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A Strategic Critique of the NRC Final Report on the NEO Threat

Defending Planet Earth:
Near-Earth Object Surveys and Hazard Mitigation Strategies
Final Report <http://www.nap.edu/catalog.php?record_id=12842>

Preface

The statement of task requires the committee to include an assessment of the costs of various alternatives, using independent cost estimating. Options that blend the use of different facilities (ground and space-based) or involve international cooperation were considered.

GS Note: Although an “assessment of the costs of various alternatives” would necessarily be required incidentally, the request from Congress was to provide 'the optimal approach'... the single *best* way. Which, by extension, would also apply “to developing a deflection capability” and “regarding the Arecibo Observatory”. No such definitive conclusions or recommendations have been provided in this work product...

"In order to assist Congress in determining the optimal approach regarding the Arecibo Observatory, NASA shall contract with the National Research Council to study the issue and make recommendations. As part of its deliberations, the NRC shall review NASA's report 2006 Near-Earth Object Survey and Deflection Study - and its associated March 2007 Near-Earth Object Survey and Deflection Study as well as any other relevant literature.

An interim report, with recommendations focusing primarily on the optimal approach to the survey program, shall be submitted within 15 months of enactment of this Act. The final report, including recommendations regarding the optimal approach to developing a deflection capability, shall be submitted within 21 months of enactment of this Act. The NRC study shall include an assessment of the costs of various alternatives, including options that may blend the use of different facilities (whether ground- or space-based), or involve international cooperation. Independent cost estimating should be utilized."

GS Note: Why was it necessary for the NAS/NRC to restate the request from Congress if not to intentionally lose something in the translation?

Page 1

Summary

A smaller amount of funding (significantly less than $1 million per year) supports study of ways to protect Earth from such a potential collision ("mitigation").

GS Note: The only funding known to the aerospace engineering community for deflection research would be the ADRC grant, which was an open title submission: won by filling in Planetary Defense and the ROSES grant element which was defined as non space-based characterization. In short, there is not enough fear in government to compel any political will to allocate or earmark any governmental funding expressly for developing deflection technology.

The committee concluded that there was no way to define "optimal" in a universally acceptable manner: there are too many variables involved that can be both chosen and weighted in too many plausible ways.

GS Note: Important decisions invariably have "many variables involved" yet nonetheless, Recommendations and Decisions must be *made*... and why you got the Big Money here. Welcome to the Real World. And herein lies the flaw in asking a scientist to do a soldier's work: an absence of subjective acuity and the courage to make a decision. Such things are usually far above a scientists pay-grade. Or perhaps it is just an absence of an honest understanding and Fear. This alone would condemn the entire report as Academic: without apparent use. Clearly this mission would have been better tasked to DoD.

All Decision Making is Risk Management. If we look at Risk as a Gamble we can better see three principal elements: Magnitude of Loss, Magnitude of Gain and the Probability of either Loss or Gain. And weighted in that order with Magnitude of Loss being the most important.

The Gamble here manifests in the existential condition. While the Decision, because we can, is to stop Gambling... or not. If we decide to continue the Gamble the Loss would be reflected in the potential extinction of our species. Whereas the Gain would be reflected in saving the cost of not developing a means to deflect such and event. So First: are willing to wager the Survival of the Species? If so, only then Second: for the prize of saving the cost of deflecting the threat? If so, only then Third: at what Probability?

If you are confused by the variables here, it must be that you have already decided to go ahead and bet the Survival of the Species and only want to negotiate the the size of the prize when Mankind throws the Cosmic dice every year. Otherwise, this would present itself as a simple annual Cost/Benefit problem, no Probabilities allowed, and you would just be haggling over the best price and terms for not Gambling anymore. Then, since all-there-is-forever is on the line here, anything less would be acceptable, and the real cost, in fact... a bargain.

But there is a larger problem here. A matter of integrity. Not being able to adequately understand the terms of the questions, you nonetheless took the coin of Congress and cost the development of our nascent Planetary Defense two years, under the false pretense that you could answer them.

Page 2

Finding: The selected approach to completing the George E. Brown, Jr. Near-Earth Object Survey will depend on nonscientific factors:

If completion of the survey as close to the original 2020 deadline as possible is considered most important, ...

If cost conservation is deemed most important, ...

GS Note: And if Mitigating the potential Harm to the citizens and society of this Nation and Mankind as a whole is “most important” in fact - which includes deflecting the prospect of our Extinction by Asteroid Impact - and not just Counting Rocks in Space, then any and all imaginable resources at our disposal should be employed. Here, If Failure is *Not* an Option then By Any Means Necessary and At Any Cost...

Even to a Scientist it should be clear that this would be the principal determinate yet you fail to find the strategic sense to even afford it an Honorable Mention...

Multiple factors will drive the decision on how to approach completion of this survey. These include, but are not limited to, the perceived urgency for completing the survey as close to the original 2020 deadline as possible, the availability of funds to complete the survey, and the acceptability of the risk associated with the construction and operation of various ground- and space-based options.

GS Note: In fact, the *optimal* variable here would be *urgency* relative to averting great Harm. Not the arbitrary Congressionally mandated budget deadline. Wouldn't the most relevant objective be to know if there is an impending impact threat of any size as soon as possible?

Then, simply finding these objects is just the beginning. Since they are in a constant state of perturbation - occasionally dramatic over the short-term - and certain not to stay as we find them, to be effective sooner or later we will have to adapt our perspective and efforts from Survey to Surveillance and watch them all... Forever. And Sooner would be better than Later.

Unless unexpected technical problems interfere, a space-based option should provide the fastest means to complete the survey. However, unlike ground-based telescopes, space options carry a modest launch risk and a more limited lifetime: ground-based telescopes have far longer useful lifetimes and could be employed for continued NEO surveys and for new science projects.

GS Note: The principal goal here is to find The Next Asteroid on its way to strike Earth: large, medium or small, in time to successfully deflect it. Not some academic census of the Solar System. Given that the potential Magnitude of Loss should we fail here includes the potential for our extinction, would not a fair and wise recommendation be for *both*... all things considered? NASA wants $1.1 billion for a space-based mission; LSST's bid for Brown was $125 million. $1.2 billion amortized over ten years is 0.0002% of Gross World Product. Last year Mankind spent $500 billion on Heroin and Cocaine! By any measure, even if we do it right, this is the cheap end of this business.

All told the committee was struck by the many uncertainties that suffuse the NEO subject.

GS Note: Had you placed yourself in the position of the sole agency responsible for deflecting The Next Asteroid on its way to strike Earth and your children and grandchildren were at Ground Zero, then perhaps many uncertainties would have resolved themselves. The Fear of Failure that goes with responsibility will focus the mind as to what is or is not relevant and what to *Do*.

One other related example: do airbursts from impactors in this size range over an ocean cause tsunamis that can severely damage a coastline?

GS Note: We do 'know' they can generate an Electromagnetic Pulse.

Recommendation: Because recent studies of meteor airbursts have suggested that near-Earth objects as small as 30 to 50 meters in diameter could be highly destructive, surveys should attempt to detect as many 30- to 50-meter objects as possible. This search for smaller-diameter objects should not be allowed to interfere with the survey for objects 140-meters in diameter or greater.

GS Note: So, being unable to make any definitive recommendation as to conducting the second observational step on this journey of a thousand miles you *are* able to predict that there will be a third... Good thing this ain't Rocket Science.

Characterization and the Arecibo and Goldstone Observatories

Obtaining the orbits and the physical properties of NEOs is known as characterization and is primarily needed to inform planning for any active defense of Earth. Such defense would be carried out through a suitable attack on any cosmic object predicted with near certainty to otherwise collide with Earth and cause significant damage.

GS Note: That "significant damage" includes the potential for our Extinction by NEO.

Recommendation: Immediate action is required to ensure the continued operation of the Arecibo Observatory at a level sufficient to maintain and staff the radar facility. Additionally, NASA and NSF should support a vigorous program of radar observations of NEOs at Arecibo and NASA should support such a program at Goldstone for orbit determination and characterization of physical properties.

GS Note: Though you have dedicated this report to Steve Ostro you could not see the inherent wisdom in promoting his recommendation for an upgraded dedicated NEO Radar facility.

And don't forget DoD as a logical source of responsibility and funding. When The Time comes it is unlikely we will Save the World without their strategic leadership, expertise... and Nukes.

But the utility of Arecibo in this issue should be obvious to all. The question is, even if the past sponsors of maintaining Arecibo remain the same where does NSF and NASA get the continued funding from? What does NSF or NASA cut to support Arecibo or should Congress appropriate new ad hoc funding sufficient for enabling the NEO characterization mission?

Page 4

Mitigation

Mitigation refers to all means of defending Earth and its inhabitants from effects of an impending impact by a NEO.

GS Note: Mitigation means to reduce the severity of a thing: Threat, Risk, Hazard. Which would encompass the applied tactics of detection and characterization with deflection to constitute our mitigating response. You can even mitigate the consequences of an impact event but you do not "mitigate" an asteroid, you "deflect" it. Even blowing it apart would be Deflection it in Detail.

3. Kinetic impactors*. In these scenarios the target's orbit would be changed by sending one or more spacecraft with very massive payload(s) to impact directly on the target at high speed in its direction, or opposite to its direction, of motion.*

GS Note: Which, in terms of effectiveness, would take us to only 200 meters or so... even before you factor in any practical mission margins of error such as technological confidence, impact certainty ellipse and precise target mass.

4. Nuclear explosions*. For non-technical reasons, this would likely be a last resort,*

GS Note: Said "non-technical reasons" being an irrational and unwarranted Fear of Nukes. Not something we would want to find in any coldly rational *Scientific* forum... or in Government.

but it is also the most powerful technique and could take several different forms, as discussed in the report. The nuclear option would be usable for objects up to a few kilometers in diameter.

GS Note: It should not take a rocket scientist to understand that nuclear explosive devices come in all sizes and have variable yields and can easily be ramped *down* in tactical execution to address lesser threats. Since we will need to maintain a standing nuclear inventory for the greater threats, why then do we need to concern ourselves with Gravity Tractors or Kinetic Impactors? As a deterministic element of an "Optimal Approach" this much should be a slam dunk. Is what we have here simply the absence of courage to *be* rational and scientific in praxis?

For larger NEOs (more than a few kilometers in diameter), which would be on the scale that would inflict serious global damage and, perhaps, mass extinctions, there is at present no feasible defense.

GS Note: False: "At present"the current world nuclear arsenal could impart 5 cm of Delta Vee on a 10 km extinction level threat. Given early warning enough (as in any weight class threat) to build and find launch windows to deliver them, our response is no less ready that our capability for dealing with anything else. For one reason or another, it is all in the theoretical and *ability* stage. No standing tested *capability* to respond to any size threat exists "at present".

That said, what part of "develop a deflection capability" do you not understand? You beg the question already asked. NASA knows what is or is not feasible "at present". They surely don't need to pay the NRC $1.5 million to verify that. Only if we think in terms of building a response *after* we detect an impending threat, relying only on extemporaneous ad hoc 11th Hour Hail Mary capabilities, would there be "no feasible defense" for such threats... and ostensibly why Congress asked the NRC how to remedy that deficit in the security of our nation and species.

For the future: how close can we come to having a reliable, standing tested response, come what may, *before* we actually need it? How many more Nukes would we need to build? There was no small/medium/large threat qualifier in the Congressional request. To the level of the Worst Case Scenario imaginable should clearly be the starting point. Finding comfort in easily responding to only Best Case Scenarios will be little more than a formula for Suicide by NEO.

For $1.5 million NASA and Congress should get something more for their money than what they already know... more than the reiterated cut-and-paste work of NASA's PA&E.

Luckily such events are exceedingly rare, the last known being about 65 million years ago.

GS Note: Such events are completely aperiodic and random: without any recursive pattern. And expectations of our continued Good Luck should have nothing to do with the quality or the magnitude of our response until we have done all we can imagine or afford. When you appeal to Good Luck the only tool at your disposal for a desirable outcome is Hope. And hope has never been a reliable survival tactic. This is simply not the way professional Strategists or Risk Managers or Decision Makers think...

Fortunately, if statistical assessments tell us anything, over the course of the next billion years of the life of Earth we will only need to deal with 10 to 20 extinction level asteroid impact events. Unfortunately, they do occur at random, and we could see the next one coming tomorrow... and we are simply not prepared.

We can regard this report as relying on Best Case Assumptions and that we will continue to be Lucky. As such, this report is about building a Hope Based Planetary Defense...

Although the committee was charged with determining the "optimal approach to developing a deflection capability," it concluded that work in this area is relatively new and immature. The committee therefore concluded that the "optimal approach" starts with a research program.

GS Note: This is where all the wheels fall of the wagon. The “optimal approach to developing a deflection capability” is a clearly Strategic question: what is essential to the conduct of implementing a response. Which, in order to determine would first require the selection of just what that *response* would be: select the *best* tactic. Pick *One* and the number of variables would be dramatically reduced and the remainder easily resolved. But instead of extending the differential analysis of NASA's PA&E and following the done math indicating Nukes as the clearly obvious Best Alternative, we get some buck-passing recommendation for yet another “research program”... A collective absence of stones.

Further Research

Recommendation: The United States should initiate a peer-reviewed, targeted research program in the area of impact hazard and mitigation of NEOs. Because this is a policy driven, applied program, it should not be in competition with basic scientific research programs or funded from them. This research program should encompass three principal task areas: surveys, characterization, and mitigation. The scope should include analysis, simulation, and laboratory experiments. This research program does not include mitigation space experiments or tests which are treated elsewhere in this report.

GS Note: So, in other words this report is recommending “targeted research” into determining the “Optimal Approach” for implementing surveys such as Brown, maintaining facilities such as Arecibo and developing an effective NEO deflection capability... Just what was it this committee was supposed to do... find a way to perpetuate the flow of pork?

This committee should have at the least known it was not qualified to do the job in the first place. It is bad enough that you nonetheless took the money under false pretenses but your short-term-self-interests have cost us precious time. The next asteroid on its way to strike Earth is closing at a million miles a day and we don't know which one it is, when it will get here or how large it is. Worse we do not know when we are going to know which, when or how large. And although a good time was surely had by all, you have put all that, along with the development of some reliable capability to deal with it off by another two years. Probably more. Time is simply not on our side here.

Perhaps you are correctly recommending differentiating between an academic scientific perspective and a practical strategic perspective: what would actually be essential to the conduct of implementing an effective response. The kind of thing they do at DoD and the Pentagon and at our national War Colleges. A thing for Security minded experts... Why didn't you just say so? Scientists just don't do Strategic well... too subjective. Congress had the good questions they simply went to the wrong authority for the good answers.

Page 5

National and International Cooperation

NEOs are a global threat, efforts to deal with them could involve international cooperation from the outset. (However, this is one area where one nation, acting alone, could address such a global threat.)

GS Note: Only as long a we retard our perception of “such a global threat” to be small and do not find ourselves *unlucky* when the *next* asteroid on its way to strike Earth is not, in fact. Only if we assume that waiting until we see it coming before we build an effective means to deflect it will actually work successfully and is somehow wise. If we chose to Gamble here, sooner or later we will lose. And what is left of all the Nukes and all the Space Programs of all the nations on the planet may not be enough... Game Over. No Joy. Restart Darwin's Clock... again.

Recommendation: The United States should take the lead in organizing and empowering a suitable international entity to participate in developing a detailed plan for dealing with the NEO hazard.

GS Note: You don't have enough *variables* already? You want to jump this into an International arena before working out the details, resolve some of those pesky variables at least in prospectus, at the National level? This is what you get when you ask Academics how to *Do* something... Bigger Committees!

major concern with such an organization, especially in the disaster-preparation area, is the maintenance of attention and morale given the expected exceptionally long intervals between harmful events.

GS Note: The First major concern should be conveying the perpetual notion of the *Random* and *Unknown* interval between Now and the Next asteroid impact event. Then we can worry about conveying the notion of the *Random* and *Unknown* interval between Now and the Next asteroid impact event... etc. etc. etc. But first quit saying there is an *expectable* interval of any duration here. Any such expectation would be the product of a completely non analogous mathematical abstraction... a purely Academic Artifact. If you can not understand or bring yourself to accept the idea of *Random,* how can you even be considered qualified to even *Think* about this threat? Let alone presume to make any recommendations on how we should or should not respond.

Countering the tendency to complacency will be a continuing challenge. This problem would be mitigated if, for example, the civil defense aspects were combined in the National Response Framework with those for other natural hazards.

GS Note: And a perpetual Public Relations program at both private and governmental levels generating a never-ending Primal Fear of Death by Rock from Sky. Only Fear defines Necessity. No Statistical Probabilistic Sophistry or Academic-Slights-Of-Mind allowed. Keep It Rational.

Recent NEO-Related Events

Recommendation: Data from NEO airburst events observed by the U.S. Department of Defense satellites should be made available to the scientific community to allow it to improve understanding of the NEO hazards to Earth.

GS Note: Which should include the relevant fundamental US Military Grade research and conclusions on Electromagnetic Pulse generation and its projected effects and consequences.

Congress passed a NASA appropriations act that called for the Office of Science and Technology Policy to determine by October 2010 which agency should be responsible for conducting the NEO survey and detection and mitigation program. Several agencies are possible candidates for such a role.

GS Note: Several? How about two: DoD and NASA. Both have well developed space programs but only DoD has the discretionary authority for the disposition of thermonuclear explosive devices (and that will never change). And only DoD has the budget to assimilate the cost of Preparation and Training and Vigilance and develop and effective response capability... and done right, globally, make this business revenue-neutral. And only DoD has over two hundred years of evolved strategic experience and culture in successfully defending the interests of this country. But since NASA has all the experience in circumstellar orbit and manned missions... why not use both! A hybrid of NASA and DoD only at the point of and as to their best relative capabilities in this issue. That way it would also be a much closer match to both Russian and Chinese space programs which are inherently departments of their respective national militaries.

Once we have created our National Planetary Defense Agency and set the rational effective precedent: and by doing so earned a leadership role, *then*, we can promote, integrate and shape an International agency of agencies... a NEO NATO if you will. There might even be something for the UN to do... in a diplomatic supporting role.

However, in the absence of a codified National Policy determination to endeavor to deflect these objects as they present themselves to be imminent impact threats at the Executive level of government, it would be unwarranted to expect the delegation of any such National Agency.

Page 6

In addition, the committee was impressed with the European Space Agency's early development of the Don Quijote spacecraft mission that would consist of an observing spacecraft and a kinetic impactor.

GS Note: *This* committee was likely impressed only because in was non Nuclear and as such Politically Correct... Green. Otherwise, why bother testing what any engineering analysis will demonstrate to be the clearly Second Best Alternative by a factor of thousands. If we resurrect the Don Quixote mission test the clear front-runner thermonuclear alternative. If we expect to actually do this, and do it well, it will be a result of Preparation, Training and Vigilance... and Practice/Practice/Practice.

Finally, the committee points out a current estimate of the long-term average annual human fatality rate from impactors: slightly under 100. At first blush, one is inclined to dismiss this rate as trivial in the general scheme of things.

GS Note: And a matter of academic-slight-of-mind. If we were to suffer an extinction level impact tomorrow then the "average annual human fatality rate" for the next billion years would be 6.5 people per year. Such statistical sophistry is little more than comfort-food-for-thought and has no strategic value whatsoever. A poorly veiled attempt to mitigate Fear without actually mitigating the threat of the Fearful Thing. What we need here is a suitable antonym for alarmist... one who promotes the irrational absence of fear.

However, one must also consider the extreme damage that could be inflicted by a single impact; this presents the classic problem of the conflict between extremely important and extremely rare.

GS Note: 'Rare' here only suggests that they are hard to find. The occasion of such events is in fact completely RANDOM: without recursive pattern and can occur at any time.

The committee considers work on this problem as insurance, with the premiums devoted wholly towards preventing the tragedy.

GS Note: Insurance is the wrong analog here. What we need is 'Ensurance'. Think your local Fire Department not Liberty Mutual.

The question then is: What is a reasonable expenditure on annual premiums?

GS Note: No, the question is what does it cost to build an effective Cosmic Fire Department and how long do you want to Gamble on not having one?

The committee offered a few possibilities for what could possibly be accomplished at three different levels of funding (see Chapter 8); it is, however, the political leadership of the country that determines the amount to be spent on scanning the skies for potential hazards and preparing our defenses.

GS Note: Task this to the militaries of the world beginning with our DoD as a good faith precedent. With a total annual world military budget in excess of one trillion dollars a mere 5% reallocation would give us a $50 billion NEO War Chest. And done pro rata it would maintain the current balance of military power and in terms of Opportunity Cost correspondingly reduce our capability for killing each other over economic, political and religious principles. In terms of actual benefit, we would probably need to call this an Inverse Opportunity Cost... Win/Win

1 Introduction

In general, we cannot predict precise times and locations of future impacts, but can make statistical statements about the probability of an impact.

GS Note: Such "statistical statements" when expressed as incremental probability reflect and promote a gross misunderstanding of the empirical nature of the event of these objects. Their use deflects a rational appreciation that in their event asteroid impacts are completely Random: without recursive pattern. In short, we can not even predict *imprecise* times and locations of future impacts. An averaged relative frequency is not an approximate relative frequency.

If we had 10 asteroid impacts in the next 100 years, then nothing for the next 900 years the average relative frequency for asteroid impact over the next 1,000 years would be 1 asteroid impact every 100 years... Statistical (Random-Chance) probabilistic assessments while although mathematically precise are, by intent and design, a complete corruption of empirical observation and evidence: academic artifacts.

How can perfectly good scientists, with their Scientific Method, possibly ascribe to such information as rational. Any Statistical Probability is a completely non predictive, non analogous mathematical abstraction... no more than an illusion of information and completely unsuitable for any form of Decision Making and as such, completely irrelevant... strategically speaking.

If we are going to respond to this threat... if we are really going to do this, we need to completely abandon all statistical probabilistic thinking and methodology as being non constructive to rational and effective Decision Making.

That said, as in the case of Apophis, when we try to meter the orbital elements of a specific asteroid to the best of our ability in order to predict its future position relative to earth, *then* "we cannot predict precise times and locations of future impacts". Such imprecise observations can take the collective form of a Stochastic (Conditional-Empiric) probabilistic assessment, which being only imprecise but nonetheless empirical, must be taken as rational predictive information constructive to Decision Making... and as such, Strategically relevant.

Objects larger than about 30 meters in diameter probably strike Earth only about once every few centuries, and objects greater than about 300 meters in diameter only once per hundred millennia.

GS Note: The "about" makes the above misleading and the "once per" makes it false...

Assessing risk is difficult primarily due to lack of sufficient data.

GS Note: If there were "sufficient data" it would no longer be Risk. The difficulty here is that Risk Assessment is an Art and Scientists just don't get it. Far too subjective in the beginning and in the end. All Decision Making deals with degrees of "We Don't Know" as such. So you just assume the Worst and simply endeavor to Leave Nothing To Chance.

Our best current estimates are given in Chapter 2, where the risk is presented with its dependence on impactor size and associated average impact frequency,

GS Note: It bears repeating, "associated average impact frequency" is an arational abstract artifact and as such, irrelevant. All these events occur at Random: without recursive pattern... Therefore, summarily, Chapter 2 is likely irrelevant. Perhaps you do not understand that in the Real World to real Risk Managers, Risk is real. No abstract artifacts allowed.

For impactor diameters exceeding about 2 to 3 kilometers, world-wide damage is possible, thus affecting all of humanity and our entire living space. While exceedingly rare, the consequences of such a collision are enormous, almost incalculable. This presents the classic "zero times infinity" problem: nearly zero probability of occurrence, but nearly infinite devastation per occurrence.

GS Note: Given that the context of this report is to respond to these events this is simply an absurd way to look at this. First, this is a statistical probability and as such must be expressed in terms of some increment of time. Second, if you want to portray the probability as small you select a small increment of time. If you want to portray the probability as large you can select a large increment of time. Third, in order for a system to be assessed statistically it must be both existential and random in its behavior: 2 to 3 kilometer threats must exist as such and occur without any recursive pattern.

Randomly, without any recursive pattern, over the next billion years of the life of Earth our planet will suffer approximately 1,000 of these 2 to 3 kilometer impact events. This would afford these events an averaged relative frequency of one such event every one million years. In other words, randomly and at any time over any one million year interval of the life of Earth we will suffer, on average, one 2 to 3 kilometer impact event. There is no rational/deterministic/empirical reason we will not see the next one coming tomorrow.

Further, the statistical probability that we would see one coming tomorrow would be no less or more than for some tomorrow a million years from now. Then, even if we did see one coming tomorrow, it would not change the statistical probability that the event would occur. The annual statistical probability for such events would always be 0.0001% and the million year statistical probability would always be 100%.

Since you did not qualify your probabilistic assessment in terms of any increment of time, the question is, why have you chosen to portray such events as something we should not worry about? Or is this a consequence of believing in your own artifacts in order to facilitate clinically dissociative rationalizations? Is this a Green irrational Fear of Nukes or an all to human primal Fear of Fearful things?

In contrast, what has a truly Non Zero probability in fact, rationally/deterministically/empirically speaking, is that we will *Not* be struck by another Chicxulub Class Extinction Level Event... Sooner or Later.

Humanity has the capacity to detect and perhaps to counter an impending natural disaster.

GS Note: Capacity is worth nothing until it is developed into a Capability.

Page 8

FIGURE 1.1 Current estimates of the average interval in years between collisions with Earth …

GS Note: A picture of a worthless idea does not make it any less worthless. Garbage In will still only get you Garbage Out.

To assess the current hazards, surveys were undertaken

GS Note: Without a great deal of Luck, Surveys do not constitute an effective Surveillance or Early Warning method. These objects have a tendency not to stay where you find them and new NEOs are being generated all the time. Since it only takes One asteroid to constitute One asteroid impact event, it takes only the mere possibility of One undiscovered asteroid to constitute the complete and unmitigated Risk of one asteroid impact. Strategically speaking, since we can never *know* if we have ever found The Last Large NEO as such, the only way we can ever reduce the Risk of large asteroid impact is to find the next large imminent asteroid impactor in fact.

Although the possibility of a large NEO impact with Earth is remote,

GS Note: “the possibility of a large NEO impact” only *seems* remote if you don't really want to think about it honestly, rationally, logically. The one thing statistical probabilities *are* good for: comfort-food-for-thought... intellectual sand for the head of the academic ostrich.

Given the low risk over a period of, say, a decade (see Chapter 2), how much should the United States invest in this insurance?

GS Note: This analogy is really off track conceptually. Insurance is a process of socializing Risk. To work in must have a number of members commensurate to the average relative frequency of the insured event to defer the pro rata cost of each event as it occurs. Where are the other Planets we can pro rata share this cost with? Think Fire Department not Fire Insurance... and one planet.

What will it cost to build an effective Planetary Defense to the level of responding to the Worst Case Scenario and how long do you want to gamble on not having such a capability.

The committee was asked to recommend the optimum approach for each of the tasks, with the definition of “optimum” left to the committee.

GS Note: Main Entry: *optimum* Part of Speech: *adjective* Definition: *best*. How is this difficult?

So, as long as this committee had a license from Congress to find the highest and best definition for “optimum”, the question then would be dependent upon what would be the optimum/best possible outcome for Brown, Arecibo, and developing a deflection capability?

Are we counting rocks in Space and looking for interesting radar images and fun reasons to go and visit asteroids? Or are we looking to detect and characterize and deflect The Next Large Asteroid on its way to strike Earth before it kills us all... At Any Cost? If Failure is Not an Option here, *then* what is the 'Optimal Approach”?

All that is standing between you and this rational is the statistical probabilistic illusion that the probability for our extinction by asteroid impact anytime in the next 100 years is low... when the rational fact is 'We Do Not Know'. Since the probability of *sooner* is equal to the probability of *later,* is leaving the prospect of our extinction to Random-Chance the “Optimal Approach”? If we chose to Gamble, then from year to year, as a matter of chance, for a while we may win and this would seem to be the cheap and easy approach. But sooner or later, even though the odds are always in our favor, we will lose... and all there is forever will be gone. The *cost* of Chance.

Then, since you were free to define “Optimum” and the question of the “optimal approach to developing a deflection capability” (which would include detection and characterization) was not bounded or qualified by only *small* asteroid threats or *after* we see one coming or with a *non nuclear* response or any *cost* constraints or analogous comparisons to *other* threats we manage or anything... how did you fail to set aside your collective Fear of Fearful Things to boldly address this threat in its Worst Case Scenario?

A unique characteristic of the NEO research premiums, which distinguishes them from the usual types of insurance, is that the entire premiums would be directed towards the prevention of the catastrophe.

GS Note: Which makes it nothing like insurance... More like maintaining a Fire Department or Police Department or a Department of Defense and a standing Military. *Ensurance*.

In no case, however, is it wise to consider application of techniques more than a few decades into the future. The technologies available at that time would likely be both more efficient and more effective, rendering present approaches obsolete. This is not to suggest waiting for those future technologies, leaving Earth unaware and threats to Earth unmitigated in the meantime.

GS Note: Reality Check... Technology does not evolve in a vacuum of economic demand. In the past 40 years of our awareness of the threat our incidental extemporaneous capability to respond to this threat has in effect, diminished. No more Saturn V launch capability and only half the nuclear arsenal we had during the Cold War... At best this logic is just another appeal to Chance and Good Luck! Where did these scientists get their blatant tendency to gamble? With this logic there would in fact never be a time for us to actually ever *build* anything because there might always be something new and improved right around the corner.

This is not to suggest waiting for those future technologies, leaving Earth unaware and threats to Earth unmitigated in the meantime.

GS Note: To some degree, this appears to be an introduction to a contradiction to the previous notion. Abandoned as a thought when its completion would clearly reveal it as such... I see why scientists have problems resolving variables. You can't keep your minds made up. No inherent subjective orientation. Don't know what you *should* want.

The threat of asteroid impact is forever. If we are going to respond to this threat successfully we need to look at this as an annual Cosmic Cost of Living. No Planetary Defense will ever be large enough or effective enough or ever be *done*. Building a Planetary Defense will be a never-ending evolutionary process. The only question is, what fraction of our standing world military budget will we re-task in response to this potentially terminal threat? In terms of Cost/Benefit, what percentage of Gross World Product are We The Species worth? The Universe is a dangerous place. It does not suffer dilettantes gladly or for long. So we need to start to pony-up ASAP.

Page 10

As to deployment of any counter measure, a main guide is the ancient maxim:"First, do no harm."

GS Note: This would be the ancient maxim for the medical profession. For those professionals responsible for Managing Risk the ancient maxim would be more on the order of "Do It Right" and "Use Clearly Superior Force" and always, "Leave Nothing To Chance"... facilitated by constant and perpetual Practice/Practice/Practice and Preparation, Training and Vigilance.

In particular, the error ellipse that describes the uncertainty in the prediction of impact might well not approach the near certainty desired, indicating the need for caution.

GS Note: And 'caution' here would manifest in the form of a margin of error and multiples of the ideal mission and consequentially, mission mass. Error ellipse, technological confidence and target mass are principal elements that effectively compound each other. An inexperienced and post detection built response may beg an overall mission Margin of Error of ten times.

At best, these cost estimates provide only crude approximations of final costs of pursuing any of these options, so the committee did not use these cost estimates in reaching its conclusions.

GS Notes: Incredible... you had outside paid professional help, CYA plausible deniability if needed, and you still could not bring yourselves to make a definitive recommendation.

What you don't understand here is that making a Decision is not about predicting the future and getting it Right or Wrong in the end but rather in the beginning can your Decision be made to Work and right or wrong will it succeed or fail. As no Plan of Battle survives contact with the enemy, no Decision survives contact with the future... we must endeavor to win in either case.

Page 11

2 Risk Analysis

the most significant risk remains from collisions with bodies on oval-shaped orbits (such as comets) and objects with orbits near that of Earth.

GS Note: This should read near that of Earth's *orbit*. Near Earth Orbit Objects... NEOO. It's easy to see why that was shortened to NEO.

The “most significant risk” is an example of narrowly perceiving Risk as synonymous with probability and ignoring the element of the magnitude of the loss and all the strategic and tactical elements in any response.

Within the category of NEOs there are Earth Orbit Crossing Objects which would constitute the most apparent proximate threat. We should keep in mind that less apparent proximate threat populations include rogue asteroids that have been perturbed from a relatively stable Main Belt orbit but do not pass close enough to Earth's orbit to be NEOs... yet: Main Belt asteroids and Jovian Trojan asteroids that orbit around the Sun/Jupiter Lagrange points which can be perturbed into a near term impact trajectory at any time: and captured short period Comets. Then there is the Kuiper Belt and the Oort Cloud. All things considered, how can we say what category of this threat is the *most* significant risk.

Until we can manipulate the geometry of the Solar System or beam these rocks to a Galaxy far, far away as we find them, then systemically speaking, there is no such thing as A Risk of Asteroid Impact we could actually do anything about. There are, however, billions of individual Asteroid Impact Risks... And the one we have to worry about forever will always be the next one on its way to strike Earth.

Page 12

Subsequent observations of Apophis ruled out an impact in 2029, and also determined that it is quite unlikely that this object could strike during its next close approach to Earth in 2036.

GS Note: This unlikelihood would be the product of a conditional-empiric probability and although rational and predictive is generally subjective and mathematically imprecise and can be extremely dynamic over even short periods of time. In the case of Apophis, a lot can happen in the next 27 years. As the event nears resolution, the increased precision in the assessments of the non random variables as well as the potential for random variables can easily change predictions as well as the final outcome... at any time.

INVENTORY OF NEOS AND POTENTIALLY HAZARDOUS NEOS
Introduction

Page 15

Current estimates (Harris 2009) indicate that there should be a total of about 940 NEOs larger than 1-kilometer in diameter.

GS Note: In their 2006 Near-Earth Object Survey and Deflection Study NASA has assessed and effectively condemned the precision of this methodology (Power Law Distribution) as having a potential margin of error of 2 to 3 times. The ESA, with their Infrared Space Observatory results challenged the albedo assumptions used and effectively doubled the estimate of categorically large asteroids in the Main Belt. Dr. William Napier determined that there may be as many as 3,000 Dark Comets, having lost their surface water ice leaving a pure carbon surface, that have been captured in short term orbits that would fall into this large object population and have so far not been considered by current estimators here.

The Area of Interest that The Next Large Asteroid on its way to strike Earth is in is over 500 trillion, trillion cubic miles. Thats a whole lot of Space to be claiming to know how *many* of what you know is out there is actually there. We are still very, very young here.

That said, the number of asteroids or comets is strategically irrelevant. It only take One to kill us all. And The Next Large Asteroid on its way to strike Earth is closing at A Million Miles A Day.

Based on this estimate and current NEO detections, we conclude that nearly 85 percent of all 1-km or larger objects in the near-Earth environment have been detected. We have also shown that none of these objects presents a threat of impact on Earth within the next century.

GS Note: Should read "*appears* to be a threat of impact on Earth within the next century". The orbits of these objects can easily change. If a 1,000 meter asteroid collides with a 100 meter asteroid (0.1% of the 1,000 meter asteroid's mass) the 1,000 meter asteroid could be displaced as much as a million miles in less than 3 years.

Estimates of the "risk" that exists in the portion of the NEO population that has yet to be discovered requires the following components:

GS Note: The "following components": All Smoke and Mirrors; statistical probabilistic sophistry; academic-slight-of-mind. At best, irrelevant. At worst, grossly misleading. You are trying to predict the roll of the dice. These components can not reflect or contain information on The Next Large Asteroid on its way to strike Earth. As such, individually and collectively, they are Tactically and Strategically irrelevant. Such "Estimates of the "risk"" reflect or contain nothing essential to the conduct of implementing a successful response.

Page 17

We can pick an object randomly from this distribution of orbits and calculate the annual probability of its impact on Earth. When an object is found and its orbit becomes known, it is removed from the pool of random objects.

GS Note: Which does not remove it from the base line of data that determines the statistical probabilistic assessment. Nor does becoming known and observed make its behavior any less random. Observing the cast of a die empirically and calculating the outcome does not make the result non random. It will still express a specific result without a recursive pattern.

Given an estimated candidate population of 1,000 unknown objects, the most rational Risk postulate of One asteroid impact in the next 100 years would reflect the expectation that One of them may be on course to strike Earth in the next 100 years and 999 of them would not.

Clearly, finding any portion of the 999 candidate objects expected not to be on course to strike Earth anytime in the next 100 years to not be on course to strike Earth in the next 100 years as a matter of empirical fact, would be expectable. Therefore, such results would have no bearing on the initial Risk postulate of One asteroid impact in the next 100 years.

If it were non-hazardous, then our total assessed statistical risk from the remaining undiscovered objects would be decreased to a lower value that we refer to as the "residual risk."

GS Note: Which is not the way statistical probabilities work. To generate a lower 'value' the object would necessarily either have to be removed from the system... beamed to a Galaxy far, far away or found not to be there in the in the first place... an error in the initial estimate. Simply looking at it or determining the outcome of a probabilistic event does not change the probability.

Flip a coin, the statistical probability that it will come up Heads is 50%. If a flipped coin does come up Heads it does not change the statistical probability that it will come up Heads to 100%. And if it comes up Tails it does not change the probability for coming up Heads to Zero.

If you flip a coin and instead meter the empirical conditions that will determine the outcome: original position, vector, angular velocity, density of the table etc., you would be able to generate a dynamic mathematical conditional probability predicting the outcome for heads at various stages of the course of the coin until it lands on the table and the potential for Heads resolves to either 100% or Zero.

You are conflating conditional-empiric stochastic probabilistic elements and methods with random-chance statistical probabilistic elements and methods. Methodologically these two perceptions are completely unique and discrete from each other and incompatible with and nonconstructive to each other. The only thing they have in common is shared nomenclature and semantics... You are trying to claim that you are doing something that you are not. No form of the Risk is being reduced here.

Since, no matter how hard you try, you cannot squeeze a prediction for the next asteroid impact event out of a systemic statistical probability. The behavior of asteroid populations is generally non deterministic to an individual asteroid's behavior and any useful and relevant probabilistic assessment for the next asteroid impact event is simply indeterminate... until we see one coming.

Finding asteroids that are not going to strike Earth anytime soon, in and of itself, is nothing. The only value to these survey's is in the random-chance they may find the next impact threat as soon as possible so we can deflect it as soon as possible.

FIGURE 2.4 Curent population estimate

GS Note: The number of NEOs is only relevant to the average relative frequency derived random-chance statistical probability which is summarily irrelevant. So, strategically speaking, the number of NEOs is irrelevant: not essential to the conduct of implementing any response.

Page 18

Disregarding non-gravitational forces for sake of discussion, we can think of all NEOs as being on deterministic trajectories, so that the probability of an impact of a given size NEO over a prescribed time period is either one or zero.

GS Note: This would be exclusively relevant only to a conditional-empiric probability...

Surveys and tracking only affect our assessment of the risk in the same sense as looking both ways before you cross the street.

GS Note: No... your “assessment” is statistically probabilistic. It would be like crossing the street with your eyes closed and trusting in the favorable odds... Gambling.

As this would be a random-chance statistical probabilistic assessment it is subject only to a change in the number of asteroids or a correction in our understanding of the laws of physics. It can not be changed by the expression of the event or the absence of any such expression.

Given: The statistical probability for asteroid impact in any 100 year increment of the life of Earth is 1:5,000. If an asteroid strikes Earth in any 100 year increment the probability for impact in that increment will still be 1:5,000. Neither the expression nor the absence of the expression of the assessed event will have any bearing on the expressed probability.

Observation does not affect the distribution of either cars or NEOs, but is indispensable for determining what actions should be taken to remain safe in both situations.

GS Note: Only to the degree that we understand that systemically speaking, the occasion of cars and asteroids are completely aperiodic and random events. Such an assessment can not forecast or predict which asteroid is Next. Therefore, by this method we can not predict when it will impact or how large it is or when we will know which, when or how large... So "Be Prepared". For cars we can simply stop at the curb or jump out of the way. For asteroids we have to be prepared to deflect the damn car... Really not a very apt analogy.

None of those detected objects has a significant chance of impacting Earth in the next century.

GS Note: Only baring any asteroid/asteroid or asteroid/comet impact perturbation. Eros, the only asteroid we have visited, had 100,000 visible impact craters on its surface. An asteroid colliding with as little as 0.1% of its mass could be perturbed a million miles in as little as 3 years.

This is like looking at a snap shot of a bucket of dice perpetually rolling across a rough table. We really don't know how many there are and can only see some of them and those we see do not *appear* to be coming up 6 anytime soon... but it only takes one 6 to kill us all.

Scientists and academics are able to afford to find comfort in manipulated statistical probabilistic rationalizations that portray a reduced Risk. But to a Strategist, tasked with the responsibility to respond to The Next Large Asteroid on its way to strike Earth, this threat necessarily presents itself as a binary problem: Is there or is there not One large asteroid on its way to strike Earth in the next 100 years... Yes/No.
In terms of any calculable Risk there will be no relevant Risk assessment until after we see one coming. But that does not justify trying to using the abstract assessment of the scientists and academics. Here, we can only afford to Hope for the Best *after* we have Prepared for the Worst.

To establish an intuition, consider that this is not as if there were 1,000 Barbarians at the Gate. All of them individually equally dire in their prospect to rape, pillage and burn and collectively a terminal threat to The City. Here, if the city's Guard dispatches 900 of them they will reduce the collective threat to The City by 90%.

But the threat of large asteroid impact was never seen to be in the Risk that all ~1,000 estimated Large NEOs would strike Earth in the next 100 years but rather that only One of them may do so.

Consider instead that there are 1,000 Pilgrims at the Gate and One of them may be a Terrorist with a Nuke. If the Guard randomly searches and interrogates 900 of them and fails to find a terrorist with a Nuke they will then have 100 Pilgrims at the Gate and One of *them* may be a Terrorist with a Nuke. The threat to The City has not changed. Clearly, the number of Pilgrims at the Gate has no bearing as to whether or not there is a Terrorist at the Gate with a Nuke. The Guard has not reduced the threat of a Terrorist at the Gate with a Nuke by only finding Pilgrims to be Pilgrims... The Pilgrims only make the threat more difficult to determine. More Pilgrims just make More Work.

Here, we can only resolve the problem once we have searched and interrogated the Last Pilgrim. In the case of asteroids, discovered and determined the Last Large NEO, as such, to be an imminent impact threat or not.

However, this is not the problem we have here. Consider that the Royal Mathematician has done his statistical due diligence and the math and determined that one in every one million Pilgrims is a Terrorist with a Nuke. Therefore there was only an initial 0.1% statistical probability that there was a Terrorist with a Nuke at the Gate in the first place. Further, since the Guard has searched and interrogated 90% of the Pilgrims and found all of them to be Pilgrims and not a Terrorist with a Nuke, that somehow the initial 0.1% probability can now be reduced by 90%.

The Royal Mathematician tells the King not to worry that the statistical probability for there being a Terrorist and the Gate is low. Go ahead and let them all into the City. The Capitan of the Guard objects. He only understands that there are 100 more Pilgrims to search and interrogate up to and including The Last Pilgrim. There may be a Terrorist at the Gate with a Nuke!

Who here speaks on the side of wisdom: the Royal Mathematician or the Captain of the Guard? Who here should you trust to be Watching the Wall? It seems it would be far more effective to task a Soldier with a mission in Space than it would be to teach a Scientist to think like a Soldier.

TABLE 2.1 Approximate Average Impact Interval

GS Note: Doubly useless. Both *Approximate* and *Averaged*...

Page 19

As noted above, most impact simulations indicate the likelihood that human life will be significantly affected by impacts over short timescales (i.e., under 1,000 years) is low.

GS Note: And yet, at random, over larger timescales the likelihood is high to absolutely certain. The question is, where are we along the current large timescale? Thinking small can always make you feel safe.

However, as we have not yet detected and characterized all NEOs, it is possible (but very unlikely) that an NEO will "beat the odds" and devastate a city or a coastline in the near future;

GS Note: If you choose to play Russian Roulette six times in a row, spin the cylinder each time, and one of those times you blow your head off, how could the bullet be seen to "beat the odds"?

If the near future is the next 100 years then the odds for any 100 year increment of the life of Earth are always the same. So it would be to an absolute certainty that sooner or later some 10 km NEO will "beat the odds" and we go the way of the dinosaurs... How did it come to pass that scientists, of all people, should be telling us when and how to gamble when they seem to know so little about the inherent ultimate certainty of chance? More to the point, when did it become wise for us to listen to them about Gambling? Walk into any casino in Vegas and the boys at the front door will tell you simply "Never bet any more than you can afford to lose". The dice have been cast and with the survival of the spices on the line which sounds to be the better wisdom?

Page 23

The plot shows fatalities per year and clearly indicates that most of the threat comes from the larger objects that exceed the global catastrophe threshold, even though the probability of an impact by these objects is very low relative to that for smaller objects.

GS Note: If you choose to Gamble, the *probability* is only relevant when rationally comparing two discrete bets. Then it is always the third and last determinate. First, the potential *magnitude of loss* must be equal between the two bets and below your subjective tolerance for loss. Second, the differential between the magnitude of the loss and the *magnitude of the win* should be equal between the two bets and appeal to your subjective asymmetrical sense of gain. Only then, if these first two elements are subjectively suitable, do the relative objective mathematics have any deterministic merit.

If we gamble and lose on the impact of large objects is it affordable? Is the gain of choosing to not effectively mitigate the threat at this level equal to or greater than the potential loss?

If Small Asteroid threats were not incidentally addressed as a matter of course and somehow we could choose between mitigating the threat of Small Asteroid threats or Large Asteroid threats, even given the greater gain if we do not, wouldn't we choose to address the Large Asteroid threats and the greater magnitude of loss as a matter of simple common wisdom.

I give you two revolvers. The first has one bullet, you spin the cylinder and point it at your head. The second has five bullets, you spin the cylinder and point it at your foot. At *Go* you will pull both triggers. The game here is that you are allowed to deflect one revolver. Which one do you choose? It's not the odds... it's always the magnitude of the loss.

The drop from >1000 to 91 expected fatalities per year clearly demonstrates the results of the Spaceguard Survey to date, which has "retired" the statistical risk from most objects above the assumed global catastrophe threshold.

GS Note: This would be true only if the Spaceguard Survey's initial postulate of the Risk were that all the Large NEOs estimated were on course to strike Earth in the next 100 years... not just One. Or if instead of merely discovering them and characterizing them they were beaming them to a Galaxy far, far away and effectively reducing the statistical probability of the residual Large NEO population... which would still be irrelevant, strategically speaking.

Page 24

Nonetheless, this survey may detect one or more NEOs on a collision course with Earth.

GS Note: Which would be the highest and best outcome for the Survey... find The Next Large Asteroid on its way to strike Earth. The only rational expectation defining success. Not finding it is nothing... failure.

Carrying out a survey, per se, does not remove whatever risk there is; we just learn more about that risk.

GS Note: Yes! You got it right... too. Unfortunately, if "we just learn more about that risk" per se and fail to find the next impact threat, the Survey has done nothing... strategically speaking. So what have you learned so far that will help you find the next impact threat.

Based on these results, one could argue that a change is needed in the minimum size of the object to be included in the search, say, from 140 meters down to 50 meters.

GS Note: And increase the current unfunded work load from finding 20,000 140 meter objects to 1,000,000 50 meter objects... The cost of finding these things can be metered by the piece. No discount for volume. In fact the smaller/the harder therefore more each. You can't even bring yourself to definitively recommend to Congress to spend the money on the 140 meter threats...

Page 25

Warning Time for Mitigation

A key issue in the hazard from NEOs is that the length of time needed to execute a mitigation strategy

GS Note: And everything we do not do *before* we have a Detection-To-Impact Window we will have to do *after*. Consequentially, anything we leave to do *after*, as a matter of time, will be charged against the final displacement period and effectively increase the force/Delta Vee and size of the mission required for a successful deflection. Then, when NEOPucker Time comes, not all the money in the world - not all the hubris, not all the resolve, not all the courage, not all the hope, not all the genus, not all the 11th hour road-to-hell-paving political good intentions Mankind can bring to bear, altogether - will buy us more *time*.

but this long period may require acting before we know with certainty that an NEO will impact.

GS Note: And why the gods have allowed Mankind the notion of Margin-of-Error when dealing with any of Murphy's Laws. We need to be prepared to send mission enough to account for our uncertainties. All things considered, perhaps as much as 10 times any of the optimized Best Case Assumption based ideal scenarios proffered so far.

Currently, by far the most probable scenario is that of a small impactor, likely to cause at most only local destruction.

GS Note: When you appeal to Chance with an expectation of Good Luck the only tool at your disposal for a desirable outcome is Hope. And Hope has never been a reliable survival tactic. Tempered only by value and capability we should endeavor to Leave Nothing To Chance... Unless you're in Vegas.

Page 26

Societal Elements of NEO Risks

Unlike most other known natural hazards to humanity, such as earthquakes, volcanic eruptions, tsunamis, hurricanes, and tornadoes, NEO impacts present a very large spread of disaster scales ranging from small property damage to global extinction events.

GS Note: Unlike “earthquakes, volcanic eruptions, tsunamis, hurricanes, and tornadoes” the occasion and magnitude, the “large spread of disaster scales ” of asteroid impact events will be distributed aperiodically and randomly... and includes the prospect for our extinction.

Page 27

coupled with an unwillingness so far of governments and agencies to expend public funds in a concerted effort to identify, catalogue and characterize as many potentially dangerous NEOs as possible as long before a damaging impact event as feasible.

GS Note: First, If you want more money from Government... Scare them better! Second and here, they hired you to recommend specifically *what* to do ostensibly so as they can do it...

Scientists must carefully assess and explain the hazard so that appropriate public policy measures, commensurate with the level of risk, can be put into action.

GS Note: “Commensurate with the level of risk” sounds like if there were an annual 0.1% statistical probability that your house would burn down you would only want to spend 0.1% of the cost of building a Fire Department each year... So in 1,000 years you would have an effective working Fire Department. Now would be the time to talk about that Fire Insurance.

2. There must be an assessment of the statistical risk from NEOs that is reasonable and acceptable to the general public.

GS Note: You are saying that scientists should spin the magnitude of the Risk with probabilities and warnings of only airbursts so as the general public does not appreciate that you would choose to Gamble with the survival of our species before you would ever promote a rational nuclear response. The problem is, what they do not understand will kill us all.

3. It is important to assess the length of time that the public is prepared to wait for scientific surveys to reach target goals of detection and characterization, and for mitigation technologies to reach desired maturity.

GS Note: Strategically speaking, the target goal for Surveys would be finding The Next Large Asteroid on its way to strike Earth. If you asked them the right question you can be sure they would tell you to do so ASAP. And since relevant technology (better/lighter nukes) will not evolve in a vacuum of economic demand: BUILD IT NOW! We can upgrade as we evolve... Never-Ending Forever Threat.

Whereas surveys will never be 100 percent complete, given the diversity of the objects, their origins, and their orbits, it is important to make surveys as close to 100% as feasible to assure the public that all reasonable precautions are being taken.

GS Note: So we will never find The Last Large NEO... didn't think so. So much for the possibility of searching and interrogating that Last Pilgrim approach and eliminating the threat of One asteroid impact in the next 100 years.

4. An assessment is needed of the levels of expenditure that the public is prepared to accept in order to reach such goals for detection, and similarly for characterization, and mitigation. Although the costs are almost vanishingly small relative to other elements of the federal budget, public support for such activities may be absent lacking demonstration of a clear and present threat.

GS Note: Task this business to the militaries of the world and fund it pro rata from 5% of their current standing budgets and it would be tax revenue-neutral. The General Public would not even have to know... except when some war actuarial noticed the 5% global reduction in our killing each other over economic, religious and political principles... Makes you want to make that NEO War Chest 10%... yes/no?

GS Note: The thing about statistical probabilities is that they are founded upon an intentional corruption of perfectly rational empirical information. Presumably anathema to any definition or application of Scientific Method. Any conclusion or inference drawn from such information would be a non sequitur. How could any rigorous scientist ever even consider using them?

Consider determining the statistical probability for the expression of 6 with a 6 sided die. You cast the die 6,000 times total the number of 6s (~1,000) and divide by the number of casts to get an averaged relative frequency of one 6 every six casts which could be expressed as a statistical probability of 16.6% or 1:6. However, the empirical observation would be that 6 did not in fact occur every sixth cast but at random: without any recursive pattern. The process of creating an averaged relative frequency is a corruption of the empirical evidence.

In contrast, consider that you were to determine the length of a day on Earth. After one year you observed that within a negligible margin of error the length of a day on Earth was consistently 24 hours long. However, when you submitted your findings you randomized them, artifactualizing your observations to portray the length of individual days as dramatically different from each other. As rational information, your findings would be worthless. Not because the reordered information was now random, random results have value, but because the empirical information was intentionally corrupted in presentation... biased. Methodologically, reordering random to non random is no less a corruption than reordering non random to random. If a randomized time of day would be scientifically unsound information then so would be a statistical probability.

Not to throw the baby out with the bath water for the sake of semantics, but conditional-empiric probabilities, what we are using to assess the impact potential of Apophis, are the foundation of foresight and have advantaged our evolution far more than the opposable thumb. But There are many good reasons to dismiss statistical probabilistic assessments as irrelevant. Pick one.

Statistical probabilities are completely non analogous mathematical abstractions. They are non predictive and arational information and completely non constructive to sound decision making.

3 Survey and Detection of Near-Earth Objects

It is possible for an NEO to come close to Earth, but to never intersect Earth's orbit and therefore not be potentially hazardous.

GS Note: Which would only be somehow relevant if we had a NEO Crystal Ball and could know they would never become Earth Orbit Crossing Asteroids and inevitably impending impactors.

The criteria for the assessment of the success of an NEO detection mandate rely heavily on estimates that could be in error, such as the size of the NEO population and the average reflectivity properties of an object's surface.

GS Note: Only if such an effort had the objective of somehow responding to the threat systemically and not as these objects present themselves as individual and unique impact threats. Then the criteria for the assessment would be limited to those elements of The Next Large Asteroid on its way to strike Earth specifically as an evergreen definition of the threat.

This difference implies that, on average, NEOs have diameters at least 10 percent smaller than previously thought,

GS Note: Which is in contradiction with the ESA's Infrared Space Observatory's empirical findings which, when compared to optical assumptions, indicate that NEO's are in fact substantially *larger* than previously thought. Effectively doubling the categorically Large Asteroid population of the Main Asteroid Belt. WISE may tell us more.

These objects could dominate the impact threat to humanity, after the completion of exhaustive searches for NEOs.

GS Note: Only if we are foolish enough to allow statistical sophistry to foster the rationalization that the absence of evidence is evidence of absence.

New objects are introduced into the NEO population from more distant reservoirs over hundreds of thousands to millions of years.

GS Note: Randomly... and likely without our notice.

We must be constantly vigilant.

GS Note: *FOREVER!*

Finding: Despite progress toward or completion of any survey of near-Earth objects, it is impossible to identify all of these objects because objects can change their orbits for example due to collisions.

GS Note: Correct. In that it only requires One asteroid to constitute an asteroid impact therefore the Risk of one asteroid impact is wholly contained and unmitigated by the mere possibility of just One dramatically perturbed discovered asteroid.

Recommendation: Once a near-Earth object survey has reached its mandated goal, the search for NEOs should not stop. Searching should continue to identify as many of the remaining objects and objects newly injected into the NEO population as possible, especially imminent impactors.

GS Note: Even after discovering The Last NEO, by the Finding here the Recommendation should read "NEVER" stop.

Page 42

Space-Based Detection Techniques

The 2003 NASA SDT study concluded that an infrared space telescope is a powerful and efficient means of obtaining valuable and unique detection and characterization data on NEOs.

GS Note: So here you go. NASA's PA&E even reiterated the concept in their 2007 NEO report. Decision Made. Optimal Approach determined... and you can point to NASA for plausible deniability. And for a mere additional $125 million you can throw in the LSST as back-up and to keep things honest and help Save The World! How is this difficult?

Page 46

Finding: The mandated survey to locate 90 percent of near-Earth objects 140-meters in diameter or greater has not yet been funded by the federal government. Because the survey requires several years to budget and build new equipment, and then to conduct the search, completion by 2020 is not realistic.

GS Note: When it is *completed* is far, far less strategically relevant than when it gets *started*. You have had 2 years. Pick one, Pick two! Otherwise Congress can simply use the failure of this report to respond to its requests and make the lack of definitive recommendations a scape goat.

Page 47

Finding: The selected approach to completing the George E. Brown, Jr. Near-Earth Object Survey will depend on nonscientific factors:

• If completion of the survey as close to the original 2020 deadline as possible is considered most important, a space mission conducted in concert with observations using a suitable ground-based telescope and selected by peer-reviewed competition is the best approach. This combination could complete the survey well before 2030, perhaps as early as 2022 if funding were appropriated quickly. A peer-reviewed competition would be held to select this mission.

• If cost conservation is deemed most important, the use of a large ground-based telescope is the best approach. Under this option, the survey could not be completed by the original 2020 deadline, but could be completed before 2030. To achieve the intended cost-effectiveness, the funding to construct the telescope must come largely on the basis of non-NEO programs.

GS Note: You have not even biased the alternatives. This decision making stuff really is way above your pay grade. You knew you were scientists and that this would come down to non scientific variables and factors... you knew the questions. Why did you choose to take the money and waste 2 years of our time in the first place? At this point in the evolution of our Planetary Defense this was no time to be playing pork barrel games. In the 2 years since you were given this task The Next Large Asteroid on its way to strike Earth has closed 730,000,000 miles. And we are no closer to being prepared.

The combination of a space-based detection mission with a large ground-based telescope will complete the survey in the shortest time, i.e., closest to the original 2020 deadline.

GS Note: And in the process give us the better chance of determining which asteroid is The Next Large Asteroid on its way to strike Earth in time to do something about it. Or is that not relevant scientifically? Best, of course, would be a dozen or so of each... think bigger. We The Species are on the line here.

Page 52

Finding: It is highly probable that the next destructive NEO event will be an airburst from a <50- meter object, not a crater-forming impact.

GS Note: This high probability will always be true. Even if you looked out your window and saw a 10 km Extinction Level Chicxulub Class Impactor 10 seconds away from impact it would still be highly probable that is would be a 50 meter airburst event. So, although it may be seen to be statistically true, it is also arational and non predictive and as such... strategically irrelevant.

Recommendation: Because recent studies of meteor airbursts have suggested that near-Earth objects as small as 30 to 50 meters in diameter could be highly destructive, surveys should attempt to detect as many 30- to 50-meter objects as possible. This search for smaller-diameter objects should not be allowed to interfere with the survey for objects 140-meters in diameter or greater.

GS Note: How could they interfere? Are astronomers going to simply ignore any 140 meter or any 10 km extinction level asteroids they happen to discover? Or is it that if you do not conflate the two objectives their may be no discrete pork barrel funding for yet another *scientific* study?

4 Characterization

Page 55

Finding: The best opportunities for physical characterization of most NEOs occur during close Earth approaches when these objects are optically bright. Existing programs of ground-based optical observations for characterization of NEOs are few in number, and are not coordinated among different observing teams. Many observable NEOs are not characterized.

GS Note: This would change with the deployment of several Space-Based infrared observatories. The ultimate goal here would be to have a full spectrum 24/7/52 real-time surveillance of the entire 500 trillion, trillion cubic mile Area of Interest that The Next Large Asteroid on its way to strike Earth is in... forever.

Page 56

Understanding asteroid composition is important for developing mitigation techniques. Radar observations have been used not only to estimate asteroid compositions,

GS Note: Asteroid *surface* compositions. It could not tells us anything about its core or much below millimeters of the surface. Not enough to confidently resolve its mass for purposes of determining the precise size of a deflection mission. Not enough power.

Page 64

Recommendation: Immediate action is required to ensure the continued operation of the Arecibo Observatory at a level sufficient to maintain and staff the radar facility. Additionally, NASA and NSF should support a vigorous program of radar observations of NEOs at Arecibo and NASA should support such a program at Goldstone for orbit determination and characterization of physical properties.

GS Note: There you go. You made a Decision. Although why you think the NSF should be involved in Planetary Defense is not apparent. No more *Science* required here. Just the engineering of method and technology. And where do NASA and the NSF get the money from? I think Congress wants more from you than a Finding that they have not appropriated the ad hoc funding required for this mission. Is this a *tacit* Recommendation?

However, plans and intentions should be made to upgrade to something dedicated exclusively to NEO interrogation with far more coverage capability and greater power. For now, something in the US Military 4 Mw Aegis Class would be nice.

Page 65

We thus now know that Apophis cannot impact Earth in 2029,

GS Note: All that would be required for Apophis to impact Earth in 2029 would be the Bad Luck collision of Apophis with as little as a 5 meter rogue asteroid today. 2029 is a long ways away: 7.3 billion miles as the asteroid flies. A lot can happen in 7.3 billion miles.

but an impact, although extremely unlikely, has not been ruled out for the approach in 2036.

GS Note: All that would be required for Apophis to impact Earth in 2036 would be the Bad Luck collision of Apophis with as little as a 10 cm rogue asteroid/meteoroid/rock (?) to put into the wrong Keyhole. A lot can happen in 7.3 billion miles. Including increased mathematical precision and accuracy which could have the same result... in terms of probability and prediction.

CHARACTERIZATION ISSUES FOR "AIR BURSTS"

Page 67

Recommendation: Additional observations and modeling should be performed to establish the risk associated with airbursts and with potential tsunami generation.

GS Note: What's with this running theme of airbursts? You dismiss the threat of Extinction by NEO (which should be our paramount concern) with probabilistic rationalizations then push 50 meter airbursts (which have a remote chance of being over something important at best and when they do hit Earth and then, not really doing any damage we cannot recover from) when there is little or nothing we can do about them except get out of Dodge if/when we do see them coming in time. How is this relevant to "Developing a Deflection Capability". Is there a ground work being laid for another *Scientific* Research grant where you will once again just find far too many variables to actually make any definitive Recommendations for any Real World response?

IN SITU CHARACTERIZATION RELEVANT FOR MITIGATION

Finding: Rendezvous spacecraft missions can provide detailed characterization of NEOs that could aid in the design and development of hazard-mitigation techniques. Such in situ characterization also allows calibration of ground- and space-based remote sensing data and may permit increased confidence in the use of remote classification of NEOs to inform future mitigation decisions.

GS Note: The *Arecibo* argument then would be that without its interim characterization capability, once we start to discover the tens of thousands of smaller NEOs we would need to rely upon hundreds of Discovery Class NEO reconnaissance missions to dismiss them as impact threats... Ok, NASA would love that... But.

HUMAN MISSIONS TO NEOS

Recommendation: If NASA conducts human missions to NEOs, these missions should maximize the data obtained for NEO characterization.

GS Note: Specifically to Earth Orbit Crossing Asteroids. Since it is just a matter of Time and Chance before all these objects find themselves on an impact trajectory with Earth, take along a couple Megatons of thermonuclear explosive device and when we go, leave behind nothing but a rapidly expanding ball of circumstellar orbital debris and space gas. Call it Cosmic Yard Work. And Practice/Practice/Practice!

Page 70

5 Mitigation

Impacts on Earth by NEOs are inevitable and range from harmless fireballs, which are very frequent, through the largest airbursts that do not cause destruction on the ground, which on average occur once in a human lifetime, to globally catastrophic events, which are very unlikely to occur in any given human lifetime

GS Note: This is nothing more than another product of statistical probabilistic rationalization. The way this kind of likelihood does *not* work would be that if you looked out your window today and see a 10 km Extinction Level asteroid 10 seconds away from impact it would still be "unlikely" that such an event would occur in your lifetime. In other words, under this metric there would never be a lifetime where globally catastrophic events would ever be *likely*. Such likelihoods are arational and non predictive: completely non analogous mathematical abstractions. Not real information.

This perspective only *seems* to work, and then only intuitively, in a myopic and narrow perspective. Say you wake up Monday and choose to play Russian Roulette... once. You load one bullet into a 6 shot revolver, spin the cylinder and put the gun to your head. The question here is, will you or will you not blow your head off? The random-chance odds are 1 in 6 that you will and 5 in 6 that you will not. The relative odds would seem to suggest that if you pull the trigger it would be unlikely that you would lose your head.

To make this analogous to our problem with the random-chance of asteroid impact, say you wake up Monday and choose to play Russian Roulette once a day for the rest of your life. You load the bullet/spin the cylinder every day. Odds are 100% you won't survive the week. The question of whether or not you will blow your head off has become moot. The question has now become, on which day will you do so. The daily odds of 1 in 6 are clearly no help, not even intuitively. They will be the same for Monday as they are for Sunday. Even on the day you blow your head off the odds will be 1 in 6 as you do so. To make this analogy more appropriate, put the image in your mind that it is not your heads we are putting the gun to here, but rather the heads of your 4 year old daughter or granddaughter...

Anecdotally, when you resolve the daily odds of an extinction level event to reflect the proportional magnitude of loss of one person, it is the same as one person playing Russian Roulette every day... Who's granddaughter is next?

So in terms of chance, if we can start to think bigger, and because we can choose to do so, the question here becomes, what are we willing to do, what are we willing to pay, to stop playing this game of Cosmic Russian Roulette?

but are probably randomly distributed in time.

GS Note: "Probably" random only if you do not understand the definition of "Random". Here, if we are dealing with the Laws of Physics in a deterministic universe and with astronomers and aerospace engineers, it would only be fair to use the mathematical definition: Without Recursive Pattern. And if you understand the geometry and dynamics of these objects in our Solar System, and that everything about their behavior is without a recursive pattern to some degree, then the occasion and magnitude of asteroid impact evens can be nothing but *Random*. Asteroid impact events would, in fact, make an excellent definitive analogy for Random. Somebody call Webster.

The risks from these NEOs, or more specifically our assessment of the risks in the next century,

GS Note: Since the only systemic probabilistic assessment possible is statistical, such an assessment would be for any and every century in the life of Earth. In other words, when you say the probability is low for the next century it is only true because by this form of assessment there can be no century where the probability is high. Which would make such an assessment either true but irrelevant or as predictive information, inherently false.

will be changing as surveys are carried out.

GS Note: "Changing" correctly, only if you find more or less objects than were estimated in the initial risk postulate or you are beaming these objects to a Galaxy far, far away as you find them.

Cast six 6 sided dice onto a table in the dark. The statistical probability that one of them would come up 6 would be 100%. If in looking for them with a flashlight you find 3 die not to have expressed a 6 you have not reduced the probability for the result of the cast. The probability is determined by the geometry and number of the dice cast. A specific outcome is irrelevant and non deterministic to the probability. Even if you find that all six dice you have cast have not come up 6 the *probability* that they would do so would still be 100%.

You are trying to conflate two kinds of probabilities here and they simply do not mix.

The only reductive conditional probability possible here would be one in which the initial Risk postulate were construed as if *all* 1,000 undiscovered Large NEOs estimated were somehow on course to strike Earth in the next 100 years. Ok, then *that* Risk has been reduced. But the Risk of One Large NEO being on course to strike Earth, as a conditional probability is a binary problem and can only be resolved by finding an imminent Large impact threat or The Last Large NEO.

Until then, the Risk of One Large Asteroid Impact in the next 100 years is unmitigated and complete with the mere possibility of One undiscovered NEO... of any size.

Given the inevitability of impacts, and noting that the entire point of surveys is so that we can take appropriate action, how can we mitigate the effects of potential impacting NEOs?

GS Note: Keep this in mind when you think about "Optimal" and funding. This business is not about counting rocks in Space. Not some Academic Astro Census. In the beginning and in the end this is a Subjective business: Risk Management, Decision Making, Strategic Thinking... The Objectivity of Scientific Method is only required somewhere in the middle.

This is now and always about The Next Large Asteroid on its way to strike Earth. And since the prospect of this event includes the potential for our extinction knowing which asteroid is The Next Large Asteroid on its way to strike Earth will always be the most important thing that Mankind can ever know. And developing a standing, tested capability to effectively deflect it, will always be the most important thing that Mankind can ever do...

The amount of destruction from an event scales with the energy being brought by the impacting object.

GS Note: As does the Risk: Probability of *Loss*. Risk is not synonymous with Probability.

the range of possible destruction is so huge, no single approach is adequate for dealing with all events.

GS Note: Now you are just being silly. The variety of tactical options within ablation and destruction inherent in Nuclear Explosive Devices offer us a robust and scalable First Alternative that affords us a One Tactic Fits All Size Threats strategic response. In that they are clearly the only feasible alternative for any threat over a few hundred meters, and must therefore be developed and maintained for *this* purpose, why do we need to seriously consider any of what has become to be, by several orders of magnitude, the now clearly stupid ways to deflect asteroids? Nukes can easily ramp down to a few hundred meter threat.

For larger events, changing the path of the hazardous object is the appropriate solution,

GS Note: In the case of Earth Orbit Crossing Objects of less than 500 meters, at our convenience these asteroids should be destroyed at any first opportunity. Even when deflected, random-chance would insist that sooner or later we would just have to deal with them again someday.

although the method for changing the path varies depending on the amount of advance notice available and the mass of the hazardous object.

GS Note: For Nukes, only the number and/or yield and corresponding mission mass would change. Not the method. Tactical approaches may vary with target cohesion and composition. However, with Nukes the tactical, target-specific driven alternatives are systemically inherent.

For the largest events, from beyond global catastrophe to events that cause mass extinctions, there is no current technology capable of sufficiently changing the orbital path to avoid disaster.

GS Note: Blatantly False! *Current* Cold War grade Nuclear Technology will work just fine. And with a modern design should easily be improvable in terms of mass to yield ratio. Given enough Nukes you could move Mars and you wouldn't even need a place to stand. Current world nuclear arsenal estimates (`~5,000 Megatons) would afford a 5 cm Delta Vee to a 10 km threat and 1 cm to a 17.5 km threat. Need to move more asteroid? Make more Nukes!

This sounds like some lame attempt to relegate the extinction level of this threat to the category of those things we can do nothing about like Rogue Black Holes and Gamma Bursts in order to afford the statistical probabilistic assessment intuitive merit as comfort-food-for-thought.

What we do *not* have here is: A) the politically incorrect heretical courage to just say *Yes* to Nukes and B) the Strategic acuity to see that waiting until we see it coming before we build and deploy a Planetary Defense is little more than sooner-or-later Suicide by NEO...

Page 71

Although all of these methods are conceptually valid, none is now ready to implement on short notice.

GS Note: Copy and Second that! Still in the "Ability" stage. Not anything close to "Capability". Much Training, Preparation and Vigilance required... a product of sufficient funding... which is a product of sufficient Fear.

In all cases, the decision to initiate mitigation is a socio-political decision, not a technical decision. This decision is implicit in earlier socio-political decisions about which methods of mitigation to develop and also depends on the level of probability considered to require mitigation.

GS Note: Which can only ever be expected to be effective as a product of the still absent *explicit* National and/or Global Codified Policy Determination that we will in fact endeavor to deflect these objects as they present themselves to be imminent impact threats.

The discussion of mitigation is rife with uncertainty.

GS Note: And Murphy's Law will see to it that the more uncertainty we resolve the more uncertainty we will create in the process. Nonetheless, Decisions must be Made, Risks must be Managed and Strategic Thinking must Evolve... or sooner or later, we all die. A responsible agency suitably able to respond at this level must be delegated. No place for committees...

There are also significant differences depending on whether we limit ourselves to current technology or include likely future technology such as the next generation of heavy-lift launch vehicles.

GS Note: And 21st Century post Cold War high efficiency Nuclear Explosive Device designs.

Thus our discussion of the range of applicability will show overlapping and uncertain ranges. Realistic mitigation is likely to include more than one technique if for no other reason than to provide confidence.

GS Note: Confidence can only come from expertise: Practice/Practice/Practice, which assumes One Tactic and a developed strategic logistical infrastructure... which assumes One Tactic. The notion of a Basket of Tactics only ever looks good on paper and in the lab but in practice is strategically insane.

Finding: No single approach to mitigation is appropriate and adequate to fully prevent the effects of the full range of potential impactors, although civil defense is an appropriate component of mitigation in all cases. With adequate warning, a suite of four types of mitigation is adequate to mitigate the threat from nearly all NEOs except the most energetic ones.

GS Note: Absurd. Aside from a *failure* of deflection and the consequential Get Out of Dodge response, there is no imaginable condition that some form of Nuclear response can not handle. And at his point, 2,000 times more effectively that any Second Best Alternative... But this is obvious. Perhaps what you have revealed here is the Scientist's natural fear of Decision Making. Even when what will work best *is* obvious.

Page 74

SLOW PUSH-PULL METHODS
Enhancement of Natural Effects
Enhanced Evaporation of Surface Material
Application of Contact Force

GS Note: These would be the Science Fiction comic book approaches to Planetary Defense.

Page 76

Application of Gravitational Force

The main caveat is the requirement for the spacecraft propulsion system to operate reliably for perhaps a decade or more.

GS Note: This is a pretty big caveat when we are talking about continuously operating a very large electrical appliance in its optimum performance range for a decade. Or decades counting interception...

Page 77

Changing the orbit of an NEO to miss one of these keyholes can be accomplished for larger objects since the required orbital change is much smaller.

GS Note: Over very large periods of time close passages to Earth by asteroids are surely common events however to actually design a mission on the astronomical random-chance occasion of such an event conveniently within a decade or so of any asteroid's terminal once-in-a-lifetime impact with Earth is like planning to take a knife to a gunfight and hoping the other guy will forget his gun.

Finding: Slow-push-pull techniques are the most accurately controllable and are adequate for changing the orbits of small NEOs (tens of meters to roughly 100 m in diameter) with decades of advance warning and for somewhat larger NEOs (hundreds of meters) in those few cases where it would pass through a keyhole that would put the NEO onto an impact trajectory.

GS Note: Or at 100 meters we could just use a teeny tinny Nuke. A 100 pound 30 year old Cold War designed 1 kiloton SADM warhead. Or use a standard strategic 300 kiloton and blow it back into Space Gas and be done with it forever. Otherwise, sooner or later... it just will be back.

However, the core vehicle design of a VASIMR driven delivery system for NEO Nuclear Mines would be indispensable for implementing an effective rapid response deflection capability. In a smaller version, it would also be an effective platform for pre characterization missions: particularly in the critically precise determination of an asteroid's mass, as well as addressing the extended post characterization task of verifying displacement.

KINETIC IMPACT METHODS

Page 78

The method is relatively simple and effective for NEOs with diameters up to half a kilometer, and is well within current capabilities given modest hardware and control developments.

GS Note: As are Nukes only at 2,000 times less mission mass...

This method would likely be the method of choice for the mitigation of hazardous objects of that size range when there are years or more of warning time.

GS Note: Perhaps when Mankind has completely forgotten how to actually make thermonuclear explosive devices.

In this approach either the spacecraft can "run into" the hazardous object, or the hazardous object can "run into" the spacecraft; only the relative velocity of the impact is relevant.

GS Note: In any realistic long term displacement period, acceleration along the Y or Z axis would likely only temporary destabilize the vector of the asteroid in its orbit. Such an approach would only ever be reliably effective in an 11th Hour/Last Ditch deflection in an impending impactor's terminal orbit.

Page 79

For example, a 1 cm/s velocity increment of a 200 m diameter body of density 3 g/cm3 impacted at 20 km/s requires an impactor mass of 1,000 kg, or one ton.

GS Note: For example, at the other end of the spectrum, given some Worst Case Assumptions: Sans any ejecta effect make that 6 tons. At a more realistic 5 km/s relative impact velocity call it 24 tons. If two out of three impactors miss make it 72 tons at launch. Then we under estimate the asteroid's mass by a factor of 2... 144 tons. And if the first one to hit disrupts the asteroid's integrity... we're just screwed.

NOTE: 1 cm/s is the order of the required velocity change to displace an NEO along its orbit by 15,000 km in 10 years.

GS Note: If you select some optimal ideal orbital example for your scenario this may be possible. However at the other end of the range 1 cm/s would be only afford 3,000 km displacement over 10 years. So the shape of the orbit would need to be just right.

The 5-ton payloads are possible now, and the 50-ton payload cases are based on the planned Ares cargo vehicle.

GS Note: Ares V may show potential for 30 ton circumstellar payloads... on paper. Though most working engineers would not likely bet their jobs on more than 25.

Achievable intercept velocities will depend on the orbital parameters of the NEO and may be limited by targeting and intercept capabilities.

GS Note: And 20 km/s relative impact velocity is only likely with a comet...

Page 80

Summary for Kinetic Impactors

The kinetic impact method is relatively robust and would be feasible to use with moderate engineering developments.

GS Note: Robust! It is clearly the least flexible of the three approaches mentioned here.

A major uncertainty is that the value of β is relatively unknown, although it has a firm lower limit of unity, applicable for highly porous NEOs from which little or no material would be ejected.

GS Note: Which according to astronomers estimates porous/rubble pile objects dominate the asteroid population. The density of the asteroid needs to be just right.

A mission based on the ESA Don Quijote concept would reduce the uncertainties, especially for high-impact velocities and highly porous bodies where the uncertainties are largest.

GS Note: Only if by chance such a mission tested against an object with known suitable conditions. Which would require a program of prospecting missions to determine and resolve the chance. The characteristics of the test asteroid would have to be just right.

important questions will have to be addressed about the ability to hit a small NEO at high relative velocity; those considerations may limit the intercept velocities at which kinetic impacts can be effective.

GS Note: In practice, it would in fact limit the size of the object this approach would be effective with at the lower margin. Smaller is harder to hit. A 200 meter object would be on the order of 1,000 times smaller target than Temple II. So the size of the asteroid would have to be just right.

an inadvertent disruption of the NEO and the resulting consequences also need further study.

GS Note: High velocity kinetic impact is the principal our modern Main Battle Tanks use to kill each other with. It's not just the inelastic shock of the kinetic impactor on the asteroid but the explosive result of the shocked acceleration of the impactor from zero to 20,000 m/s. A 200 meter asteroid struck by a 1 ton object would not have a chance. This would work fine if you want to blow it up... otherwise the asteroid has to be just right.

Then, since the efficiency of the impact is directly proportional to the relative velocity and the degree of difficulty to successfully hit the asteroid is inversely proportional (and something more than directly) to the relative velocity of impact the speed of the asteroid has to be just right.

Then, the problem here, is that if you expect to get the ejecta effect and compound the effect of the momentum transfer then the asteroid has to be hard. But not so hard that the compound effects of the impact fragment the asteroid. The density of the asteroid has to be just right.

Then, in half the cases it will be better to accelerate the asteroid away from the center of target Earth rather than decelerate the asteroid the long way across Earth... or the probability ellipse as the case may be. And to accelerate an asteroid with a kinetic impactor would require a velocity superior to that of the asteroid and several times the launch capability for a deceleration mission. So the best path for deflection has to be just right.

Then, since impacts are only feasible as prograde orbital interceptions, the incidence of the angle of interception will be determined by the orbital elements of the asteroid and its position relative to Earth. And to get anything close to an orthogonal crossing and achieve a high enough relative impact velocity to be effective the target's orbital elements will need to be just right.

Then, if you want to take advantage of a deflection at perihelion then the position of the asteroid in its orbit relative to Earth would be conditioned upon having a launch window that is just right.

Then, when high velocity interceptions are determined to problematic and rendezvous is seen to be more reliable we can see that the asteroid's orbit relative to Earth has to be just right.

Then, in the event of an early unintentional disruption, disabling or deflecting any subsequent Kinetic Impactors in a sequential application would be... problematic at best. So again the density and the cohesion of the asteroid need to be just right.

Then, If we accidentally strike and accelerate the asteroid along its Y or Z axis instead of along its X axis orbital path, we would disrupt the vector of the asteroid in its orbit and effectively make any targeting solutions useless and likely impossible to re determine on the fly. So the extremely precise initial targeting has to be just right.

Finally, to achieve the volume of high velocity ejecta and the effect portrayed in the 200 meter example many, many things would need to be just right.

Aside from the fact that it is thousands of times more massive and therefore thousands of times less effective than Nukes in terms of mission mass, the Kinetic Impactor, far from being "robust", is in fact a Goldilocks approach, reliant *not* upon the engineering of technology and method but rather upon compounded vagaries of Random-Chance and very, very Good Luck to make many things *Just Right*.

However, since the clearly preferred scientific method for deflecting asteroids here is by chance and mitigated statistical probabilistic assessments, and eventually astronomers will complete Brown and eliminate the perception of risk of small asteroid impact too, and all you really want to do is *talk* about and *research* deflecting asteroids, then in terms of being Politically Correct and Green the Kinetic Impactor would be Just Right... What will *work* best is in fact, irrelevant... Scientifically speaking.

With the same warning time of 40 years as discussed for the gravity tractor, one could launch a series of perhaps ten 10-ton impactors

GS Note: When the proponents of Gravity Tractor describe launching a 10 or even 20 ton vehicle it is only to some Earth orbit. It transports itself to the target... which could take as long as 10 years. At present we do not have even a 10 ton heavy launch capability to circumstellar orbit to accommodate a kinetic impactor.

Finding: Kinetic impactors are adequate to prevent impacts on Earth by moderately sized NEOs (many hundreds of meters to 1 kilometer) with decades of advance warning. The concept has been demonstrated in space, but the result is sensitive to the properties of the NEO and requires further study.

GS Note: Even given: "For example, a 1 cm/s velocity increment of a 200 m diameter body of density 3 g/cm3 impacted at 20 km/s requires an impactor mass of 1,000 kg, or one ton." Which is clearly highly optimized with Best Case Assumptions that bias the KI approach.

Research presented at the 2009 Aerospace conference in Granada by the ADRC and LLNL enhanced the NASA PA&E findings for the 100 times differential of Nukes over KI in terms of effectiveness to the point that a one ton Nuclear Ablation mission could impart a 2 cm/sec velocity increment on a 1,000 meter object. Making Nukes still 250 times more effective than even this idealized Best Case example.

If we then allow for the optimization of the Nuclear option commensurate to some degree with the KI example portrayed here, and afford a modern ad hoc device design in terms of mass/yield efficiency, we may see that differential increase to as much as 1,000 times.

Given the relative differential in effectiveness, just what was the rational that defined what would be "the likely be the method of choice for the mitigation of hazardous objects of that size range" if not an irrational Fear of Nukes?

NUCLEAR METHODS

Nuclear explosives constitute a mature technology, with well-characterized outputs. They represent by far the most mass efficient method of energy transport and should be considered as an option for NEO mitigation.

GS Note: The challenge of doing business in Space is in logistics: Moving mass from point a to point B. The seasoned cost of putting one ton of mass into circumstellar orbit is $40 million, which, for this argument, should be considered a metric of human endeavor... time. If we see our deflection response to be initiated only after we see it coming then we need to appreciate that every thing we put off to after we see it coming is charged to the displacement period and effectively increases the the Delta Vee target and correspondingly the force and size of the mission required. Mission mass is directly proportional to success. As such it is the principal determinate for any deflection tactic... particularly when the relative mass differential between tactics in any class of threat is clearly as great as it is.

In 2007 NASA's PA&E determined that, in terms of mission mass, Nuclear Ablation would be 100 times more effective than the Second Best Alternatives. In 2009 this margin was increased to 2,000 times by research presented in Granada. Since these estimates are based on 30 year old Cold War system designs it would be fair to speculate that a modern design would likely be able to improve the mass/yield ratio and increase this margin to 10,000 times.

Nuclear explosives provide the only option for large NEOs (> 500 meters) when the time to impact is short (years to months), or when other methods have failed and time is running out.

GS Note: Or when *Success* becomes the objective and not catering to an irrational unwarranted Fear of Nukes. So when the next 500 meter asteroid comes around factoring in a x10 margin of error we would likely need to choose between a 1,250 ton Kinetic Impactor mission and a 250 *pound* Nuclear Ablation mission... How is this difficult?

With decades of warning, the required change in velocity (ΔV) from the explosion is millimeters to a centimeter per second and can be met for NEOs many kilometers in diameter.

GS Note: There is no scientific or technological upper limit here... only in our current knee-jerk Political Will. And that can be engineered and eliminated with Logic and Reason... and a primal Fear of Death by Rock from Sky.

Page 81

The longest lead-time item for incorporating such a device in a rocket system is the development of a container to deliver the device and a fusing system capable of operating with the timing constraints required by the spacecraft velocities near impact with the NEO.

GS Note: Which would only be relevant as problematic if we are stupid enough to choose to wait until after we see an asteroid coming before we think about doing it...

This "latency time" between the decision to act and the launch can be reduced dramatically (perhaps 100 fold) by designing and testing these critical components in advance of discovering a hazardous NEO.

GS Note: Strategically speaking: "designing and testing" and also building and maintaining a sufficient arsenal of such devices to deal with any Worst Case Scenario. Then, given the dramatic change in the environment where these devices will be used they may be able to be designed to be Earth Friendly...Then we can better consider the random-chance of having suitable launch windows or not and the strategic wisdom of circumstellar pre deployment.

Models and Uncertainties

Just as with kinetic impactors, the greatest uncertainty in their use lies in the NEO response, particularly our understanding of shock propagation through low-density material

GS Note: In terms of net Force and Work produced, it doesn't take a Rocket Scientist to understand that the distributed reactive effect of Nuclear Ablation, potentially over hundreds of thousands of square meters of an entire hemisphere of the asteroid, will be far, far less problematic or potentially disruptive than a kinetic impact pulse over a single square meter.

Consider as examples: Asteroid Itokawa, like many asteroids, appears to consist of rubble weakly bound together by gravity.

GS Note: And as such poor candidates for the disruptive potential of a Kinetic Impactor and require the broad and gentle touch of Nuclear Ablation.

Except for NEOs 10 kilometers in diameter or larger, it is generally likely that nuclear explosives can provide a more than large enough ΔV,

GS Note: Is there some rationale or argument along the lines of the Laws of Physics to go with this proclamation or is this just a sociopolitical assumption of never ending non proliferation? This seems to be absurd. Little Rock/Little Nuke. Big Rock/Big Nuke. Great Big Rock/Great Big Nuke (or lots of just Big Nukes). Again: How is this difficult? This is surely not the time or the place to be giving up and become resolved to our sooner or later Extinction by NEO.

Page 82

If sufficient warning time is available, the largely fusion device can be chosen from tested designs and built with modern safety and security features.

GS Note: Or if sufficient strategic foresight and wisdom are employed *Now*, that would be from a standing, tested and pre deployed response-ready arsenal.

NEOs come in many more sizes, shapes, and structures than what the committee could include in this simulation.

GS Note: This is at the core of what makes the Nukes such a robust tactic. A) They be made in sizes ranging from mere tons of TNT in yield and weighing only pounds to yields in the tens of Megatons of TNT and weighing tens of tons but they can be designed with individual yield variabilities that could be changed on-the-fly to suit immediate target conditions. B) They can be employed effectively in proximity anywhere from one radius of the target to near surface or in a subsurface approach with penetration armor. C) A total yield can be archived by either a single device or divided into many incremental applications. D) The duration between incremental applications can be varied to suit the potential for unintentional target disruption. E) As the situation warrants and done right they can be applied to completely destroying these objects. F) In terms of target size, there is no theoretical scientific or technological upper or lower limit to their effectiveness. G) They could easily be applied to any “shepherding” task post deflection. Until something Faster/Cheaper therefore Better comes along, Nukes are the strategic ideal: One Tactic Fits All Size Threats. The NEO Silver Bullet.

One clear advantage is that there is no need to maneuver for a low approach speed as might be required for a surface or just subsurface delivery.

GS Note: However, “low approach speed” does not effect the execution as in Kinetic Impactors and can be seen as an advantage if/when high velocity fly-by interceptions are determined to problematic and rendezvous missions found to be more reliable... H)

Conclusions

Nuclear explosives can provide considerable protection against a potential NEO impact. This may be the only current means to prevent an impact by a large (>500 meters in diameter) hazardous object with a warning time under a decade

GS Note: Or given merely the extreme mass differential to any other approach, clearly the Best Alternative at any mass and at any warning time... all Politically Correct/Green Fear of Nukes considerations aside.

While the nuclear option provides considerable mitigation potential, above some size NEO tested limits will become inadequate. Although no detailed simulations have been done, NEO diameters greater than 10 kilometers are likely to be problematic for the devices in the nuclear stockpile, which go up to megatons of equivalent energy.

GS Note: Then you see this only as a One-Shot-One-Kill tactic... *That* would be the problem. A failure of imagination. Then for 10 km threats it is *not* a problem of science or technology but rather a problem of logistics and just-in-time inventory... a problem of Supply and Demand. Easy fix: Build More Nukes! And feel free to use more than one.

And then, how would this in any way be different than that any other deflection tactic? With Nukes at least we already have a current world arsenal large enough to impart 5 cm/s to a 10 km threat and anything less in the process.

When defense concerns no longer apply, the governments involved may either accept the longer response time for a Manhattan-Project-like effort, or decide if adequate safeguards can be developed for some entity to maintain a small number of nuclear explosive packages to allow humanity to counter an NEO that could, for example, cause mass extinctions.

GS Note: Not if the confused and inexperienced "experts" persist in fostering Risk Assessments that mitigate only the perception and Fear of such events with probabilistic sophistry and academic slights-of-mind rationalizations and fail to mitigate the potential for the event of the Fearful thing itself. With a rational and honest appreciation of the magnitude of the common threat, The Enemy of My Enemy becomes My Friend and those pesky little Defense Concerns dissipate... and Swords become Plowshares! World Peace as a perk...

DELIVERING PAYLOADS TO NEOS

We note that the time to design, build, and launch a mission is typically a large fraction (>1/2) of a decade, but this time could be shortened with a necessarily expensive crash program.

GS Note: Or eliminated altogether by doing so in advance of finding ourselves in any Detection-to-Impact window. To accentuate this strategy consider that the potential for having any suitable launch windows when we need them will purely be a matter of random-chance. It would not be safe to assume that the launch window we need would be conveniently positioned in the Detection-to Impact window or even that there would be one at all. Appeals to Chance with an expectation of Good Luck is not Method.

Further, even with Nukes, all things considered that could be hundreds of heavy launch missions in the case of of a 10 km threat... so the range for design/build could be to multiples of decades.

The key parameters of a launch are the mass that can be launched to escape Earth's gravity and then the additional velocity that must be provided to put the spacecraft on a trajectory to the NEO of interest.

GS Note: Which makes the position of the asteroid in its orbit relative to where Earth is in its orbit at any given time the principal determinate and qualifier of the key parameters. And in terms of the limitations of our launch capabilities and the demands of the mission mass required for successful deflection, the prospect for enough launch windows, a mater of random-chance. Even a Nuclear mission for a 10 km threat may require of hundreds of Aries V launches.

Page 86

The most challenging trajectories are those to long-period comets, largely because of the short time from discovery to impact on Earth coupled with the very elongated orbits. In general these comets would require a spacecraft that is ready to launch when the decision is made to act.

GS Note: Comets! Another good reason for Build It Now/Build It Now/Build It Now!. After all, who would think it to be in any way wise that waiting until your house is on fire would be a good time to build a Fire Department?

After 65 million years of evolution, have we managed to lose sight of what foresight is *for*? Sometimes it seems that the smarter we get the easier it is to fool ourselves.

Page 88

Finding: For a wide range of impact scenarios, launch capability exists to deliver an appropriate payload to mitigate an NEO. For some scenarios, particularly short warning scenarios, the capability is inadequate. Development of foreseen heavy-lift launch vehicles, such as the Ares cargo vehicle, should enable the use of a variety of methods for NEOs up to 2 times larger than is possible with current launch vehicles

GS Note: The resolution is not technological but rather a matter of a strategic pre deployment. Do the heavy lifting, so to speak, before we see it coming. Perhaps to the orbit of Mars?

Page 89

DISRUPTION

the kinetic impact and nuclear detonation methods are capable of including larger changes in velocity of the NEO than discussed above, particularly for smaller objects, but in those cases these methods deliver so much energy that there is a likelihood of totally disrupting the NEO (i.e., fragmenting it).

GS Note: In the case of Nukes: only if we do it stupid/wrong.

In the case of a very large impactor (say 10-kilometer-diameter, civilization destroying) discovered without many years of warning, adequate orbital change may not be possible, leaving disruption as the only option for mitigation.

GS Note: Given that the principal quality if a well designed, practiced and executed *successful* disruption would be to accelerate all the fragments beyond the escape velocity of the center of gravity, in terms of nuclear applications, the energy requirements of disruption would be orders of magnitude greater than any deflection approach.

To the extent that these calculations and laboratory experiments are relevant, they suggest that disruption might leave one much smaller object on an impact trajectory while most of the smaller pieces would spread out over a cross-section much larger than Earth within less than a year.

GS Note: Nukes are cheap. If these “laboratory experiments” would simply factor in larger Nukes and quit trying to do NASA Grade Rocket Surgery, that “one much smaller object” becomes pulverized into nothing more than gravel and space gas... Elegance does not count. Geterdone do.

Thus disruption might be a useful mitigation technique.

GS Note: Particularly in the case of small asteroids such as Apophis. In this case, no matter what course Apophis has in regard to 2036, if it is on a close passage as is or by our intervention, as an Earth Orbit Crossing Asteroid random-chance insists that sooner or later it will be back and strike Earth. So at our convenience, if we have to or choose to go there for any reason: characterization or science or because-it's-there, when we leave... blow it up. Place a few Megatons of Nukes on its surface in a reciprocal "earmuff" configuration and when it is on the other side of the Sun... turn it into a rapidly expanding ball of pulverized circumstellar orbital debris and space gas.

Even this, as simple as it sounds, can easily be done wrong. We should be looking for suitable Earth Orbit Crossing Asteroids as practice targets and doing such a mission every year to develop and perfect an expertise in this before we find ourselves having to do this for real.

SUMMARY

Page 91

With the current uncertainty regarding both the properties of the NEOs themselves and the efficiency of interaction with an NEO for kinetic and nuclear deflection, and even from the general standpoint of confidence of success, functional redundancy is crucial.

GS Note: From here and now, when you factor in the potential probability ellipse, the technological confidence and target mass, these elements would compound each other to the point of multiples of the ideal mission. Perhaps to as much as 10 times.

Instead of changing the orbit of an NEO with a single kinetic impactor, a series of impactors spread slightly in time provides much more reliability and in some situations might even allow assessment of the effect of the first impactor before the second arrives.

GS Note: Same for Nukes. Only in the case of Nukes we could easily disable or self-destruct subsequent applications on the fly if the additional force we problematic: as in the case of an unintentional disruption. How would you disable or deflect a Kinetic Impactor?

Alternatively, as long as there is a nuclear capability, one could consider readying a nuclear mission as a late-stage backup for a kinetic impactor that might, even with some very low probability, fail. Similarly, a kinetic impactor might be a backup for a gravity tractor on the chance that the gravity tractor might suddenly have a fuel leak or some other failure...

GS Note: From here and now and as things stand, with all the new subsections of Murphy's Law standing between our efforts and success, how can you characterize the probability of *failure* as low? And then go on to expect that Random-Chance will afford us a *second* opportunity to deflect the next asteroid impact threat when we will be lucky to have even one.

If Nukes are in fact far more effective: Faster and Cheaper and *therefore* Better than Kinetic Impactors or Gravity Tractors in the first place, and if you are being scientific and coldly rational, why relegate Nukes to the "backup" status? If Success is the First Rule here, you lead with your Best Shot then back it up with a *second* Best Shot...

This is not some kind of experiment or game where we have to play fair and give the asteroid a chance to win with some kind of surgically proportional response. You lead with The Hammer of God times ten and back it up with The Hammer of God 2.0. Nuke It! First, Second and Last. It seems that you are allowing some irrational Fear of Nukes to bias your differential logics here.

after a long but incomplete period of "pulling" the NEO.

GS Note: Or a “long and incomplete period” of getting to the target.

A nuclear detonation approach, however implemented, is likely to raise significant public concern.

GS Note: With all the movies, going back to the 1970s film “Meteor” the public at large is likely inured to the prospect of using Nukes in Space to defend us from asteroid impact. Their Fear of Nukes is rationally in association with war and terrorism. What is of interest here is that you would attribute a Fear of Nukes on to the public at large when this report clearly betrays an inherent Fear of Nukes in this committee of scientists. It seems to be the principal “variable” driving the definition of “Optimal Approach”. As far as any *public* concern, if you want to really piss off the general public, tell them you are going to Nuke an Asteroid in Space and not going to let them watch it live on Pay-Per-View!

After all: Nukes don't kill people, people kill people... and Asteroids. Asteroids kill people. Plan A: Let's use Nukes to kill Asteroids! Win/Win! The general public gets this. Why can't you?

If an NEO capable of massive death and destruction were discovered with certainty to be on a collision path with Earth and there were no other way to stop it, presumably any concerns about the nuclear approach would be over-ridden.

GS Note: The “Public” is not incapable of foresight. When NEOPucker Time comes, and it will, and it's your children and grandchildren at Ground Zero, with nowhere to run and nowhere to hide, would you tolerate the Powers That Be to use the 10,000 times Second Best Alternative, or even the 1,000 times Second Best Alternative to save you and your's from Harm's Way? How about even the Second Best by a factor of 2? This much ain't Rocket Science. The *Public* gets it.

Similarly, as noted in the section on nuclear methods, the question of whether to maintain a nuclear stockpile for NEO mitigation purposes is not a technical question.

GS Note: So, if clearly we must use the Nuclear Option for larger impact threats, then the question here is not whether or not to develop, build and maintain a Nuclear stockpile for this purpose but rather to what degree: Should we endeavor to address this threat in its Worst Case manifestation? Or is this where we just leave things to the odds and Cosmic Random-Chance?

Perhaps the most significant conclusion that can be drawn is the large uncertainty in the effectiveness of the mitigation techniques because of their dependence on the physical properties of NEOs that are not well known, and because of the difficulty of scaling any laboratory experiments to this regime.

GS Note: YES! Time to get this out of the Lab and Nuke a few Rocks in Space. Get Empirical!

92

The Don Quijote mission that was studied by ESA, but is no longer under active consideration, would have addressed most of these goals.

GS Note: How about doing the “Don Quijote mission” in Nukes and develop research to advance the understanding and reliability of the clearly First Best Alternative? Why research the Kinetic Impact approach when it is so clearly limited and so far, far behind Nukes in net effectiveness?

Recommendation: If Congress chooses to fund mitigation research at an appropriately high level, the first priority for a space mission in the mitigation area is an experimental test of a kinetic impactor along with a characterization, monitoring and verification system, such as the Don Quijote mission that was previously considered, but not funded, by ESA. This mission would produce the most significant advances in understanding and provide an ideal chance for international collaboration in a realistic mitigation scenario.

GS Note: Even if the next asteroid on its way to strike Earth is small enough to use a Gravity Tractor, or *Just Right* enough to use the Goldilocks approach of the Kinetic Impactor, as long as we must develop, build and maintain a Nuclear option for larger threats, as is suggested by this report, why do we need to even have a *list*? Given the relative margin of effectiveness, why are we still talking about the Second Best Alternatives? It seems that at their apparent effective operating range the only justification for not using the far more effective Nuclear Options would be an irrational Fear of Nukes. This is apparent not as an indirect projection of any general public or governmental perception but rather in the bias of our coldly rational and objective scientists.

Page 94

6 Research

Dealing with the NEO impact hazard is complicated because it involves balancing its imprecisely known risks against the costs, risks and benefits of proposed responses.

GS Note: Complicated only when you think small and are unskilled at thinking strategically. The response to this threat is simple, albeit very, very large... and difficult. No one thought that Saving the World from asteroid impact would be cheap or easy... Ok, maybe the astronomers.

Since the NEO impact risk is partly probabilistic in nature, it is difficult to grasp and difficult to communicate,

GS Note: Apparently for Scientists and Academics... Rationally/Strategically speaking, how is We Don't Know “difficult to grasp and difficult to communicate”? No matter what statistical probabilistic assessment you try to impose, the binary and absolute conditional question remains: Is there or is there not one large asteroid on its way to strike Earth in the next 100 years? Yes/No. At least “We Don't Know” is Strategically relevant information. It defines what we need to do.

Clearly you are trying to conflate statistical and conditional probabilistic methodologies. These two perspectives are unique and discrete from each other, non constructive to each other and incomputable with each other. The only thing they have in common is a shared semantics and nomenclature. It's no wonder you find it “difficult to grasp and difficult to communicate”.

There are three discrete Risk perceptions to consider here:

Existential Risk: Existential because it addresses the threat of The Next Asteroid on its way to strike Earth and fosters both the question of whether or not it will strike Earth anytime in the next 100 years and is there or is there not One asteroid on its way to strike Earth in the next 100 years.

Strategic Risk: Strategic because it addresses what is essential to the conduct of implementing a response to the threat and, incorporating all three tactical elements of detection, characterization and deflection, fosters the question of will we succeed or fail in our response.

Academic Risk: Academic because it addresses the average relative frequency of randomly occurring events probabilistically which would be a corruption of empirical evidence and as such would be without any apparent use to any actual response.

Clearly, only the Existential Risk is relevant to the Strategic Risk. The Academic Risk is only relevant to promoting comfort-food-for-thought and a metric for Hope if we choose to Gamble.

Likewise, an appropriate and necessary aspect of mitigation of the NEO impact hazard is a research program.

GS Note: Only if you are going to find a better way to make or use Nukes... or something better.

A research program is needed to address all of these issues in order to assess and quantify the risks associated with the NEO impact hazard.

GS Note: Nonsense. Asteroid impacts are random and aperiodic both in their occasion and magnitude... period. We can understand that now. There is nothing to be derived from any degree of any systemic analysis of the asteroid population that will help us determine Which one is next, When it will get here, How Large it is or When we will know Which/When/How Large.

The only way to determine that would be a full spectrum real-time surveillance of the entire 500 trillion, trillion cubic mile Area of interest 24/7/52 forever. And then, after we have left as little to Chance as we can afford or imagine, only then, Hope we see it coming in time to do something about it.

Page 95

Recommendation: The United States should initiate a peer-reviewed, targeted research program in the area of impact hazard and mitigation of NEOs. Because this is a policy driven, applied program, it should not be in competition with basic scientific research programs or funded from them. This research program should encompass three principal task areas: surveys, characterization, and mitigation. The scope should include analysis, simulation, and laboratory experiments. This research program does not include mitigation space experiments or tests which are treated elsewhere in this report.

GS Note: This recommendation is nothing more than an appeal to the Academic Pork Barrel. Academic: Without apparent use.

And isn't this what this committee should have done in answering the questions of Congress?

Some specific topics of interest for this research program are mentioned below. This list is not intended to be exhaustive:

GS Note: They missed one:

• Study the effectiveness of scientists and academics in Decision Making, Risk Management and Strategic Thinking: what is essential to the conduct of implementing a response.

Scientists have already retarded the development of a Planetary Defense two years with this failed and academic report. Now you want funding that will delay any real progress for decades? This is not some new barrel of Space Pork for the fun and games of scientists.

Page 97

7 National and International Coordination and Collaboration

However, the Office of Science and Technology Policy (OSTP) has been directed by Congress to "recommend a federal agency or agencies to be responsible for protecting the United States from a near-Earth object . . . expected to collide with Earth." The OSTP is directed to produce such a recommendation by October 2010.

GS Note: And if the Director of the OSTP takes the advice of this report to shape and inform his recommendation to Congress we are all Doomed...

EXISTING ORGANIZATIONS

GS Note: Then there is the US. Russian and Chinese militaries... who have all the Nukes...

NATIONAL

Page 98

It also seems more efficient to place the program under the control of a single entity in coordination with other relevant government organizations.

GS Note: Like DoD... Strategically speaking. They have a 200+ year record of success in defending the US from any and all threats to our interests and security... and all the Nukes. With NASA, given their experience in circumstellar orbit and manned missions, taking the more tactical role (and most of the funding). If this is going to be an international program it should be kept in mind that the Russian and Chinese space programs are an integral part of their *militaries*.

INTERNATIONAL

Page 101

Recommendation: The United States should take the lead in organizing and empowering a suitable international entity to participate in developing a detailed plan for dealing with the NEO hazard. The lead U.S. representative to this group could be the chair of the standing committee, or the chair's designee.

GS Note: This business is not about *Science* but *Security*. This is not about "Man In Space" but "The Survival of the Mankind". The *First* approach would be to put this issue into the hands and minds of those who are best able to respond to such things. Task this mission to the militaries of the world... beginning with our DoD. A NEO NATO if you will. A Global Mutual Defense Pact. This *is* where We The Species not only keep all the Nukes but also our best strategic and tactical minds, our most critical risk managers and our ground-truth-sound decision makers. This is clearly the logical Human agency to put between Us and Harm's Way.

Every nation in the world has one. They even come with their own plug-and-play bureaucracies. The beauty part is, that they come with their own budget... $1 Trillion dollars a year.

Only 5% of the current world military budget would give us an annual $5 billion NEO War Chest. In a hundred years or so we would have a good chance of having a standing Planetary Defense to the level of the Worst Case Scenario. Done pro rata, it would have little or no effect on any relative balance of power and in terms of Opportunity Cost we would suffer a 5% reduction in our ability to kill each other over economic, political and religious principles. More if the re-tasked allocations specify offensive capability. In terms of benefit, that would actually be an Inverse Opportunity Cost. And the impact to the taxpayers of the world would be Revenue Neutral: Win/Win/Win! Make that 10% of the total world military budget and WIN/WIN/WIN!!!

OkOkOk, all Political things considered, this may seem even harder than deflecting a 10 km extinction level asteroid threat but at least it gives the statesmen and diplomats and policy wonks and the UN something to do. And if the Generals get fed up with their diplomatic machinations and baggage and negotiating over who gets what chair they can take them out and shoot them... Win/Win/Win/Win.

Because doing this right this will not be cheap or easy or fast does not change the fact that we must nonetheless *do* this... and we must begin ASAP.

The longer we Gamble, the sooner we Lose... and we've been throwing these dice every day for 65 million years. Should we still feel Lucky?

EDUCATION AND PUBLIC OUTREACH

GS Note: A) Stop trying to diminish the magnitude of this Risk with irrelevant probabilistic rationalizations. B) Tell them the truth about the relative effectiveness of Nukes. C) Tell them how large a venture this will truly be and just how much it will really cost... *Scare Them Better!* Only Fear Defines Necessity.

Although popular movies raise general public awareness of the threat from NEOs, they do little to educate the public of the true risk to humanity and may result in significant misconceptions due to the highly distorted science presented.

GS Note: Of greater concern here should be the distorted perception conveyed by these movies to scientists that they somehow have the inherent aptitude and expertise to qualify them as sound Decision Makers, and reliable Risk Managers and effective Strategic Thinkers...

Page 102

8 Optimal Approaches

103

Finding: A $10 million annual level of funding would be sufficient to continue existing surveys, maintain the radar capability at the Arecibo and Goldstone observatories, and support a modest level of research on the hazards posed by NEOs. This level would not allow achievement of the goals established in the George E. Brown, Jr. Near-Earth Object Survey Act on any timescale. A $50 million annual level of funding for several years would likely be sufficient to achieve the goals of the George E. Brown, Jr. Near-Earth Object Survey Act. A $250 million annual level of funding if continued for somewhat under a decade, would be sufficient to accomplish the survey and research objectives, plus provide survey redundancy and support for a space mission to test in situ characterization and mitigation.

GS Note: This is embarrassing... $250 million is what We The Species spend on Heroin and Cocaine every four *hours*... What We spend on maintaining our world wide capability to kill each other over economic, political and religious principles every *two* hours. And less than *two minutes* worth of our annual Global World Product. And then for less than a decade... As if this threat will go away or somehow be reduced in ten years... or ever.

$250 million a year would be a very, very small first step... but in the right direction. And We'll take it... However, rest assured We'll be back... for more, *Forever*.

And unless scientists want to work on better ways to make or employ or deliver Nukes or something more effective than Nukes, you really don't to allocate much more to scientific research. There simply are no *scientific* issues left to be resolved here. We already understand everything we need to understand about this issue as a threat and developing an effective Response that science has to offer. Let's *do* something in the direction of Preparation, Training and Vigilance with this money... Academic research will be the death of us all yet.

It would be wise to afford this threat the rational Fear it is due and respond to it seriously while we can still afford to perceive it as the Ultimate Risk Management challenge and not wait until it has manifest as the Ultimate Crisis Management challenge.

It should be clear, that with little more than a glance at a single point of light, that at random and at any time this threat can become the single most important threat Mankind can and must face. Therefore, it must become the single most important threat Mankind *should* face *Now!*

Foresight can be an expensive survival trait. Just how much are We The Species worth?

The prospect of our Extinction by Asteroid Impact is a rationally manifest existential risk.

Fortunately, over the course of the next billion years of the life of Earth, given the number, dynamics and distribution of these objects in our solar system, Chance would suggest that We The Species will only have to suffer or deal with 10 or 20 extinction level impact threats...

Unfortunately, these events will be occurring completely at random: without any recursive pattern, and we could see the next one coming tomorrow...

Fortunately, We have evolved the technological understanding and have the basic resources to develop an effective defense against such dire events...

Unfortunately, astronomers and assorted scientists and academics have offered and hold to the risk assessment that since the averaged relative frequency for extinction level asteroid impact events is 1 in 50 to 100 million years then "the probability for large asteroid impact any time in the next century is low". Effectively dismissing the threat and retarding any political will to further evolve and develop our technological capabilities and basic resources into a standing tested capability in fact.

There is simply no way to justify or defend this risk assessment as any way constructive or relevant to sound decision making. In other words, if decision making is necessarily predictive, how can such a probability shape or inform a rational deterministic relevant prediction?

How do such assessments help us actually deal with the uncertainty here? Here, how are such assessments anything more than hollow artifacts, non analogous mathematical abstractions and little more than comfort-food-for-thought? At best, a metric for Hope if we choose to Gamble.

Hope is not Method. Time to put this into the hands and minds of those that understand that.

A Million Miles A Day,
R. Dale Brownfield
Gaiashield Group

E Glossary and Acronym List

GS Note:

Mitigation: Part of Speech: *noun* Definition: alleviation, to make less intense or severe.

Hazard: Something far less than the extinction of the species.

Academic: Without apparent use.