

Results of Multi-Agency Deflection and Disaster Exercise

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ABSTRACT

A prominent recommendation of citizen groups and past planetary defense conferences was to conduct a well scripted exercise in disaster response to an asteroid threat. At the request of NASA Headquarters (HQ), an internal long-range think tank at Headquarters Air Force in conjunction with NASA HQ conducted the first-ever interagency tabletop exercise with participants at the action officer level from relevant US government agencies (National Security Council (NSC), Office of the Secretary of Defense (OSD), US Joint Staff, Department of Homeland Security (DHS), Department of State (DOS), US Coast Guard, US Navy, National Aeronautics and Space Administration (NASA), US Air Force) and response command posts (National Military Command Center (NMCC), Air Force Group (AFG), Federal Emergency Management Agency (FEMA), Defense Threat Reduction Agency (DTRA)) to assess likely responses both to mitigation and disaster response in the absence of clear policy on roles and missions, and capture key considerations. The exercise itself was a full day, and was conducted with participants playing the role of their agency as if the event was happening in real time. The specific threat involved a binary asteroid with the larger body an equivalent size to Apophis, and the smaller approximately 50m (size Berringer Crater impactor), one of which would hit the United States or US East Coast and stress continuity of government, the other which would strike in international waters and would stress foreign notification and foreign disaster response. The group was broken into two teams to assess two different cases. The mitigation team was given one synodic period (7 years) before impact to plan for deflection or disruption. The disaster response team had only 72 hours from discovery to impact to respond. While the exercise itself was an academic exercise and does *not* represent the official position of *any* participating agency, it nevertheless highlighted multiple insights which may be relevant to future planners, and are discussed below.

OVERVIEW

This paper summarizes the insights gained from a one-day Natural Impact Event Interagency Planning Exercise, sponsored by Air Force Future Concepts and Transformation Division (AF/A8XC) on 4 Dec 2008, in Alexandria, Virginia.[1]

Twenty Seven Subject Matter Experts from across US Government, including the Department of Defense (DOD), Department of Energy (DOE), Department of State (DOS), Department of Homeland Security (DHS), National Aeronautics and Space Administration (NASA), and the National Security Council (NSC) participated in a single day, academic tabletop exercise to explore “whole of government” response to a simulated impending asteroid strike.

The event was an academic exercise designed to explore possible future challenges, and participants did not represent official positions of their parent agencies and enjoyed academic freedom to consider all options. Although these results **in no way constitute a coordinated interagency document or reflect an official position of any of the participating agencies**, they nevertheless provide interesting insights into likely trajectories of problem analysis and decision-making and problems that are likely to arise in an actual event.

The specific scenario involved a mythical asteroid, “2008 Inoculatus.” 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, which 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.

AIR FORCE FUTURE CONCEPTS: WHO WAS THE SPONSOR

Air Force Future Concepts (AF/A8XC), or “AF DeepLook” is the Air Force’s internal long-range think tank, charged with exploration of challenges and development of concepts beyond the Future Years Defense Plan (FYDP).

A8XC fulfills its 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.

IMPETUS: WHY WAS THE EVENT HELD

In 2008, A8XC received a request from NASA HQ to consider a natural impact event as part of its strategic planning explorations. This request was consistent with A8XC’s own internal audit following the 2006 Quadrennial Defense Review (QDR’06) of potentially catastrophic events and previous Air Force documents (SpaceCast 2020 and AF2025) which had established a natural impact event as a significant threat to national and international security. Further exploration was therefore consistent with A8XC’s general charge to examine future challenges, as well as the specific 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 Air Force equities under DoD Directive 3025.1 (Military Support to Civil Authorities), DoD Directive 5100.46 (Foreign Disaster Relief), NSPD 49 National Space Policy, and the existing Executive Order 12656 on Disaster Preparedness.

SCOPE CONSIDERATIONS AND DECISIONS

In deciding the scope and 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). The ADRC event had included representatives from A8XC, Air Force Research Laboratory (AFRL), NASA, DTRA, National Science Foundation (NSF), DHS, and Defense Intelligence Agency (DIA), as well as members of the Congressionally-tasked National Research Council (NRC) to examine the current state of deflection technologies. The ADRC event highlighted a significant deficit in interagency command and control (C2) which might be facilitated through an interagency response exercise which 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.
[2]

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.[3]

A8XC, because of its expertise in wargaming and topic-specific expertise 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 (Office of Science and Technology Policy (OSTP), NRC) were examining the policy discussions through high-level interagency formal processes, A8XC constructed an Action-Officer (AO) level game of actual executors (NASA Minor Planet Center, NASA Jet Propulsion Laboratory (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 Lab, and executing Combatant Commands), to discuss potential responses for disaster response and mitigation should a threat be presented today under the existing policy regime.

SCENARIO CONSIDERATIONS AND SELECTION

The specific scenario involved a mythical asteroid, “2008 Innoculatus.” It was a binary asteroid consisting of a two hundred and seventy meter diameter (270m) rocky rubble pile projected to strike the Gulf of Guinea and a fifty meter diameter (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.

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.

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.

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 Asteroids (PHA’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 (US Northern Command (NORTHCOM) / Federal Emergency Management Agency (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.

Based on these considerations, A8XC decided the specific scenario which would have maximum benefit for an initial exercise would be 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). With hopes that the scenario would help inoculate our systems against the shock of an actual threat, the mythical asteroid was named “2008 Innoculatus.”

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/>)

PARTICIPANTS: WHO WAS INVOLVED AND WHY WERE THEY SELECTED?

A8XC sought to exercise the actual organizations that likely would have a hand in coping with an actual contingency, to understand what sort of procedures they would likely follow and what sort of considerations and information / service needs they would have in execution. Therefore participants were invited based upon a “best guess” of which agencies would likely be involved in actual real-life execution or had unique expertise. 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.

Not all desired organizations were able to attend, but in most cases there were individuals with expertise to fill the gaps. Attendance was open to interested parties, and included some policy observers. 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.

Attendees were “Action Officer” (not senior decision-maker) level, and were drawn from the following agencies: National Security Council (NSC), National Aeronautics and Space Administration (NASA), Department of Energy (DOE) (HQ, Lawrence Livermore National Laboratory (LLNL), Sandia National Laboratory (SNL)), Department of Homeland Security (DHS), Department of State (DOS), Defense Threat Reduction Agency (DTRA), Missile Defense Agency (MDA), Joint Staff (J4 & J5), Office of the Secretary of Defense - Policy (OSDP) (Strategic Policy, Policy Planning, Homeland Defense), National Security Space Organization (NSSO), United States Air Force (USAF) (A8XC, “Checkmate” (HAF/CK), Air Force Operations Group (AFOG), Air Armaments Center (AAC), Air Force Research Laboratory (AFRL)), United States Navy (USN), and United States Coast Guard (USCG).

Put succinctly, the exercise had a fair representation at the action officer level of agencies that likely would have a hand in coping, including the Joint Staff, OSD, three services (AF, Navy, USCG), five civilian agencies (NASA, DOE, State, DHS, NSC), three DOD agencies (NSSO, DTRA, MDA), and three laboratories (Sandia, LLNL, AFRL).

EXERCISE PLAY

The event was held at the UNCLASSIFIED level. 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. The stated purpose was to 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.

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

Participants assembled as if they were a high level task force assembled by the President of the United States (POTUS) 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 deliberate planning for the eventuality of a natural impact, past recommendations, extant guidance, recent and upcoming national and international events, and indeterminate organizational responsibility.

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 which included a review of the recent real-world experience with 2008 TC3, 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. A key consideration for real world planners is anticipating the need for decisionmaker education and anticipating likely but unproductive lines of inquiry that stem from limited understanding of missile and missile defense capabilities and the nuances orbital mechanics (mass, deltaV & fuel, time, and kinetic energy), which can delay critical action formulation.

After the initial brief, players were broken into two teams. Players then acted in-role to fulfill POTUS’ intent to respond appropriately and provide options, identify current capabilities & expertise as well as articulate known shortfalls. 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.

Teams reconvened at the end of the day to outbrief their thoughts. The discussion resulted in ten major insights for future planning consideration.

EXERCISE INSIGHTS

The major insights are summarized below:

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.

NASA has an existing contingency process (which terminates in notification), but downstream agencies do not. Players felt that downstream agencies (National Military Command Center (NMCC), State Department, DHS, and US Combatant Commanders (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 Potentially Hazardous Object (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.

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 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.

Exercises enumerated for consideration by the participants included: National Level Exercises (NLE), NORTHCOM exercises, DHS Multi-hazard scenario exercises, TOPOFF (Top Officials) exercises, and the annual interagency Continuity of Government (COG). Players suggested future exercises should seek increased participation from: FEMA, US Northern Command (USNORTHCOM), US Strategic Command (USSTRATCOM), National Nuclear Security Agency (NNSA), National Ocean and Atmospheric Agency (NOAA), Justice Department and DoD/Air Force General Council, State Department, Homeland Security Council (HSC) Staff, National Guard, DOE Emergency Preparedness (COG), and include one or more state emergency managers as well as more senior policy individuals and the US President's Office of Science and Technology Policy (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.

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.

Players felt the appropriate level for decision was the National Security Council (NSC)/Homeland Security Council (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 responsibilities in existing documents, plans and mission statements, and variously recommended a re-examination of the 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 (UCP), as well as COCOM CONPLANS and Operations Plans (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.

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 which 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.

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 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 astronomical 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.

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 the potential for impact and provide a news release, or even speed notification to the President of the United States (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.

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 under current capabilities, the error ellipse is likely to be too large to adequately constrain/inform effective evacuation 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 search for and discover short warning impactors and rapidly determine their impact position within the relevant timeframe (approximately 72 hrs) to support evacuation 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

Because the public may become aware of the situation slightly before or simultaneously with the national and international 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 size area of uncertainty, and to be able to display this information graphically.

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). 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.

DISCUSSION REGARDING FUTURE EXERCISES

There are a number of areas in which a future scenario architect may wish to deviate from what was accomplished above.

A number of player critiques felt this exercise or one like it should be held at a higher level. From player critiques, it was also clear that the presence of high level individuals and their expertise, particularly representatives from NSC, and OSD Strategic Policy significantly added to the event.

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 asteroid / comet body as a baseline reference case for mission planning and technology evaluation.

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.

While the simulation products & visuals 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.”

Future planners may wish to reconsider the above decisions regarding attendance:

- Significant expertise in the area of Planetary Defense 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, especially from:
 - o Those nations threatened by the particular scenario
 - o Space Capable Nations
- External interested organizations are highly knowledgeable, and likely to supply alternate and either constructive or disruptive “authoritative voices” in the media ((B612, ASE, SFF, NSS, Planetary Society).
- Press / Media might provide very useful considerations and may be pre-educated to provide a constructive role in public safety.

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