AUTHORIZATION ACT

On Oct 15, the President signed HR 6063, the 2008 NASA Authorization Act into Law. Find the full text here: http://www.govtrack.us/congress/billtext.xpd?bill=h110-6063 Relevant to this exercise, it contains the following language (highlights NOT in original):

TITLE VIII--**NEAR-EARTH OBJECTS**
SEC. 801. REAFFIRMATION OF POLICY.
(a) Reaffirmation of Policy on Surveying Near-Earth Asteroids and Comets- Congress reaffirms the policy (g)) (relating to surveying42 U.S.C. 2451set forth in section 102(g) of the National Aeronautics and Space Act of 1958 (near-Earth42 U.S.C. 2451(g)) (relating to surveying near-Earth asteroids and comets).
(b) Sense of Congress on Benefits of Near-Earth Object Program Activities- It is the sense of Congress that the near-Earth object program activities of NASA will provide benefits to the scientific and exploration activities of NASA.
SEC. 802. FINDINGS.
Congress makes the following findings:
(1) Near-Earth objects **pose a serious and credible threat to humankind**, as many scientists believe that a major asteroid or comet was responsible for the mass extinction of the majority of the Earth's species, including the dinosaurs, nearly 65,000,000 years ago.
(2) Several such near-Earth objects have **only been discovered within days of the objects' closest approach to Earth** and recent discoveries of such large objects indicate that many large near-Earth objects remain undiscovered.
(3) Asteroid and comet collisions rank **as one of the most costly natural disasters that can occur**.
(4) The time needed to eliminate or mitigate the threat of a collision of a potentially hazardous near-Earth object with Earth is measured in decades.
(5) Unlike earthquakes and hurricanes, asteroids and comets can provide adequate collision information, enabling the United States **to include both asteroid-collision and comet-collision disaster recovery and disaster avoidance in its public-safety structure**.
(6) **Basic information is needed for technical and policy decisionmaking** for the United States to create a comprehensive program in order to be ready to eliminate and mitigate the serious and credible threats to humankind posed by potentially hazardous near-Earth asteroids and comets.
(7) **As a first step to eliminate and to mitigate the risk of such collisions, situation and decision analysis processes**, as well as **procedures and system resources, must be in place well before a collision threat becomes known**.
SEC. 803. REQUESTS FOR INFORMATION.
The Administrator shall issue requests for information on--
(1) a low-cost space mission with the purpose of rendezvousing with, attaching a tracking device, and characterizing the **Apophis** asteroid; and
(2) a medium-sized space mission with the purpose of detecting near-Earth objects equal to or **greater than 140 meters** in diameter.
SEC. 804. ESTABLISHMENT OF POLICY WITH RESPECT TO THREATS POSED BY NEAR-EARTH OBJECTS.
Within 2 years after the date of enactment of this Act, the Director of the OSTP shall--
(1) develop a policy for **notifying Federal agencies and relevant emergency response institutions of an impending near-Earth object threat, if near-term public safety is at risk**; and
(2) recommend a Federal agency or agencies to be responsible for--
(A) protecting the United States from a near-Earth object that is expected to collide with Earth; and
(B**) implementing a deflection campaign**, in consultation with international bodies, should one be necessary.
SEC. 805. PLANETARY RADAR CAPABILITY.
The Administrator shall maintain a planetary radar that is comparable to the capability provided through the Deep Space Network Goldstone facility of NASA.

SEC. 806. ARECIBO OBSERVATORY.
Congress reiterates its support for the use of the Arecibo Observatory for NASA-funded near-Earth object-related activities. The Administrator, using funds authorized in section 101(a)(1)(B), shall ensure the availability of the Arecibo Observatory's planetary radar to support these activities until the National Academies' review of NASA's approach for the survey and deflection of near-Earth objects, including a determination of the role of Arecibo, that was directed to be undertaken by the Fiscal Year 2008 Omnibus Appropriations Act, is completed.
SEC. 807. INTERNATIONAL RESOURCES.
It is the sense of Congress that, since an estimated **25,000 asteroids of concern have yet to be discovered and monitored,** the United States should seek to obtain commitments for cooperation from other nations with significant resources for contributing to a thorough and timely search for such objects and an identification of their characteristics.

SEC. 1105. INNOVATION PRIZES.
(a) In General- Prizes can play a useful role in encouraging innovation in the development of technologies and products that can assist NASA in its aeronautics and space activities, and the use of such prizes by NASA should be encouraged.
(b) Amendments- Section 314 of the National Aeronautics and Space Act of 1958 is amended--
(1) by amending subsection (b) to read as follows:
'(b) Topics- In selecting topics for prize competitions, the Administrator shall consult widely both within and outside the Federal Government, and may empanel advisory committees. The Administrator shall give consideration to prize goals such as the demonstration of the ability to provide energy to the lunar surface from space-based solar power systems, **demonstration of innovative near-Earth object survey and deflection** strategies, and innovative approaches to improving the safety and efficiency of aviation systems.'; and
(2) in subsection (i)(4) by striking '$10,000,000' and inserting '$50,000,000'.

APPENDIX H: SUMMARY OF A8XC ACTIONS

Within the intervening period, A8XC:

- Produced and presented an educational video on the subject for FG'05
- Presented the topic to the DARPA Defense Science Research Council
- Attended Aerospace Corporation sponsored 2007 Planetary Defense Conference
- Authored opinion pieces for:
  - 2007 Planetary Defense Conference
  - Air and Space power Journal
  - Journal of Astropolitics
- Submitted as a topic for study to:
  - RAND Project Air Force
  - AF Scientific Advisory Board 2005, 2006, 2007, 2008
  - AFIT, INSS, Air University annual topics, Blue Horizons
  - Army Science Board 2008
- Nominated the topic for 2005 legislative initiative
- Provided support to the National Security Space Office (NSSO) for AF cooperation in NASA's congressionally-tasked Analysis of Alternatives (AoA) for detection and deflection
- Requested and received an AFRL review of NASA AoA and future propulsion needs
- Requested and received AFRL munitions examination of mission considerations and modeling of kinetic impactors
- Requested and received AU/CSAT consideration of asteroid mitigation system in its 2008 Blue Horizons operations research model
- Engaged with various advocacy groups to understand their perspective:
  - AIAA
  - B612 Foundation
  - Association of Space Explorers
  - ProSpace
  - Space Frontier Foundation (SFF)
  - National Space Society (NSS)
  - Gaia Shield Group
  - Secure World
- Nominated NEOs become a topic for the Joint Space Partnership meeting (29 Oct)
- Requested USAFA Eisenhower Center host policy event
- A8XC compiled a list of relevant organizational POCs
- Nominated for AFRL leadership consideration in Focused Long Term Challenges (FLTC) strategic planning
- Provided support to Legislative Liaison in support of Congressional Aid Inquiry
- Briefed Air Force Strategic/Space Policy on threat analysis and policy gaps
- Briefed OSD Strategic/Space Policy on threat analysis and policy gaps
- Briefed State Dept on current threat analysis and policy gaps and security equities
- Engaged AFSPC Future Concepts and Counter-Space
- Nominated for inclusion of shocks in OSD Policy Planning
- Nominated topic to Office of Net Assessment for scenario exploration
- Co-Sponsored Iowa State Asteroid Deflection Research Center's (ADRC) 2008 Asteroid Deflection Symposium in Washington, DC[liii]
- Briefed Congressionally tasked National Research Council (NRC) review of NASA's NEO efforts
- In concert with the National Security Space Office, NASA, DTRA, and MDA, began compiling list of organizational representatives for broad interagency policy discussion to inform OSTP Congressional tasking to recommend a lead agency

END NOTES

[i] **Preparing for Planetary Defense**, presentation by Mr. Lindley Johnson to AF/A8XC

[ii] See ***Asteroid Threats: A Call for Global Response*** report to UN COPUOS at:
http://www.space-explorers.org/committees/NEO/docs/ATACGR.pdf
and http://www.space-explorers.org/committees/NEO/neo.html

[iii] Conference Announcement: **www.congrex.nl/09c04/First_Announcement.pdf**

[iv] See Appendix G or: **http://www.govtrack.us/congress/billtext.xpd?bill=h110-6063**

[v] **Known Advocacy Groups** & Websites for Planetary Defense:
ADRC(Iowa State) **http://www.adrc.iastate.edu/about-adrc.html**
AIAA http://www.aero.org/conferences/planetarydefense/2007papers.html
Association of Space Explorers (ASE)
http://www.space-explorers.org/committees/NEO/neo.html
B612 Foundation http://www.b612foundation.org/
Gaia Shield Group http://gaiashield.com/two.html
Lifeboat Foundation http://lifeboat.com/ex/asteroid.shield
National Space Society (NSS) http://www.nss.org/settlement/asteroids/index.html
Planetary Society http://www.planetary.org/programs/projects/apophis_competition/
Secure World Foundation (SWF) http://secureworldfoundation.org/ &
http://75.125.200.178/~admin23/index.php?id=16&page=Near_Earth_Objects
Space Frontier Foundation (SFF)
http://spacefrontier.org/forums/mapcom/neos-asteroid-mining
Billion Year Plan **http://billionyearplan.blogspot.com/**
Planetary Defense Blog **http://planetarydefense.blogspot.com/**

[vi] Excerpts from **Executive Order 12656** on Disaster Preparedness

(a) The **policy of the United States is to have sufficient capabilities at all levels of government to meet essential defense and civilian needs during any national security emergency**. A national security emergency is **any occurrence, including natural disaster**, military attack, technological emergency, or other emergency, that **seriously degrades or seriously threatens the national security of the United States**.

(b) **Effective national security emergency preparedness planning requires: identification of functions that would have to be performed during such an emergency; development of plans for performing these functions; and development of the capability to execute those plans**.

(d) National security emergency preparedness **functions that are shared** by more than one agency **shall be coordinated** by the head of the Federal department or agency having primary responsibility and **shall be supported** by the heads of other departments and agencies having related responsibilities.

Sec. 105. Interagency Coordination.

(a) All appropriate Cabinet members and agency heads shall be consulted regarding national security emergency preparedness programs and policy issues. **Each department and agency shall support interagency coordination to improve preparedness and response** to a national security emergency and shall develop and maintain decentralized capabilities wherever feasible and appropriate.

Sec. 201. General. The **head of each Federal department and agency**, as appropriate shall:

(1) **Be prepared to respond adequately to all national security emergencies**, including those that are international in scope. and those that may occur within any region of the Nation;

(2) **Consider national security emergency preparedness factors in the conduct of his or her regular functions**, **particularly those functions essential in time of emergency**. Emergency plans and programs, and an appropriate state of readiness, including organizational infrastructure, shall be developed as an integral part of the continuing activities of each Federal department and agency;

[vii] From: **An Open Letter to Congress on Near Earth Objects**. July 8, 2003. Available at: http://www.nss.org/resources/library/planetarydefense/2003-OpenLetterToCongressOnNearEarthObjects.pdf
Recommendation #3:
Develop NEO Contingency and Response Plans
Just as the federal government plans appropriate responses to disasters such as hurricanes and earthquakes, it should prepare contingency plans for dealing with an NEO impact. The government should begin planning now to deflect any NEO found to pose a potential threat to Earth. It should also plan to meet emergency response and disaster relief needs created by an impending or actual NEO impact. This government/private sector planning should include international coordination to address the issues of NEO detection, potential hazards and actual impacts. To guide essential contingency planning, we recommend the following:
• **Establish an Interagency NEO Task Force to address the NEO Impact Threat:** This Task Force should be composed of senior representatives from appropriate government agencies: Department Of Homeland Security; Department of Defense; Department of State; Department of Energy; NASA; Federal Emergency Management Agency; National Science Foundation; Office of Science and Technology Policy; and the National Research Council. The Task Force should also include appropriate representatives from industry and academia. It should be assigned responsibilities for guiding NEO impact contingency planning through an NEO Impact Response Center (see below), including identification, monitoring and analysis, international coordination of NEO search efforts, impact response and mitigation, and deflection strategies and technology.
• **Establish an NEO Impact Response Center:** This Center should be assigned responsibilities to -- (1) collate accurate information from all available sources on the threat potential of any potentially hazardous NEOs; (2) distribute such information and analysis to public agencies, both in the United States and overseas; (3) develop and implement contingency plans, to include the actions required to deflect an NEO if that becomes necessary; and (4) ensure that an unexpected impact is not misinterpreted as an attack on any country. The Center should collect astronomical and technical data about NEOs provided by existing research and search efforts. More importantly, it should verify this information and provide authoritative analysis to the President (and Secretary of Homeland Security), and the relevant committees of the Congress in the event of a projected NEO impact. The Center would enable U.S. civil and military authorities to develop the appropriate responses to an impact prediction and disseminate impact information worldwide.

[viii] From 2007 AIAA 2007 Planetary Defense Conference White Paper:
http://www.aero.org/conferences/planetarydefense/2007papers/WhitePaperFinal.pdf
2.3 Impact Consequences and Response
Many small objects enter Earth's atmosphere on a daily basis and a few yield fragments that survive to reach the surface as meteorites. While some small object entries lead to wrong place could be mistaken for an attack, potentially causing a dangerous response. Quick notification of such events, should they be detected, would help avert such consequences. Larger objects enter

less frequently, but the effects increase as size increases. As noted earlier, the 1908 Tunguska event occurred after an airburst of a 30- to 50-meter-diameter object, which caused widespread devastation. The energy released had previously been estimated in the range of 10 to 20 megatons. More recent estimates suggest that the energy released could have been as low as 3 to 5 megatons. An entry of this size is estimated to occur once every 1000 years on average. The statistical likelihood of such an entry this century is 1 in 10. Based on responses to past disasters, predictions are that an impact would result in initial confusion at all levels of leadership. The lack of understanding of the characteristics of a major impact event and impaired command and control are likely to result in delayed initial response efforts and resulting additional loss of life and suffering. As noted by Michael Chertoff, Secretary, U.S. Department of Homeland Security, in his testimony to the Select Committee Hearing after the Hurricane Katrina disaster: "This tragedy 'once again' emphasized how critical it is that we ensure our planning and response capabilities perform with seamless integrity and efficiency in any type of disaster situation—even one of cataclysmic nature."

Recommendations

2.3.1. **Conduct an Impact Response Exercise—a well-scripted and well-designed tabletop exercise, driven by improved gaming, modeling and simulation resources to increase understanding of the evolution of an impact disaster and demands on response agencies and communication systems.** For many natural disasters, agencies responsible for assisting those affected conduct simulations involving all segments of disaster response to identify issues and develop solutions. An unexpected NEO impact should be added to the set of disasters simulated. The disaster could be either from an ocean impact, where the effects could be experienced by a long expanse of coastline and possibly affect several or many nations, or from a land impact. The simulation would focus on effects of a 50- to 140-meter class NEO, a size that would likely impact without warning. Ideally, the exercise would involve all stakeholders that would be involved in a response, including local and national governments, military organizations, disaster responders, and members of the press.

2.3.2. **Incorporate the NEO hazard into the mandates of agencies, both national and international, that are charged with addressing very large-scale natural and man-made catastrophes.** Nations should assess the risk relative to natural and man-made hazards, and encompass the NEO response within existing national and international frameworks that address the more familiar hazards, ensuring that emergency response capabilities are suited to dealing with NEOrelated scenarios.

2.3.3. **Conduct additional research to advance understanding of the relationship between NEO size and event consequences.** This relationship is critical for setting the lower limit of our detection efforts and making the decision to initiate a deflection campaign or other mitigation efforts. Previously, NEO explosions above Earth's surface (events believed typical of a class of smaller NEOs) have been treated as point-source explosions. New information indicates that the shock and flow field generated throughout the entry trajectory may be important contributors to ground effects (tsunamis, etc.). Additionally, an impact could release an electromagnetic pulse that could interrupt communications among disaster responders. We may not yet understand the complete nature of the hazard associated with PHO impacts and the dependence of impact consequences on object size.

[ix] **FEMA**: **http://www.fema.gov/about/what.shtm**

The disaster life cycle describes the process through which emergency managers prepare for emergencies and disasters, respond to them when they occur, help people and institutions recover from them, mitigate their effects, reduce the risk of loss, and prevent disasters such as fires from occurring.

And at every stage of this cycle you see FEMA -- the federal agency charged with building and supporting the nation's emergency management system.

On March 1, 2003, the Federal Emergency Management Agency (FEMA) became part of the U.S. Department of Homeland Security (DHS). The primary mission of the Federal Emergency Management Agency is to reduce the loss of life and property and protect the Nation from all hazards, including natural disasters, acts of terrorism, and other man-made disasters, by leading and supporting the Nation in a risk-based, comprehensive emergency management system of preparedness, protection, response, recovery, and mitigation.

DHS Mission: **http://www.dhs.gov/xabout/strategicplan/**
This Department of Homeland Security's overriding and urgent mission is to lead the unified national effort to secure the country and preserve our freedoms. While the Department was created to secure our country against those who seek to disrupt the American way of life, our charter also includes preparation for and response to all hazards and disasters. The citizens of the United States must have the utmost confidence that the Department can execute both of these missions.

We will lead the unified national effort to secure America. We will prevent and deter terrorist attacks and protect against and respond to threats and hazards to the Nation. We will secure our national borders while welcoming lawful immigrants, visitors, and trade.
http://www.dhs.gov/xlibrary/assets/DHS_StratPlan_FINAL_spread.pdf

[x] **Coast Guard Missions: http://www.uscg.mil/top/missions/**
The United States Coast Guard is a military, multimission, maritime service within the Department of Homeland Security and one of the nation's five armed services. Its core roles are to protect the public, the environment, and U.S. economic and security interests in any maritime region in which those interests may be at risk, including international waters and America's coasts, ports, and inland waterways.

The Coast Guard provides unique benefits to the nation because of its distinctive blend of military, humanitarian, and civilian law-enforcement capabilities. To serve the public, the Coast Guard has five fundamental roles:

Maritime Safety: Eliminate deaths, injuries, and property damage associated with maritime transportation, fishing, and recreational boating. The Coast Guard's motto is Semper Paratus—(Always Ready), and the service is always ready to respond to calls for help at sea.

Maritime Security: Protect America's maritime borders from all intrusions by: (a) halting the flow of illegal drugs, aliens, and contraband into the United States through maritime routes; (b) preventing illegal fishing; and (c) suppressing violations of federal law in the maritime arena.

Maritime Mobility: Facilitate maritime commerce and eliminate interruptions and impediments to the efficient and economical movement of goods and people, while maximizing recreational access to and enjoyment of the water.

National Defense: Defend the nation as one of the five U.S. armed services. Enhance regional stability in support of the National Security Strategy, utilizing the Coast Guard's unique and relevant maritime capabilities.

Protection of Natural Resources: Eliminate environmental damage and the degradation of natural resources associated with maritime transportation, fishing, and recreational boating.

EPA Mission: http://www.epa.gov/epahome/aboutepa.htm
EPA leads the nation's environmental science, research, education and assessment efforts. The mission of the Environmental Protection Agency is to protect human health and the environment. Since 1970, EPA has been working for a cleaner, healthier environment for the American people.

[xi] **USNORTHCOM**: **http://www.northcom.mil/About/history_education/vision.html**

USNORTHCOM anticipates and conducts Homeland Defense and Civil Support operations within the assigned area of responsibility to defend, protect, and secure the United States and its interests USNORTHCOM's AOR includes air, land and sea approaches and encompasses the continental United States, Alaska, Canada, Mexico and the surrounding water out to approximately 500 nautical miles. It also includes the Gulf of Mexico and the Straits of Florida. The defense of Hawaii and our territories and possessions in the Pacific is the responsibility of U.S. Pacific Command. The defense of Puerto Rico and the U.S. Virgin Islands is the responsibility of U.S. Southern Command. The commander of USNORTHCOM is responsible for theater security cooperation with Canada and Mexico.

USNORTHCOM consolidates under a single unified command existing missions that were previously executed by other DoD organizations. This provides unity of command, which is critical to mission accomplishment.

USNORTHCOM plans, organizes and executes homeland defense and civil support missions, but has few permanently assigned forces. The command is assigned forces whenever necessary to execute missions, as ordered by the president and secretary of defense.

Civil service employees and uniformed members representing all service branches work at USNORTHCOM's headquarters located at Peterson Air Force Base in Colorado Springs, Colo. The commander of USNORTHCOM also commands the North American Aerospace Defense Command (NORAD), a bi-national command responsible for aerospace warning and aerospace control for Canada, Alaska and the continental United States.

USNORTHCOM's civil support mission includes domestic disaster relief operations that occur during fires, hurricanes, floods and earthquakes. Support also includes counter-drug operations and managing the consequences of a terrorist event employing a weapon of mass destruction. The command provides assistance to a Primary Agency when tasked by DoD. Per the Posse Comitatus Act, military forces can provide civil support, but cannot become directly involved in law enforcement.

In providing civil support, USNORTHCOM generally operates through established Joint Task Forces subordinate to the command. An emergency must exceed the capabilities of local, state and federal agencies before USNORTHCOM becomes involved. In most cases, support will be limited, localized and specific. When the scope of the disaster is reduced to the point that the Primary Agency can again assume full control and management without military assistance, USNORTHCOM will exit, leaving the on-scene experts to finish the job.

[xii] **USSTRATCOM Mission: http://www.stratcom.mil/about-visionmissionpriorities.html**

The missions of US Strategic Command are: to deter attacks on US vital interests, to ensure US freedom of action in space and cyberspace, to deliver integrated kinetic and non-kinetic effects to include nuclear and information operations in support of US Joint Force Commander operations, to synchronize global missile defense plans and operations, to synchronize regional combating of weapons of mass destruction plans, to provide integrated surveillance and reconnaissance allocation recommendations to the SECDEF, and to advocate for capabilities as assigned.

[xiii] **DTRA Mission: http://www.dtra.mil/about/index.cfm**

The Defense Threat Reduction Agency is a combat support agency of the U.S. Department of Defense. Founded in 1998, the agency headquarters is located in Fort Belvoir, Virginia. DTRA employs 2,000 men and women, both military and civilian at more than 14 locations around the world.

The threat of weapons of mass destruction is real and growing. Weapons of mass destruction can be chemical, biological, nuclear, radiological or high-explosive. DTRA is the go-to part of the Department of Defense to counter these weapons.

Mission

The Defense Threat Reduction Agency safeguards America and its allies from Weapons of Mass Destruction (chemical, biological, radiological, nuclear and high explosives) by providing capabilities to reduce, eliminate, and counter the threat, and mitigate its effects.

Vision

Our agency's vision is to make the world safer by reducing the threat of weapons of mass destruction.

DTRA is the intellectual, technical and operational leader for the Department of Defense (DoD) and the U.S. Strategic Command in the national effort to combat the weapons of mass destruction (WMD) threat.

[xiv] **MDA Mission**: **http://www.mda.mil/mdalink/html/aboutus.html**
To develop and field an integrated, layered, ballistic missile defense system to defend the United States, its deployed forces, allies, and friends against all ranges of enemy ballistic missiles in all phases of flight.

1. Retain, recruit, and develop a high-performing and accountable workforce.
2. Deliver near-term additional defensive capability in a structured Block approach to close gaps and improve the BMDS.
3. Establish partnerships with the Services to enable their operations and support of the BMDS components for the Combatant Commanders.
4. Substantially improve and demonstrate the military utility of the BMDS through increased system integration and testing.

5. Execute a robust BMDS technology and development program to address the challenges of the evolving threat through the use of key knowledge points.

6. Expand international cooperation through a comprehensive strategy to support our mutual security interests in missile defense.

7. Maximize mission assurance and cost effectiveness of MDA's management and operations through continuous process improvement.

[xv] **AFSPC Mission: http://www.af.mil/factsheets/factsheet.asp?fsID=155**
AFSPC's mission is to deliver space and missile capabilities to America and its warfighting commands.

[xvi] **NASA Mission Statement: http://www.nasa.gov/about/highlights/what_does_nasa_do.html**
To advance and communicate scientific knowledge and understanding of the Earth, the solar system, and the universe and use the environment of space for research. To explore, use, and enable the development of space for human enterprise. To research, develop, verify, and transfer advanced aeronautics, space, and related technologies.

NASA's mission is to pioneer the future in space exploration, scientific discovery and aeronautics research.

[xvii] **About DOE**: **http://www.energy.gov/about/index.htm**

The Department of Energy's overarching mission is to advance the national, economic, and energy security of the United States; to promote scientific and technological innovation in support of that mission; and to ensure the environmental cleanup of the national nuclear weapons complex. The Department's strategic goals to achieve the mission are designed to deliver results along five strategic themes:

1 **Energy Security:** Promoting America's energy security through reliable, clean, and affordable energy

2 **Nuclear Security:** Ensuring America's nuclear security

3 **Scientific Discovery and Innovation:** Strengthening U.S. scientific discovery, economic competitiveness, and improving quality of life through innovations in science and technology

4 **Environmental Responsibility:** Protecting the environment by providing a responsible resolution to the environmental legacy of nuclear weapons production

5 **Management Excellence:** Enabling the mission through sound management

[xviii] **NNSA: http://nnsa.energy.gov/about/index.htm**

NNSA is responsible for the management and security of the nation's nuclear weapons, nuclear nonproliferation, and naval reactor programs. It also responds to nuclear and radiological emergencies in the United States and abroad. Additionally, NNSA federal agents provide safe and secure transportation of nuclear weapons and components and special nuclear materials along with other missions supporting the national security.

[xix] **NSF: http://www.nsf.gov/nsf/nsfpubs/straplan/mission.htm**

The National Science Foundation (NSF) is an independent federal agency created by Congress in 1950 "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…"
The National Science Foundation Act of 1950 (Public Law 81-507) set forth NSF's mission and purpose:

To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense....
The Act authorized and directed NSF to initiate and support:

- basic scientific research and research fundamental to the engineering process,
- programs to strengthen scientific and engineering research potential,
- science and engineering education programs at all levels and in all the various fields of science and engineering,
- programs that provide a source of information for policy formulation,
- and other activities to promote these ends.

Over the years, NSF's statutory authority has been modified in a number of significant ways. In 1968, authority to support applied research was added to the Organic Act. In 1980, The Science and Engineering Equal Opportunities Act gave NSF standing authority to support activities to improve the participation of women and minorities in science and engineering. Another major change occurred in 1986, when engineering was accorded equal status with science in the Organic Act.
NSF has always dedicated itself to providing the leadership and vision needed to keep the words and ideas embedded in its mission statement fresh and up-to-date. Even in today's rapidly changing environment, NSF's core purpose resonates clearly in everything it does: promoting achievement and progress in science and engineering and enhancing the potential for research and education to contribute to the Nation. While NSF's vision of the future and the mechanisms it uses to carry out its charges have evolved significantly over the last four decades, its ultimate mission remains the same.

[xx] **NOAA Mission: http://www.noaa.gov/about-noaa.html**
To understand and predict changes in Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social, and environmental needs

[xxi]

2002	2005	Space Goal
32%	35%	Build satellites in Earth orbit to collect solar energy to beam to utilities on Earth
23%	17%	Develop the technology to deflect asteroids or comets that might destroy the Earth
4%	10%	Send humans to Mars
2%	7%	Search for life on other planets
6%	7%	Build a human colony in space
5%	4%	Build a base on the moon for humans to use for exploration of the moon
3%	6%	Develop a passenger rocket to send tourists into space
11%	2%	None of the above, we should stop spending money on space
13%	10%	No Opinion
1%	2%	None of the above

2002 Survey - National Space Goals
Matula & Loveland, 2006

- **Over the years, a number of goals have been proposed for the U.S. space program including missions to Mars (Zubrin 1996), space colonization (O'Neill 1976), a return to the moon (Spudis 1996), and space tourism (David 2004). The purpose of this exploratory study was to measure the level of public interest in different space goals.**
- **Two goals stood out far beyond all others. The first of these goals was developing the capability of using Space-Based Solar Power (SBSP) or space energy to meet the nation's energy needs. In 2002 32 percent, nearly 1/3 of the respondents, supported this goal. In 2005, 35 percent, again nearly 1/3 of respondents, supported the development of SBSP. The second goal that appeared to receive broad support was developing the technology to deflect asteroids or comets that might threaten the Earth with impact (planetary defense).**

[xxii] 333x more powerful than Hiroshima yield using numbers available at Wikipedia: http://en.wikipedia.org/wiki/Nuclear_weapon_yield

[xxiii] 10x more powerful than the most powerful US Nuclear Explosion, Castle Bravo which was 15 Megatons, and 10,000x as powerful as Hiroshima

[xxiv] 1 Gigaton = 1,000,000 kilotons, approximately 66,666x as powerful as Hiroshima

[xxv] **Comet/Asteroid Protection System (CAPS): Preliminary Space-Based System Concept and Study Results**. NASA/TM-2005-213758, May, 2005. (page 23)

[xxvi] **INVITATION:**

-----Original Appointment-----
From: Garretson, Peter Lt Col AF/A8XC **On Behalf Of** RSS - AF/A8XC Master Calendar
Sent: Friday, November 21, 2008 3:36 PM
To:
Subject: Natural Impact Interagency Deliberate Planning Workshop
When: Thursday, December 04, 2008 8:00 AM-5:00 PM (GMT-05:00) Eastern Time (US & Canada).
Where: 2461 Eisenhower Ave Room 116 (Hoffman Building, Alexandria Across from Eisenhower Metro) Conference Room

Please RSVP to: peter.garretson@pentagon.af.mil Agenda & Pre-brief forthcoming.

Air Force Future Concepts (AF/A8XC), **"AF DeepLook" invites** you:

- To participate in **a one day, Action-Officer-level seminar/workshop,** designed to encourage interagency collaboration
- On the subject of an **Impending Natural Impact Event (asteroid strike)**
- The event **will discuss both disaster response and mitigation options**.

As part of the Futures Game Series, DeepLook hosts a number of scenarios to ensure the AF is adequately prepared for the future. This event complies with:

- Examine AF capabilities across a range of possible contingencies and shocks, #1 priority of 2008 National Defense Strategy: Defend the Homeland & QDR 04 Guidance to examine capabilities to prevent/respond to catastrophic events
- 2008 NASA HQ memorandum to AF/A8X to consider this topic in AF Strategic planning activities
- Executive Order 12656 direction on emergency preparedness planning, and AF equities under
  - DoD Directive 3025.1 (Military Support to Civil Authorities)
  - DoD Directive 5100.46 (Foreign Disaster Relief)
  - NSPD 49 National Space Policy
- AF 2008 Strategic Plan Goal 2.1 “Maximize Participation of Joint, interagency, and coalition partners in Air Force planning, capability development, and training in core and emerging missions” and CSAF Title 10 wargaming authority

Event will be **a scripted tabletop exercise**. Discussion will take place “**in role**” as if the event were actually occurring.

Event is **Non-attribution, Academic environment**. Participants bring expertise but do not formally represent the position of their organization. Participants pay own travel expenses.

You may suggest additional participants for consideration.

POC: Lt Col Peter Garretson peter.garretson@pentagon.af.mil 703-428-0891
or Jay Lovell james.lovell.Ctr@pentagon.af.mil (703) 428-0910

READ AHEAD MATERIAL contained:

Welcome to the Natural Impact Interagency Deliberate Planning Workshop
This event is **part of an on-going series** of events held by **Air Force Future Concepts** to ensure the AF is adequately prepared for the future.

This workshop **responds to a memorandum from NASA asking us to consider a natural impact event** (a colliding asteroid or comet) as part of AF Strategic Planning, and previous concerns identified by internal AF planning documents such as SpaceCast2020 and AF2025.

I would like to acknowledge the outstanding support from NASA, OSDP, NSSO, Joint Staff, DTRA, DOE and DHS in putting this together on such short notice.

We have constructed a scenario for this event that creates what we think will be a **significant challenge to near-term capabilities and processe**s, and will examine **both disaster response and mitigation** actions. It is built in such a way to test near-term response capabilities against a mid-level asteroid threat which **stresses domestic response/continuity of government, and foreign disaster response and notification**.

Our hope is to **better understand and identify our current capabilities and shortfalls**, to understand the required **timelines, required actions, location of expertise and capability**, and to be able to put together a "**strawman plan**" for a disaster that has never been exercised upon which **future efforts can build**.

It has a secondary purpose to **encourage broader interagency deliberate planning**.

The event itself is a **scripted Tabletop exercise**.

Event is **Non-attribution, Academic environment**. Participants bring expertise but do not formally represent the position of their organization. Participants pay own travel expenses.

[xxvii] Mr. Mark Boslough of Sandia National Laboratories (SNL): http://www.sandia.gov/news/resources/releases/2007/asteroid.html

[xxviii] Mr. Mark Boslough of Sandia National Laboratories (SNL): http://www.sandia.gov/news/resources/releases/2007/asteroid.html

[xxix] **Survey of Technologies Relevant to Defense From Near-Earth Objects**. NASA/TP-2004-213089, July, 2004

[xxx] Dr. Steven Ward of University of California at Santa Cruz http://es.ucsc.edu/~ward/

[xxxi] Available at: http://www.whitehouse.gov/news/releases/2003/02/20030228-9.html

[xxxii] http://www.whitehouse.gov/news/releases/2003/12/20031217-6.html

[xxxiii] Available at: http://www.dhs.gov/xprevprot/programs/editorial_0827.shtm

[xxxiv] **Near Earth Object (NEO) Mitigation Options Using Exploration Technologies**. Robert B. Adams, et. al., 2007

[xxxv] **Preparing for Planetary Defense: Detection and Interception of Asteroids on Collision Course with Earth**. White Paper on Planetary Defense of the Air University Spacecast 2020 Study Group, 1995

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