Toward a Cost-Benefit Analysis of Nuclear Terrorism Prevention Technology

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1. INTRODUCTION

This report examines issues pertinent to allocating resources to the prevention of nuclear terrorism. We begin the report by describing current spending by the Department of Homeland Security (DHS) on nuclear terrorism prevention. Next, we discuss how various estimates of the probability and cost of a nuclear attack can be used to model the expected value or risk of an attack. We then review some technologies that are currently being developed in the effort to prevent a nuclear attack. Finally, we provide an illustration of how a cost benefit analysis framework can make use of estimates of the expected value of an attack and of the effectiveness of technologies to help inform spending decisions.

2. Government Spending on Nuclear Terrorism Prevention

Though much of the fight against nuclear terrorism occurs overseas through the efforts of the Department of State (DOS), Department of Defense (DOD), and the Central Intelligence Agency (CIA), the Department of Homeland Security(DHS) is America's "last best chance" from detonating a weapon in a US city.[1] DHS is a unique institution because it was built out of other existing departments and agencies thereby creating new and vast bureaucratic demands. Within DHS's mission to "prevent and deter terrorist attacks and protect against and respond to threats and hazards to the nation" comes the obligation to prevent nuclear terrorism.[2] This paper will begin by describing current DHS spending on the prevention of nuclear terrorism and will then explore methods of evaluating the effectiveness of such spending.

The Department of Homeland Security Fiscal Year 2006 Budget request asked for $34,152.143 million in discretionary funding. Of this funding, the majority is allocated as follows: 20 percent goes to the US Coast Guard, 16 percent to US Customs and Border Patrol, 14 percent to Transportation Security Administration, and 13 percent to Federal Emergency Management Agency (FEMA). Most significant for nuclear terrorism prevention is the 3 percent set aside for the Science and Technology Directorate. This funding request is an increase of over $2.2 billion from FY2005, and $4.2 billion from FY2004.[3]

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[1] See *Last Best Chance* Film, Nuclear Threat Initiative, 2005.
[2] Department of Homeland Security Strategic Goals, available on <http://www.dhs.gov/dhspublic/interapp/editorial/editorial_0413.xml>, accessed December 6, 2005.
[3] Department of Homeland Security, Budget-in-Brief, Fiscal Year 2006, available on < http://www.dhs.gov/dhspublic/interweb/assetlibrary/Budget_BIB-FY2006.pdf>

Though the focus of this paper is on Department of Homeland Security nuclear prevention funding, it is important to understand that this exists within the context of other nuclear security programs. In particular, the Nunn-Lugar Comprehensive Threat Reduction Program does much to prevent the acquisition of nuclear capabilities by terrorists.[4] Nunn-Lugar was first authorized in 1991, with a budget of $12 million. The original goal of Nunn-Lugar was to control loose nuclear weapons in Russia and the former Soviet Union from theft—which is only one step away from terrorism. Since then, this program's mandate has expanded to include issues of nuclear weapons and expertise, as well as other weapons of mass destruction. Its budget has also expanded reaching a peak of $458.100 million in 2000, but has hovered between that high and its current level of $415.000 million over the last five years.

DHS's spending falls under the 4 DHS branches: Border Protection, Coast Guard, FEMA, and the Science and Technology Directorate. While some budget requests were nuclear specific, often DHS programs cut across all weapons of mass destruction (WMD) or all types of border protection. Where possible, this paper separates out the specific dollar values that are earmarked for nuclear programs; however, this is not always specified by DHS' budget request or Congress' budget appropriation.

The main tool for combating nuclear terrorism is the creation of a Domestic Nuclear Detection Office (DNDO) under the Science and Technology Directorate (STD) of the DHS. This agency is being created across DHS competencies with the mission of securing America from a nuclear or radiological attack. In order to do this, DNDO will create and administer a comprehensive detection system that will target illicit nuclear and radiological materials and weapons as they enter the United States and gather information about attempts and threats. This

[4] Nunn-Lugar Report 2005, Office of Senator Dick Lugar, available on <http://lugar.senate.gov/reports/Nunn-Lugar_Report_2005.pdf>, accessed December 6, 2005.

office will both deploy available technologies and stimulate new and emerging detection technologies as a part of its general mission. Though positioned within the DHS, the DNDO will have a major interagency component with officials from DHS, Department Of Energy (DOE), DOD, and the FBI on staff and with other coordinating features across other departments. There will also be coordination of government at all levels with the international community as well as private sector regarding detection. For FY2006, DHS requested $227.314 million.[5] Congress appropriated $318.014 million in its 2006 budget.[6]

Under DNDO comes the aforementioned Weapons of Mass Destruction detection system. In order to construct this detection system, DHS requested and received $125 million under the above DNDO budget. This system is meant to provide a "non-intrusive means of screening trucks and other conveyances for the presence of radiological materials."[7] This system would set up protective machinery that would detect various types of radiation at ports of entry into the United States. Further, $81 million of the DNDO funding has been allocated for nuclear detection research and development activities. This will supplement the separate Cargo Screening Initiative, for which DHS requested an additional $138.800 million to pre-screen cargo for security before it is sent to America.

Further, also coordinated under DNDO but administered through the Coast Guard is $7 million for better Radiological and Nuclear detection. This will enhance the abilities of the Maritime Safety and Security Teams to detect these materials in multiple locations. Further, it provides funding to place emission sensors on cutter fleets for better detection of threatening

[5] All above information from DHS budget request.
[6] Note: This, as with all other references to Congress' 2006 Homeland Security appropriation are from: H. R. 2360, 109th US Congress, "An Act Making Appropriations for the Department of Homeland Security for the Fiscal Year ending September 30, 2006 and for other purposes," Public Law as of October 18th, 2005.
[7] DHS Budget-in-Brief.

ships. Moreover, funds will be used for training and development that will enhance the ability to detect and respond to these threats.

Other DHS initiatives include a requested Radiological/Nuclear Countermeasures Test and Evaluation Complex at the Nevada Test Site. This initiative will comprise a set-up of the highest-level sensors, as well as research into these sensors, that will allow for the evaluation of response performance to specific threats. DHS set aside $9 million for this facility. Also, $5 million has been set aside for the Nuclear Incident Response Team under FEMA. This will be DHS and DOE's first line of response and will be able to assess and manage needs in the event of any incident. The funding will help with training and preparedness.

This Nuclear Incident Response Team (NIRT) should be put in the full-context of federal government expenditures. The majority of NIRT is funded under the DOE, which requested $118.800 million for this program in FY2006—nearly a 10% increase from FY2005. This team would be a central point of contact in the event of a nuclear incident in which the DOE's expertise is required. Under NIRT is the Nuclear Emergency Support Team (NEST), for which $77.200 million of the above budget was requested in FY2006.[8] NEST trains scientists for an event where they would need to locate and perform tests on a suspected nuclear device.

The DHS is pursuing an aggressive track of increased funding in FY2006. It is taking an active roll in the prevention of nuclear terrorism; however, its funding for specific programs is still, in total, less than that of Nunn-Lugar. While the total funding of nuclear programs is nearly $340 million, this is still only 1 percent of the DHS overall budget.

[8] "Budget Highlights: Department of Energy FY2006 Congressional Budget Request", Office of Management, Budget and Evaluation, Department of Energy, February 2003, pg. 29, available on < http://www.mbe.doe.gov/budget/06budget/Content/Highlights/06_highlights.pdf>

DHS Nuclear Spending by Program

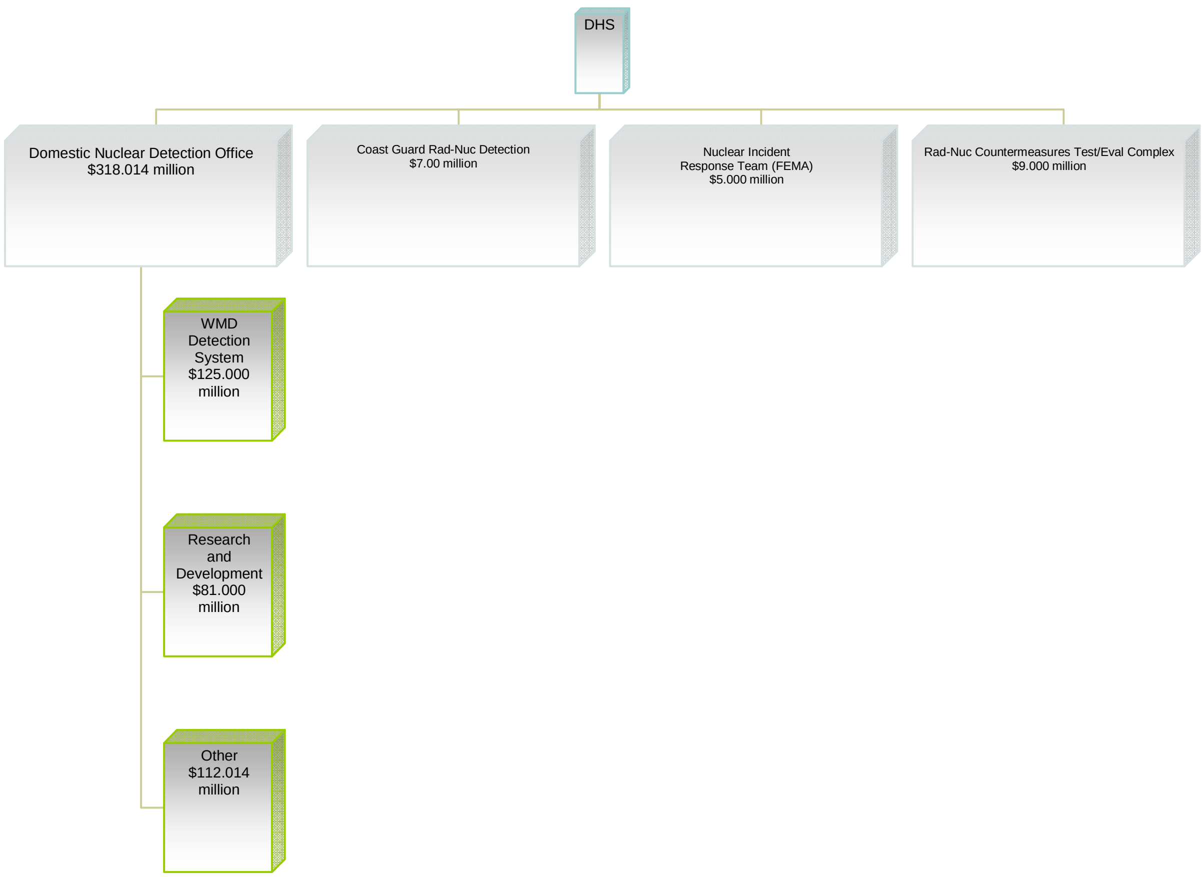
Program	Dollar Value
Domestic Nuclear Detection Office	$318.014 million
Of which: WMD Detection System	$125.000 million
Research and Development	$81.000 million
Other	$112.014 million
Coast Guard Rad-Nuc Detection	$7.000 million
Rad-Nuc Countermeasures Test/Eval Complex	$9.000 million
Nuclear Incident Response Team	$5.000 million
Total:	$339.014 million
Other DHS:	
Cargo Screening	$138.000 million
Checked Baggage Explosives Detection	$45.000 million
Nunn-Lugar	$415.000 million
Nuclear Incident Response Team	$118.800 million
Of which: Nuclear Emergency Support Team	$77.200 million
Total of all above programs:	$1133.014 million

Nunn-Lugar Funding by Year[9]

1992	$12.900 million
1993	$246.300 million
1994	$592.700 million
1995	$380.000 million
1996	$295.000 million
1997	$363.600 million
1998	$381.500 million
1999	$440.400 million
2000	$458.100 million
2001	$442.400 million
2002	$400.000 million
2003	$416.000 million
2004	$450.800 million
2005	$409.200 million
2006	$415.000 million

[9] See Nunn-Lugar note above

Department of Homeland Security Funding Organization



3. Toward an Expected Value of a Nuclear Terrorist Attack

One key piece in determining the correct level of funding to prevent a nuclear terrorist attack is to find the expected value (EV) of an attack.[10] For our purposes, the expected value is the amount of money you would pay to indemnify yourself against the damages of an attack.[11] The expected value is the product of the probability of an outcome and the expected monetary consequences of that outcome. For a nuclear attack, this would be:

$$EV = P(\text{Nuclear Attack}) * \text{Cost}_{\text{Nuclear Attack}}$$

Often, the expected value is simply called the “risk.” One more piece of information will give us a rough estimate of the per year expected value: the number of years until we expect to see an attack.[12]

In order to determine the expected value of a nuclear terrorist attack, we must discover two variables—the probability of such an attack, and the expected damage from such an attack—neither of which is easily determined. Even the rough estimates described below incorporate much uncertainty; to capture this uncertainty we have run probabilistic models of the variables in the expected value formulas. Our results are therefore in 95 percent confidence intervals, rather than point estimates.

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[10] Throughout this paper we will use the technical term “expected value,” rather then the more intuitive term “expected cost.”

[11] Assuming, for the sake of argument, that the technology or strategy reduced the EV of an attack by the exact amount invested in that technology. This assumption is unlikely to hold in the real world and we will relax it in our analysis in Section 5.

[12] This formula is an admittedly crude estimation of the per year costs. For instance, the probability of a nuclear attack in a particular year will depend on whether or not an attack has occurred in the previous years. Secondly, because the probability of an attack increases with each non-attack year that passes, there is incentive to “front load” your investment into the earlier years. Yet our model does give estimates for the average EV over the estimated timeframe until we expect to see an attack. Even with these limitations, our findings are useful. Certainly they are more useful than no findings at all: using the following data sources to estimate an EV is completely novel.

We found three sources for the probability of a nuclear terrorist attack. In 2004, Senator Richard Lugar surveyed roughly 80 terrorism and nuclear experts, and has a useful distribution of their predictions of nuclear attacks within 5 and 10 years. Second, the Nuclear Threat Initiative, led by former Senator Sam Nunn, has ventured a prediction of an attack on US soil within 10 years. Finally, we use a recently published article modeling the frequency and severity of terrorist attacks since 1968 to extrapolate the probability of a nuclear terrorist attack. All of these probabilities have significant—perhaps even fatal—shortcomings; however, we feel strongly that having little information is better than having no information at all, particularly when it comes to our risk of a nuclear terrorist attack.

To model the economic damage of the attack, we relied on three sources to bound our predictions. The recent damage to New Orleans from Hurricane Katrina serves, unfortunately, as a good starting point. A nuclear attack will likely have greater, more complex, and more permanent damage than Hurricane Katrina, but the damage serves as an appropriate baseline estimate of the destruction of a city, roughly $150 billion. Second, the Department of Homeland Security has estimated that damage from nuclear terrorism will reach "hundreds of billions of dollars." Finally, a report from Abt Associates has determined that a nuclear terrorist attack at a major port facility would cause between $150 billion and $700 billion in direct damage.[13] We think the likeliest range of estimates to be between $250 billion and $1 trillion, with any amount within that range equally likely to obtain. We have specifically excluded the higher order, macroeconomic effects of an attack (e.g. currency devaluation, worldwide depression) from our model because of the difficulties in determining those effects.

[13] Clark C. Abt, "The Economic Impact of Nuclear Terrorist Attacks on Freight Transport Systems in an Age of Seaport Vulnerability," Prepared for DOT, April 2003. Available at: http://www.abtassociates.com/reports/ES-Economic_Impact_of_Nuclear_Terrorist_Attacks.pdf

I. ESTIMATE DERIVED FROM THE CLAUSET AND YOUNG POWER LAW

Earlier this year, two researchers at the University of New Mexico discovered that, since 1968 (when collection of data began), the frequency and severity of terrorist attacks have followed a power law.[14] This relationship means that as the number of casualties of an attack increases, the average frequency (or average likelihood) of an attack that size decreases by a power of ten. Clauset and Young analyzed the Memorial Institute for the Prevention of Terrorism/RAND database, which is considered the largest and best maintained collection of terrorist data. The general equation for this power relationship is:

$$P(X=x) = X\char`^(-\alpha)$$

Where alpha is the "power index." Parsing the data, they find a (cumulative) power index for terrorist attacks in G7 countries of 1.7. Thus, for G7 countries, the frequency of a terrorist attack of x number of casualties is given by the equation:

$$P(X=x) = X\char`^(-1.7)$$

This finding is quite remarkable and very useful. Using this formula, we should be able to predict, on average, how often various-sized attacks should occur. This discovery could have profound implications on counter-terrorism budgeting, planning, priorities, and strategies.

However, extrapolating future events from this explicitly historical model requires several assumptions, all of which are problematic. First, the model implicitly assumes that states will continue to be as successful (or unsuccessful) at preventing terrorism as they have been in

[14] Clauset and Young. "Scale Invariance in Global Terrorism." arXiv:physics/0502014 v2 1 May 2005.

the past. Conversely, the model assumes that terrorists will continue to attack at their historical frequency. This assumption is particularly worrisome, since Clauset and Young find that the rate of attacks is slowly increasing. Incorporating this trend into the model is beyond our level of statistical expertise. For the purposes here—estimating the EV to help guide DHS spending—we feel that the above model is still useful.

Extrapolating to nuclear-sized attacks brings additional problems. Power laws tend to decay, becoming less predictive as events move to higher orders of magnitude. (The researchers have assured us through email that we can still use the power law to find the frequency of an attack with casualties around 200,000. An attack of this size would, almost by definition, be a nuclear attack.) WMD terrorist attacks, though rare since 1968, still follow the power law; however, because nuclear terrorist attacks have not occurred and are therefore absent from the historical dataset, extreme caution should be used when making decisions using this model.

Taking the above power equation and applying basic calculus shows that the power law equation of *any particular level of casualties or greater casualties* in G7 countries is given by:

$$P(X>x) = X^{(-0.7)}$$

Among the several indices the researchers found, this 0.7 index is the lowest. Other indices were found for: non-G7 countries, various modes of attacks, and pre- and post-1998. The highest power index involving the United States was 1.0.[15] (This 1.0 index specifically models the frequency-severity distribution of *global* attacks since 1998.) To build uncertainty into the estimation of the power index for use in predicting some future nuclear terrorist attack, we have

[15] While the index for non-G7 countries was 2.5, this universe of attacks does not include the United States, so we dismissed it.

taken 0.7 and 1.0 to be the outer limits of possible power indices for attacks on G7 countries (rather than taking the G7 number alone).

We ran a Monte Carlo simulation in Crystal Ball to model the expected value of an attack, divided by the number of years until that attack (i.e. roughly the minimum amount needed to be spent, per year, to indemnify against the risk of a nuclear terrorist attack—assuming, for the sake of argument, that each dollar spent reduces the EV by one dollar). Our assumptions in that model are:

1. A power index between the bounds found by Clauset and Young (0.7 and 1.0), clustered around the mean.
2. Casualties between 100,000 and 300,000; but with 200,000 being the most likely.
3. Cost between $250 billion and $1 trillion, with an equal likelihood of any number in that range.

Unfortunately, this model suggests even small changes in the power index yield large variation in the expected frequency of nuclear terrorist attacks. Hence, the resulting 95 percent confidence range is remarkably broad. However, we still feel that even this raw information would be useful to policy makers, at least as part of general due diligence. This estimation is, in any event, completely novel. The statistical details of our modeling can be found in the appendix.

The results are summarized in the table below. We divided the expected value of the attack by the average number of years until we expect to see an attack, in order to determine what level of yearly budgetary funding would be appropriate.[16] For the sake of clarity, we have not discounted for time.

[16] The number of years changes with each iteration of the model, depending on the power law and level of casualties the program generates. The number of years is, therefore, itself a distribution. However, if you use the mean casualties and the mean index, the model predicts an attack just under every 20 years.

If each G7 citizen shares that risk equally, the US would account for 40 percent of the risk (the US has 40 percent of G7 population). However, considering the likely targets of nuclear equipped terrorists, the US is at much greater risk of an attack *per capita* than Japan and Canada. The US probably has more risk *per capita* than France, Britain, Germany, and Italy. Therefore, the US probably faces risk significantly higher than 40 percent of the G7 total.

Table: Expected Value of Nuclear Terrorist Attack Using Power Law, per Year

	Mean	95% Confidence Range
Nuclear Attack in G7 country	*$58 billion*	*$7.3 billion to $208 billion*
40 Percent of G7 Risk	*$23.2 billion*	*$2.92 billion to $83.2 billion*

II. NUCLEAR THREAT INITIATIVE ESTIMATE

The Nuclear Threat Initiative promotes awareness of the problem of nuclear proliferation, and specifically advocates for accelerating the Nunn-Lugar program, which secures Russian nuclear material from theft. Ted Turner, Senator Sam Nunn, former Secretary of Defense William Perry, and former Kennedy School dean Graham Allison are some of the personalities and experts associated with this venture. NTI does not paint a pretty picture of America's risk of a nuclear terrorist strike.

The Nuclear Threat Initiative estimates that in the next 10 years the probability of a terrorist group having materials or weapons sufficient to carry out a nuclear attack is about 50 percent. Matt Bunn provided this estimate at a news conference at the National Press Club in Harvard University on March 12, 2003, prior to the release of NTI's report titled, *Controlling Nuclear Warheads and Materials*. This report focused on steps to accelerate and strengthen nuclear threat reduction. The report also called for expanding the efforts to address insecure nuclear stockpiles around the globe.

Bunn provided this estimate in view of certain observations. There are hundreds of buildings around the world where the essential ingredients of nuclear weapons are insecure. Once the nuclear material required to make a bomb is obtained, terrorist groups with achievable levels of funding and expertise could make a nuclear bomb using highly enriched uranium. Slamming together two blocks of highly enriched uranium fast enough can make a simple gun-type nuclear bomb. Other experts associated with NTI often cite this same 50 percent probability.[17]

[17] A high ranking former Defense Department official, now affiliated with NTI but not working for it, has personally given one author this figure off the record. Other NTI affiliates also quote that number.

This estimate offers us a much more straightforward estimate of the expected value of a nuclear terrorist attack:

$$EV = (0.5) * Cost_{\text{Nuclear Attack}}$$

Using the same distribution of possible costs we used above ($250 billion to $1 trillion, each with an equal probability of obtaining), we again ran a Monte Carlo simulation in Crystal Ball. Our only assumption was:

1. Cost between $250 billion and $1 trillion, with an equal likelihood of any number in that range.

The details of this model can be found in the appendix. We took the total expected value and spread it over NTI's 10-year estimate, again declining to discount for time, for the sake of clarity. The results are summarized below:

Table: Expected Value of Nuclear Terrorist Attack Using NTI Estimate, per Year

	Mean	95% Confidence Range
Nuclear Attack in US	*$31.3 billion*	*$9.3 billion to $53.3 billion*

In this model, the wide confidence range derives from the wide distribution of the cost estimate.

III. Estimates from The Lugar Survey of Nuclear and Terrorism Experts

In June 2005, Senator Lugar published the results of a survey that he conducted on various WMD proliferation threats and responses. In this survey Senator Lugar collected the opinions of non-proliferation and national security experts with the intent of discovering consistencies and divergences in their expert opinions on non-proliferation. The experts chosen were men and women who have dedicated their professional careers to the study and practice of preventing weapons of mass destruction and materials from falling into unauthorized hands. Some of the experts were national security leaders in other countries.[18]

Roughly 80 experts responded to the survey. We must emphasize that the experts queried do not represent a random sample of experts; as a result, the data only reflects the beliefs of the experts queried and not the national security community as a whole. In addition, we have done no analysis of the response rate and its possible biases. Thus, the data reflects any biases of the sample.

We contacted Senator Lugar's office to try to obtain the raw, anonymous responses he received. They declined citing privacy concerns. However, the report available online has aggregated data sufficient for our purposes of estimation.[19]

According to the experts surveyed, the possibility of a WMD attack against a target somewhere in the world is real and increasing over time. Even within the next five years, the chances of such an attack were judged to be substantial. The median estimate of the probability of a nuclear attack during the next 5 years was 10 percent. The average estimate was 16.4 percent. When the time frame was extended to 10 years, the median response doubled to 20 percent and the average response almost doubled to 29.2 percent. By comparison, the estimates

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[18] Lugar, Senator Richard. *The Lugar Survey On Proliferation Threats and Responses*. The Office of Senator Richard Lugar. Washington, DC, 2004. Can be found at http://lugar.senate.gov.

[19] Because we could only use data aggregated in to ranges, or "bins", our means in the appendix differ slightly than Senator Lugar's.

of the probability of a biological or chemical attack during the same time periods were each judged to be equal to or only slightly higher than the risk of a nuclear attack.

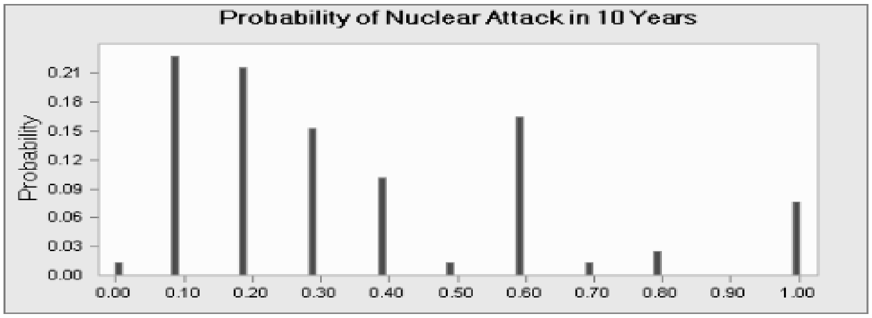
The group saw the chance of a radiological attack as significantly higher. The median and average estimates of probability were 25 percent and 27.1 percent respectively over the next five years. Over ten years, both the median and the average estimate of probability jumped to 40 percent. The median estimate of the probability of a radiological attack over ten years was twice as high as the estimate for a nuclear or biological attack during the same period.

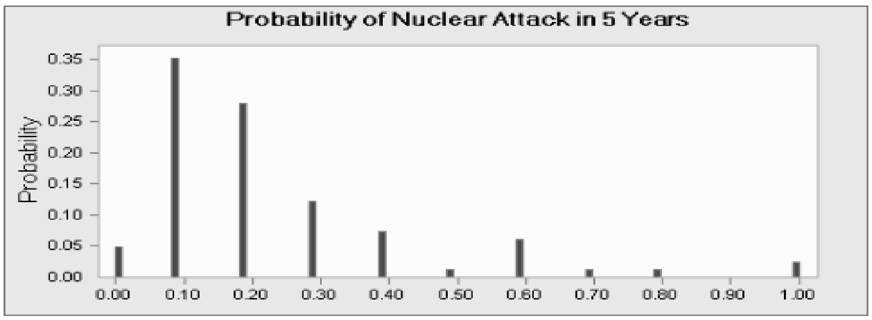
If one compounds these answers, the chances of some type of WMD attack occurring during the next decade are extremely high. The survey responses suggest that the estimated combined risk of a WMD attack over five years is as high as 50 percent. Over ten years this risk expands to as much as 70 percent. The survey asked specifically:

> In your opinion, what is the probability (expressed as a percentage) of an attack involving a nuclear explosion occurring somewhere in the world in the next 5 (10) years?[20]

We took the aggregated responses from Senator Lugar's survey and created probability models based on them. These are shown in the histograms below. The probability (expressed as a percentage) of an attack is given across the x-axis. The y-axis shows the number of respondents at a particular prediction, translated into a probability. Thus, in both distributions, relatively few people thought there was a zero percent chance of an attack. The highest number of respondents answered between 1 percent and 9 percent; slightly fewer answered between 10 percent and 19 percent; and so on.

[20] Lugar, Senator Richard. *The Lugar Survey On Proliferation Threats and Responses*. The Office of Senator Richard Lugar. Washington, DC, 2004. Can be found at http://lugar.senate.gov.
Later in the survey, fully 79 percent of respondents thought this attack would come from a terrorist group, with the remaining 21 percent predicting a state.





For the cost of the attack, we used the same distribution as we did before. For this Monte Carlo simulation, our assumptions were:

1. Cost between $250 billion and $1 trillion, with an equal likelihood of any number in that range.
2. The probability of an attack as given in the distributions found in the two charts immediately above.

One major caveat

At first glance, our expected cost distribution seems wildly excessive for this particular model; since the threat of an attack in this survey is global (and not limited to either G7 countries or the US), the cost of the destruction of a city should reflect the lower monetary value of developing nations' cities. For instance, however great the death toll from the 2004 tsunami in South East Asia, the economic damage to the coastal areas was not as great as it would have been in the US because those areas were so underdeveloped.

Let us propose another interpretation. Since the experts mostly believe that the nuclear detonation will come from terrorists (as noted above) and since nuclear equipped terrorists are only likely to target western (or G7) cities, we can use our standard cost distribution (between $250 billion and $1 trillion, with an equal likelihood of any number in that range) to estimate the cost of a G7-level, "expensive" city.

Table: Expected Value of Nuclear Attack Using Lugar Survey Distributions, per Year

	Mean	95% Confidence Range
Using "within 5 years" distribution	*$28.9 billion*	*$0 billion to $85.7 billion*
40 percent of total	*$11.56 billion*	*$0 billion to $34.28 billion*
Using "within 10 years" distribution	*$21.9 billion*	*$0 billion to $59.9 billion*
40 percent of total	*$8.76 billion*	*$0 billion to $23.96 billion*

IV. Summary Findings

Considering how diverse our sources of data are, and how much uncertainty we build into each model, the suggested yearly expected value is remarkably consistent across models. The expected value of a nuclear attack on an American city, when spread out across the number of years until we expect to see an attack (which varies from model to model) are summarized below:

Table: Summary Conclusions for EV of Nuclear Attack on US City, per Year

Model	Mean	95% Confidence Range
Power Law	*$23.2 billion*	*$2.92 billion to $83.2 billion*
NTI Estimate	*$31.3 billion*	*$9.3 billion to $53.3 billion*
Lugar "5 year" data	*$11.56 billion*	*$0 billion to $34.28 billion*
Lugar "10 year" data	*$8.76 billion*	*$0 billion to $23.96 billion*

4. NUCLEAR DETECTION TECHNOLOGY

Technology to detect smuggled nuclear material and weapons is improving dramatically, according to researchers at the national laboratories and defense contractors.[21] Whereas thin layers of lead shielding would thwart radiation detection technology from even five years ago, today's technology has surmounted these technical barriers. Determining the effectiveness of widespread deployment of such detection equipment is still difficult. In particular, estimates of the probability of successfully detecting smuggled radioactive materials are either non-existent, or are classified. We are left to describe the promising technology now being developed, and their prospects for use in a national, integrated network to detect illegal nuclear materials.

Research is located in several clusters. The DHS Science and Technology Directorate guides federal, state, and local government policy to prevent Nuclear, Chemical, Biological and Radiological (NCBR) materials and weapons from entering the country. DHS also stimulates the dissemination of nuclear detection technology from technology developers to technology consumers (mainly through its large state and local grant program).

Lawrence Livermore National Laboratory (LLNL) leads the federal government's research on nuclear detection technology. LLNL's Detection and Tracking System uses dispersed sensors to track nuclear material traveling along ground transportation corridors in the U.S. It consists of a network of detectors linked by wireless communication to a central monitoring station. These detectors contain sensors that measure gamma rays and neutrons, two signatures of nuclear material. As a potential threat moves through this network, not only are

[21] http://www.llnl.gov/str/September04/Labov.html

monitors alerted, but also the system extrapolates likely destinations of the vehicle—helping law enforcement intercept the threat.[22]

As the name suggests, the strength of detection networks is in their networked nature. A nuclear signal's strength diminishes exponentially as it is positioned progressively further away from the detector. Networking increases the potential of each sensor to facilitate detection. For example, if the sensors are set for 350 counts per second, and a device that emits 50 counts per second passes through the sensor, the 300 counts per second from the background radiation will combine with the 50 from the device, alerting the sensor. If another sensor is activated, monitors can extrapolate the path of potential hazards. However, in spite of such innovations, the technology is not "intelligent" enough. The sensors used on detection networks are not always able to distinguish threatening targets from normal background radiation that is not being used for nuclear terrorism. The real sensors put into place are more complicated than the models; calculating algorithms for 100 sensors requires great computing power.[23]

Last year, the Washington Post reported on an investigation into the effectiveness of such systems. According to the article, ABC News was able to successfully import depleted uranium into the country in lead containers. Depleted uranium "can be legally imported and gives off a radiation signature similar to that of highly enriched uranium."[24]

Cargo container screening is also a LLNL developed technology. A facility called ICONEX is part of an attempt to detect WMD's and dirty bombs. It was designed for the purpose of testing radiation detection technology against realistic threats. This facility helps various agencies with cargo screening. A system called ARAM (Adaptable Radiation Area Monitor) is a very sensitive portable detection system that is ideal for monitoring relatively small movable

[22] http://rdc.llnl.gov/rdp/urban_defense.html
[23] http://www.llnl.gov/str/JulAug01/Hills.html
[24] "Deficiencies in US Screening of Cargo are Acknowledged," Washington Post, 15 October 2004, A 21

items, such as cargo. The ARAM system currently designed screens objects that pass by a portal and detects any radionuclides that may be present.[25]

[25] http://rdc.llnl.gov/rdp/intermodal.html

5. Evaluating Spending Decisions Using EV Estimates: A Cost-Benefit Analysis Approach

So far in this report we have presented a range of estimations of the expected value of a terrorist nuclear attack calculated using various estimates of the probability and cost of such an attack. We have also described DHS' current spending on the effort to thwart a nuclear attack and have reviewed developing technologies that are available to DHS in this pursuit. In this section, we attempt to address the question of how we can use estimations of the expected value of an attack combined with estimations of the effectiveness of various technologies to make decisions about future spending.[26]

While we initially hoped to provide an assessment of whether DHS' current spending regime makes sense given the current threat, a lack of public data on the effectiveness of many of the technologies being pursued prevented us from undertaking such a comprehensive analysis. As an alternative analysis, we will undertake an exercise to evaluate a spending decision on one particular type of technology for which effectiveness estimates are available: active neutron interrogation of cargo containers. We hope that this analysis will be useful insofar as it presents a framework that can be utilized to help inform future spending decisions. It also gives us an opportunity to gauge how sensitive spending decisions may be to the range of expected value estimates we've presented.

The hypothetical spending decision we evaluate is as follows: Should DHS invest in a comprehensive active neutron interrogation program for all U.S.-bound cargo containers? That

[26] In Section 3 we made an assumption that each dollar spent on nuclear attack prevention would lower the expected value of an attack by one dollar. Here we relax this assumption and begin to look at how we can utilize estimates of the actual effectiveness of technologies to inform spending decisions.

is, should DHS ensure that each and every cargo containers bound for entry into the U.S. is screened for nuclear weapons? We have selected this question because estimates for the cost and effectiveness of such a program are available in a 2003 report prepared by Abt Associates for the Department of Transportation. The report estimates that such a program, which would require installing active neutron detection devices at 100 major ports around the world, would cost approximately 10 billion dollars a year and would reduce the probability of a nuclear weapon hidden in a cargo container arriving in the U.S. to about 9 percent.[27]

Before presenting the analysis we must make a number of important qualifications. First and foremost, we realize that as a matter of political feasibility, it is unlikely that DHS would single-handedly foot the bill for the installation and operation of detection devices in foreign ports. It seems more likely that the U.S. would share the costs of such a project with other nations also subject to the threat of a nuclear attack or that port operators themselves would be made to bear the project costs since the threat of nuclear attack might be seen as a negative externality of trade that private industry should be made to internalize. We will suspend our disbelief on the political feasibility of this decision so that we may go through the exercise of evaluating it from a cost benefit perspective.

Our second qualification is that, for the sake of being able to compare the probability of a nuclear attack before instituting this comprehensive screening program with the 9 percent post-program probability, we must assume that cargo containers are the only means by which a nuclear weapon could arrive in the U.S. Again, this assumption is not likely to hold in the real world, but we make it for the purposes of this analysis.

Finally, we must reiterate that all of the parameters we use in our calculations (from the EV estimates we have already forecasted to the Abt report's figures) are quite crudely estimated

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[27] Clark C. Abt, "The Economic Impact of Nuclear Terrorist Attacks on Freight Transport Systems in an Age of Seaport Vulnerability," Prepared for DOT, April 2003. Available at: http://www.abtassociates.com/reports/ES-Economic_Impact_of_Nuclear_Terrorist_Attacks.pdf

and that, as a result, the accuracy of the analysis is highly questionable. Again, we hope that the analysis will be useful as an illustration of how expected value estimates may help inform spending decisions in the future.

Our mode of analysis is a relatively simple application of cost-benefit analysis. We limit our analysis to the ten-year time frame used in the Lugar and NTI probability estimates. We start by calculating the expected value of an attack without investing in comprehensive cargo screening. We calculate both a best-case scenario, in which we use low-end point estimates of the probability and cost of an attack, and a worst-case scenario, in which we use high-end point estimates for both parameters. Next, we calculate the expected value of an attack after implementation of the comprehensive cargo-screening program, which lowers the probability of an attack to 9 percent. Again, we calculate a best-case scenario, which assumes a low-end estimate for the cost of an attack, and a worst-case scenario, which assumes a high-end estimate for the cost of an attack. At this point we subtract the expected value of an attack given that the program is implemented from the expected value of an attack in the absence of the program. The difference between the expected values is the benefits of the program *in terms of avoided expected costs from an attack*. To calculate the net benefits of the program, we simply subtract the program costs (10 billion dollars/year for 10 years) from the benefits. If the net benefits are positive, the program should be implemented.

In shorthand:

$$\text{Net Benefits of Program} = \text{Program Benefits} - \text{Program Costs}$$

Where:

$$\text{Program Benefits} = EV| \text{ no program} - EV| \text{ program}$$

$$\text{Program Costs} = 10 \text{ billion dollars/year} * 10 \text{ years}$$

Our calculations of the worst-case and best-case scenarios are as follows:

Worst-case scenario (uses probability estimate from NTI and high cost of attack):

EV| no program = Probability of attack * cost of attack
= .5 * 1 trillion dollars = 500 billion dollars

EV| program = Probability of attack * cost of attack
= .09 * 1 trillion dollars
= 90 billion dollars

Program Benefits = EV| no program - EV| program
= 500 billion dollars – 90 billion dollars
= 410 billion dollars

Program Costs = 10 billion dollars/year * 10 years
= 100 billion dollars

Net Benefits = Program Benefits – Program Costs
= 410 billion dollars – 100 billion dollars
= 310 billion dollars

Best-case scenario (uses probability estimate from Lugar survey and low cost of attack):

EV| no program = Probability of attack * cost of attack
= .35 * 250 billion dollars = 87.5 billion dollars

EV| program = Probability of attack * cost of attack
= .09 * 250 billion dollars
= 22.5 billion dollars

Program Benefits = EV| no program - EV| program
= 87.5 billion dollars – 22.5 billion dollars
= 65 billion dollars

Program Costs = 10 billion dollars/year * 10 years
= 100 billion dollars

Net Benefits = Program Benefits – Program Costs
= 65 billion dollars – 100 billion dollars
= -35 billion dollars

Our worst-case scenario analysis shows that the net benefits of comprehensive cargo screening are positive and that the 100 billion dollar program is therefore a worthwhile investment. In the best-case scenario analysis, however, net benefits are negative and the program is not worthwhile.

Again we wish to emphasize that we've walked through these calculations primarily as a thought experiment in order to illustrate how a cost benefit analysis framework can make use of expected value estimates to help guide spending decisions. The fact that our worst-case scenario suggests that the proposed spending program is worthwhile while the best-case scenario leads us to the opposite conclusion is illuminating. The contradictory results show that analyses of spending decisions will be quite sensitive to risk estimates. Though we did not vary the estimate of the program effectiveness, it is obvious that this is also a key parameter and the estimation of this figure will greatly impact our analysis.

We hope that our discussion calls attention to the fact that further refinement of risk estimates will greatly benefit decision makers' ability to make well-informed choices about homeland security investments. Also, estimates of the effectiveness of various technologies are currently lacking (or are simply not made publicly available) and such estimates would also greatly improve our capability to make sensible spending decisions.

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7. TECHNICAL APPENDIX

Appendix A
Spreadsheet detailing Three Estimated Values of Nuclear Terrorist Attacks per Year

Appendix B
Crystal Ball Report of Nuclear Attack Scenario