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The Day After

Action in the 24 Hours Following a Nuclear Blast in an American City

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A Report Based on a Workshop Hosted by

The Preventive Defense Project

Harvard and Stanford Universities

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THE PREVENTIVE DEFENSE PROJECT'S *"DAY AFTER"* WORKSHOP

Foreword

On April 19, 2007, the Preventive Defense Project convened a workshop of leading federal government civilian and military officials, scientists, policy experts, and journalists to address the actions that can and should be taken in the 24 hours following a nuclear blast in a U.S. city.[1]

Through efforts like the Nunn-Lugar program, the U.S. government and many of the Day After Workshop participants, including us, have long sought to prevent nuclear weapons and fissile materials from falling into new and threatening hands, especially terrorists. But we all know that these efforts have not reduced the probability to zero. It is also a common refrain among policy thinkers concerned with the growing nuclear threat – again, ourselves included – to frame the issue of prevention in terms of a provocative question, "On the day after a nuclear weapon goes off in a U.S. city, what will we wish we had done to prevent it?"[2]

But our Preventive Defense "Day After Workshop" asked a different question: "What will we *actually do* on the day after prevention fails?" What will we want to do? How can we prepare now to be able to do it? We asked the distinguished participants in the Workshop to catapult themselves vividly and concretely into the aftermath of a nuclear detonation on a U.S. city.

The needed actions by government and the public on the Day After will fall into two categories: actions to recover from the first detonation, and actions to prevent a second detonation. The Workshop addressed both types of action in as much detail, including technical detail, as possible. Topics included emergency response, evacuation and sheltering, immediate radiation effects, follow-on threats to the first nuclear weapon, attribution and retaliation, and the long process of cleanup – especially the uniquely difficult problem of fallout and residual radioactivity.

The Day After is a grim prospect to contemplate. But policymakers have no choice, since the probability of nuclear terrorism cannot be calculated but is surely not zero. The actions of public officials on the Day After will affect the lives of many thousands, the welfare of many millions, and the well-being and even cohesiveness of the nation and the world. For that reason we decided to conduct this Workshop. During the Cold War, "thinking the unthinkable" was also a fearsome task but resulted in sturdy policies like deterrence and arms control that prevented disaster and – over time – were

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[1] The Day After Workshop participants are listed at the end of this Report.

[2] See, for example, Sam Nunn, "The Day After an Attack: What Would We Wish We Had Done? Why Aren't We Doing it Now?" Testimony Before the 9/11 Public Discourse Project (27 June 2005).

understood and accepted by the population. As we formulated the seven findings and recommendations of this Report, we concluded that a similar forthrightness by government was also warranted as it planned to fulfill its duties on a possible Day After, and would return dividends in terms of real protection in the terrible event that efforts to prevent nuclear terrorism fail.

This report is based on the Day After Workshop. The Workshop itself was off-the-record and emphasized discussion rather than consensus. Thus none of the findings and recommendations in this report should be attributed to any of the Workshop participants. All errors or omissions in this report are ours alone.

The Preventive Defense Project, a Harvard-Stanford collaboration, performs policy research on a wide variety of defense and national security issues, including issues related to weapons of mass destruction (WMD). The Day After Workshop was the sixth in a series of WMD-related workshops conducted by PDP. Previous workshop topics in this series have been:

- Plan B for Iran[3]
- The U.S.-India Nuclear Deal.[4]
- Plan B for North Korea[5]

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[3] See Ashton B. Carter and William J. Perry, "Plan B for Iran: What if Nuclear Diplomacy Fails?" Report based on May 22, 2006 workshop hosted by the Preventive Defense Project, Harvard and Stanford Universities, 10 September 2006 available at http://bcsia.ksg.harvard.edu/publication.cfm?program=CORE&ctype=book&item_id=486 and Sean Patrick Hazlett, "Plan B for Persia: Responding to Iran's Nuclear Weapons Program Absent Diplomatic Agreement," Kennedy School of Government Policy Analysis Exercise, 4 April 2006 available at http://bcsia.ksg.harvard.edu/publication.cfm?program=ISP&ctype=book&item_id=487.

[4] See Ashton B. Carter, "The India Deal: Looking at the Big Picture." Statement before Foreign Relations Committee, U.S. Senate, 2 November 2005; Ashton B. Carter, "America's New Strategic Partner?" *Foreign Affairs* 85, no. 4 (July-August 2006), 33-44; and Ashton B. Carter, "Assessing the India Deal." Testimony before the Committee on Foreign Relations, U.S. Senate, 26 April 2006.

[5] See William J. Perry, "Confronting the Specter of Nuclear Terrorism – Proliferation on the Peninsula: Five North Korean Nuclear Crises," *The Annals of the American Academy of Political and Social Science*, Philadelphia, PA: September 2006, 78-86; Ashton B. Carter and William J. Perry, "The Case for a Preemptive Strike on North Korea's Missiles," *TIME (time.com)*, 8 July 2006; Ashton B. Carter and William J. Perry, "If Necessary, Strike and Destroy," *The Washington Post*, 22 June 2006, A-29; Ashton B. Carter, "Implementing a Denuclearization Agreement with North Korea." Testimony before the Committee on Foreign Relations, U.S. Senate,15 July 2004; Ashton B. Carter, Arnold Kanter, William J. Perry, and Brent Scowcroft,"Good Nukes, Bad Nukes, " *The New York Times,* 22 December 2003, section A, 31; Ashton B. Carter, "The Korean Nuclear Crisis: Preventing the Truly Dangerous Spread of Weapons of Mass Destruction," *Harvard Magazine,* September – October 2003, 38-41; Ashton B. Carter, "Alternatives to Letting North Korea Go Nuclear." Testimony before the Committee on Foreign Relations, U.S. Senate, 6 March 2003; Ashton B. Carter, "Three Crises with North Korea." Testimony before the Committee on Foreign Relations, U.S. Senate, 4 February 2003; Ashton B. Carter and William J. Perry, "The Crisis Last Time," *The New York Times,* 19 January 2003, section 4, 13; and Ashton B. Carter, "Nuclear Over North Korea: Back to the Brink," *The Washington Post*, 20 October 2002, B-1 & B-5.

- Updating the NPT Regime[6]
- Improving WMD Intelligence[7]

Workshop reports, published papers, Congressional testimony, and op-eds based on PDP's Washington WMD Workshops, and other PDP activities and publications, can also be found on the Project website at *preventivedefenseproject.org*.

The Preventive Defense Project's Washington WMD Workshops are supported by the Richard Lounsbery Foundation, the Carnegie Corporation of New York, the John D. and Catherine T. MacArthur Foundation, and the Herbert S. Winokur Fund. We appreciate the collaboration of our co-author Dr. Michael May of Stanford University. PDP Associate Director Gretchen Bartlett and Research Assistant Jonathan Lachman were of great assistance in preparing the Day After Workshop and this report, and we are grateful to them.

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[6] See Ashton B. Carter and Stephen A. LaMontagne, "Toolbox: Containing the Nuclear Red Zone Threat," *The American Interest* 1, no. 3 (Spring 2006), 28-40; Ashton B. Carter and Stephen A. LaMontagne, "A Fuel Cycle Fix," *The Bulletin of the Atomic Scientists* (January/February 2006), 24-25; Ashton B. Carter and Ronald Lehman II (co-chairs) with Robert Einhorn, Alan A. Foley, Arnold Kanter, David Kay, Susan Koch, Lawrence Scheinman, and William Schneider, Jr. (members), Policy Advisory Group on Nonproliferation, "Interim Report on Nuclear Threat Reduction and the Fuel Cycle," Memo to Senator Richard G. Lugar, Chairman, Senate Committee on Foreign Relations, 1 July 2005.

[7] See Ashton B. Carter, "Worst People and Worst Weapons," Statement before The 9/11 Public Discourse Project's Hearings on "The 9/11 Commission Report: The Unfinished Agenda." 27 June 2005; Ashton B. Carter, "A Failure of Policy, Not Spying," *The Washington Post*, 5 April 2005, A-23; Ashton B. Carter, "Overhauling Counterproliferation Intelligence," Statement before The Commission on the Intelligence Capabilities of the United States Regarding Weapons of Mass Destruction (The "Robb-Silberman" Commission), 4 October 2004; Ashton B. Carter, "How to Counter WMD," *Foreign Affairs* 83, no. 5 (September-October 2004), 72-85; Ashton B. Carter, "Overhauling Counterproliferation," *Technology in Society: An International Journal – Special Issue: Technology and Science: Entering the 21st Century*, George Bugliarello and A. George Schillinger, eds., 26, nos. 2/3 (April/August 2004), 257-269; Ashton B. Carter, "Seven Steps to Overhaul Counterproliferation." Testimony before the Armed Services Committee, U.S. House of Representatives, 17 March 2004; and Ashton B. Carter, "Overhauling Counterproliferation," Testimony before the Committee on Foreign Relations, U.S. Senate, 10 March 2004.

THE SCENARIO

In the baseline scenario considered by the Workshop, a ten kiloton uranium fission nuclear weapon was detonated at or about ground level (for example, in a high-rise building) in a major U.S. city without advance warning.

An explanation of the key variables is as follows:

YIELD: Ten kilotons (10 kT) is the approximate yield of a fully successful entry-level fission bomb made by a competent terrorist organization. It is about the same as the yield of the Hiroshima and Nagasaki bombs, which exploded with their full expected yields after years of experimentation, and one full test (at Alamogordo, New Mexico), by the world's greatest scientists. Terrorists could either obtain a nuclear weapon from one of the nine governments that have made them, or make a weapon out of fissile material obtained from the dozens of nations possessing plutonium and highly enriched uranium. If the weapon used against a U.S. city was home-made by terrorists without extensive experimentation or testing, it is possible and perhaps likely that the first attempt would be a "fizzle" of lower yield (a few kT or below). The nuclear weapon tested underground by North Korea in the summer of 2006 had a yield of half a kiloton and apparently fell short of its design yield. On the other hand, a bomb stolen from the Russian stockpile could be larger – hundreds of kilotons. The consequences described below would vary quantitatively, but not qualitatively, according to the exact yield of a terrorist bomb. Our findings and recommendations do not depend on the precise yield.

NUCLEAR WEAPON TYPE: Nuclear weapons can be made with either highly enriched uranium (HEU) or plutonium. It is easier to make an improvised nuclear weapon with HEU, and it would be the terrorists' fissile material of choice, all other things being equal. The Day After scenario therefore posited this type of device. The consequences do not depend much on the type of fissile material used.

HEIGHT OF BURST: In this scenario, terrorists detonate the bomb at ground level or in a high building (hundreds of feet in the air) rather than from an airplane (thousands of feet in the air). The Hiroshima and Nagasaki bombs were detonated high in the air after being dropped from an aircraft. A groundburst nuclear weapon like that posited in the Day After terrorist scenario would spread blast damage and fire over a smaller area than an airburst of comparable yield but would produce much more radioactive fallout than the World War II bombs. (There are two reasons for this: 1. The bomb debris from the Hiroshima and Nagasaki airburst bombs remained at altitude, settling to the ground only after much decay and subsequent radiation had dissipated harmlessly in the air, 2. No buildings or soil were made radioactive by the fireball; this induced radioactivity would also settle more quickly in the event of a groundburst.) So the result of groundburst versus airburst is less blast and fire damage to the affected city, but much more radiation.

AMERICAN CITY: The scenario assumes an American city as the target. The scenario does not specify the American city, but participants indicated that Washington has unique characteristics as the seat of government and the home of much of the nation's response capability. Europe (London, Madrid, Paris, Rome, Berlin, Brussels, Warsaw, etc.), Russia (Moscow), Asia (Beijing, Tokyo, Seoul, Delhi, Singapore, etc.), and the Middle East (Baghdad, Riyadh, Istanbul, Jerusalem, Tel Aviv, Cairo, etc.) are also possible targets. Much of the technical content of this report would naturally apply to attacks on these locations, too.

WARNING: Would terrorists in possession of a nuclear weapon announce their intentions in advance? The Day After Workshop assumed they might not, for three reasons. First, catching a city by surprise obviously would increase the amount of destruction and chaos the terrorists could cause. Second, advance notice might risk having the plot foiled before it could be completed. Third, there is no reason to believe that "loose nukes" would come one at a time – wherever terrorists got one weapon, they might have obtained several. Setting off a first bomb with no warning would still permit the terrorists to claim that more detonations were to come and to sow widespread panic – a likely tactic of terror even if, in fact, they only obtained a single nuclear weapon. So there would appear to be benefits to the attacker to act without warning, and the Day After Workshop accordingly posited this scenario as more likely. For the responders, if warning did come it would present obvious opportunities to save lives but would also present dilemmas – whether to panic the population on the basis of a possible hoax, whether to "negotiate" with the terrorists on the basis of their demands, and whether to believe that the terrorists had multiple bombs. All these dilemmas are likely on the Day After anyway, since responders will have to assume they are facing a campaign of terror and not a single detonation.

WHO DID IT? The scenario did not specify the perpetrators – al Qaeda and its offshoots, indigenous Islamist extremists in western countries, or the multitude of non-Islamist extremists around the world and in the United States itself who preach mass terrorism. Many, though not all, of the issues in this report do not depend on the identity and motives of the bombers.

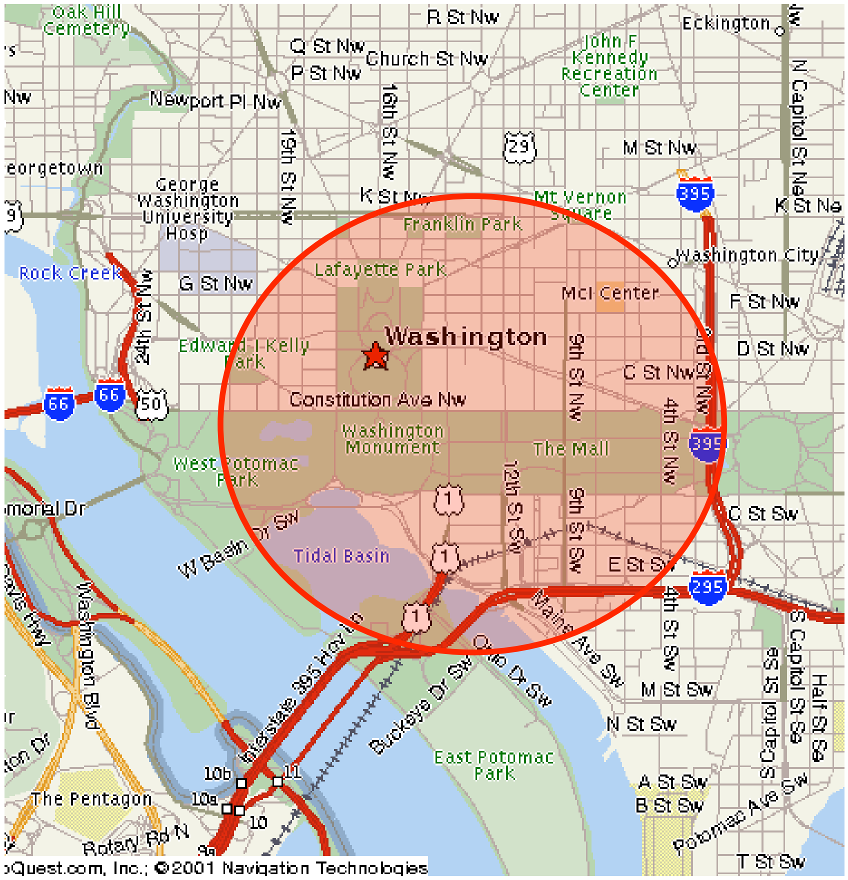
CONSEQUENCES: The grisly effects of a 10-kiloton groundburst have been calculated and, while there are some unknowns and variations depending on circumstance, the broad outlines are clear.[8] The downtown area would be obliterated. Just outside the area leveled by blast, people wounded by flying debris, fires, and intense radiation would stand little chance of survival: emergency workers would not get to them because of the intense radiation, and in any event their injuries (burns and acute radiation exposure) would require sophisticated and intensive medical care to offer any chance of survival; only a tiny fraction of them could hope for such care. Further downwind from the

[8] See "National Planning Scenarios." The Homeland Security Council, Version 20.1 Draft (April 2005); William C. Bell and Cham E. Dallas, "Vulnerability of Populations and the Urban Health Care Systems to Nuclear Weapon Attack – Examples From Four Cities," *International Journal of Health Geographics* 6:5 (28 February 2007); Charles Meade and Roger C. Molander, "Considering the Effects of a Catastrophic Terrorist Attack," RAND Technical Report, Center for Terrorism Risk Management Policy (2006).

detonation point, a plume of radioactive debris would spread. Its shape and size would depend on wind and rain conditions, but the area over which people who did not shelter themselves or flee within hours would receive lethal radiation doses within a day would range from five to ten square miles: the area of Brooklyn for New York, northwest Washington for Washington, DC, or the upper peninsula for San Francisco – but the direction from ground zero depending on the wind. Those people who were relatively close to the detonation point, or who did not shelter themselves from the radiation (which would be most intense on the Day After and then subside with time) would receive large but varying doses of radiation. If the dose was intense (more than 400 rems), they would get sick and die; if strong but moderate (50-400 rems), they would get sick but probably recover; if moderate (below 50 rems), they would not notice the effect immediately but would have a greater chance of contracting cancer over their lifetime than if they had received no dose. Since there is little that could be done for those in the area in and around the blast zone, responders would concentrate on minimizing the radiation dose to the population further downwind and preventing chaos amongst the rest of the population, which would be physically unaffected but traumatized and deprived of whatever utilities and services were located in the affected area.

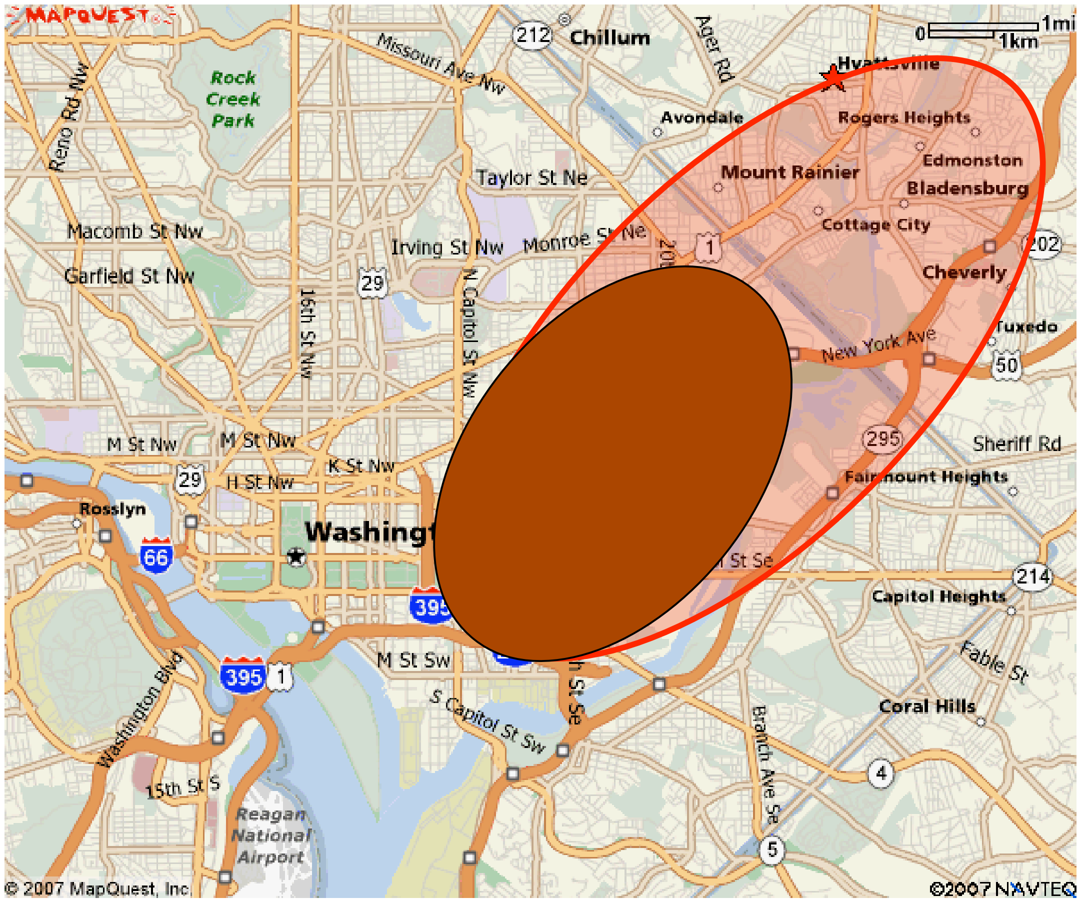
In the months and years following the Day After, policymakers would face a tradeoff in the large downwind plume area. If they allowed residents to return early, those residents would experience a higher average cancer rate later in their lives (perhaps not perceptible to each individual, but resulting in many additional deaths when averaged over a large population). If, on the other hand, those people were unwilling to accept a larger lifetime cancer rate, they would have to abandon their homes. The city center itself would remain too radioactive to rebuild for a year or longer.

Ten-kiloton groundburst in Washington DC: Prompt Effects



Over 50% of the population in the red circle (approximately 2 miles in diameter) would suffer immediate major injuries or fatalities from all causes (blast, burns, prompt radiation). Most of the buildings would be severely damaged or destroyed. The drawing is approximate only and for illustrative not planning purposes.

Fallout Plume from Ten-kiloton groundburst in Washington, DC

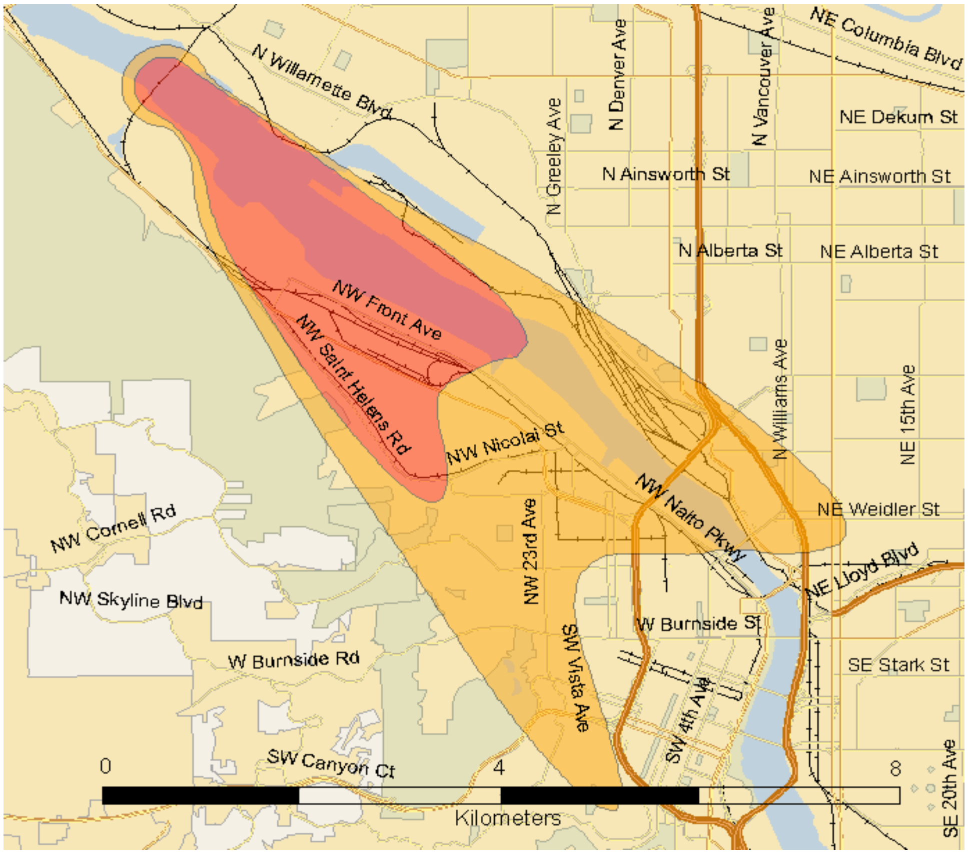


Over 50% of the population within the dark red oval (approximately 5 miles long) would incur fatal radiation in the course of the first day if they stayed unsheltered in that area. Absent elaborate shelters people should leave as soon as possible.

Over 10% of the population in the lighter oval (about 8 miles long) would incur severe radiation injury, sometimes fatal, in the first day if they stayed unsheltered in that area. Light shelters could offer significant protection. There and nearby, sheltering offers the better option.

The drawing is approximate only and for illustrative not planning purposes.

Alternative Plume Shape: Ten-kiloton groundburst



This butterfly pattern, rather than an ovoid pattern, would arise from wind shear (different wind speed and direction at different altitudes).

Source: Lawrence Livermore National Laboratory[9]

[9] The authors are grateful to the National Atmospheric Release Advisory Center at Lawrence Livermore National Laboratory for these illustrative graphics.

FINDINGS AND RECOMMENDATIONS

1. **PREVENTION VERSUS RESPONSE. Prevention remains by far the best protection against nuclear terrorism.** None of the recommendations in this Report, even if implemented perfectly, would stop the Day After from being the most catastrophic single event in the nation's history and the gravest possible failure of public policy. The overwhelming judgment of those contemplating their government's responsibilities on the Day After has to be, "If I were in you shoes, I wouldn't be in your shoes." It so happens that nuclear terrorism, unlike terrorism generally, has a simple cure: preventing terrorists from getting nuclear weapons or fissile materials from the governments that have them. No matter how fervent or twisted their motivations, terrorists will not have the capability to go nuclear on their own, since enriching uranium or reprocessing plutonium is beyond the reach of sub-state groups. They have to have help, witting or unwitting, from a government. Every failure of nonproliferation creates a new source of potential nuclear terrorism. It is therefore disturbing to note the serious setbacks to nuclear terrorism prevention in recent years represented by North Korea's new nuclear weapons arsenal, Iran's unchecked nuclear developments, continuing political risk in nuclear-armed Pakistan, and inadequately safeguarded weapons and fissile materials still remaining in Russia and elsewhere. All these setbacks have increased the probability of nuclear terrorism.

2. **FEDERAL GOVERNMENT PLANNING. The federal government should stop pretending that state and local officials will be able to control the situation on the Day After.** The pretense persists in Washington planning for the Day After that its role is to "support" governors and mayors, who will retain authority and responsibility in the affected area. While this is a reasonable application of our federal system to small and medium-sized emergencies, it is not appropriate for large disasters like a nuclear detonation. As the fiasco after Hurricane Katrina suggests, most cities and states will quickly be overwhelmed by the magnitude of the humanitarian, law and order, and logistical challenges of responding to a nuclear detonation. Yet this fiction persists stubbornly in the nation's preparedness bureaucracies at all levels: state and local governments guard their supposed "authorities" under the federal system, and Washington seeks to evade responsibility. The result is a failure to plan realistically. Instead, the federal government should plan on the basis that in the event of a nuclear detonation, it will shoulder principal responsibility for all aspects of response. On the first day after the event, of course, federal assets will not yet have made it to the scene. But shortly thereafter they should plan to outnumber and supercede the state and local responders. Rather than await such a determination by the President on the Day After, law and regulation should stipulate that a nuclear detonation automatically triggers a full federal response. Local responders and authorities will continue to play key roles, however, so that training and exercises should focus on cooperative responses led by the Federal government but suited to the often very different local circumstances.

The federal government needs a realistic response plan specific to the Day After scenario that marshals the resources of all the agencies. Remarkably, such a plan does not yet exist, though one is being drafted. A good plan prepared in advance of the Day After would not guarantee a flawless federal response, but without a plan a failure of a scope that would dwarf the failures following Katrina is certain. The plan has to assume a lead federal role in all aspects of response, must describe the fully coordinated actions of all federal agencies including the Department of Defense, must reflect hard choices (e.g., between evacuation and shelter-in-place), and must point the way to investments that need to be made to give the responders capabilities they currently lack.

A response plan should provide at least for the following essentials:

- An agreed and exercised incident command structure specific to a nuclear terrorism scenario, coordinated with state and local responders and authorities.
- Provisions for maintaining or restoring communications within the command and response structure, to Washington and to the media and public. Contrary to some popular depictions, electronic interference with means of communication due to electromagnetic pulse (EMP) in this groundburst scenario will be largely limited to the areas physically destroyed after the first few minutes. Most media will be up and transmitting, especially if a modicum of emergency planning is in place. Access to all means to inform the public and to update that information is essential to limit panic and other adverse reactions. In this connection, it is essential for responsible government officials to correct any erroneous guidance to responders and to the public as soon as they are able. Errors are certain to occur, if only because wind patterns will shift and other unforeseen events will occur. Correcting those errors promptly is necessary to maintain trust. Most media will be unaffected and will be communicating into the area, and they will give a platform to many uninformed sources. The government sources will have to compete with those sources successfully and in real time.
- While much of the telecommunications, internet, and mass media in the affected city will survive and operate to communicate warnings and advisories from responsible government officials to responders and the public, these can and should be augmented by an updated version of the Emergency Broadcast System (now called the Emergency Alert System). This 1950s-era system is familiar to Americans from the tone interrupting their radio and TV programming followed by the announcement, “This is a test of the Emergency Broadcast System. . .” This system and the Department of Homeland Security’s National Warning Systems (NAWAS) connecting DHS and other echelons of government are based on outdated technology. DHS should be funded to establish a new system using modern media, and whose vulnerability to outages in an emergency could be assessed and minimized in advance. The modern media could include, for example, the capability to send text messages or emails to all citizens and/or responders who have wireless devices (cell phones, Blackberry and other PDA

devices, etc.). A system of this sort is already in operation among the many federal and local emergency response managers in the Washington, DC area.[10]

- Identification of sites for temporary storage of radioactive wastes. Hospitals outside the immediate impact area in particular and other assistance sites will be dealing with contaminated clothing and other items and will not be able to operate long without facilities for temporary disposal and instructions on how to use them.

3. **SHORT-TERM SHELTERING VERSUS PROMPT EVACUATION. Fallout shelters deserve a comeback.** Radioactivity, and in particular radioactive fallout, poses a problem peculiar to nuclear terrorism. For most people in the city struck, their best bet to avoid serious radiation exposure would be to shelter below ground for three or so days until radiation levels had subsided and only then to evacuate the area. The alternative – mass and chaotic evacuation during the time when radiation dose rates are greatest – would result in large and unnecessary additional loss of life over and above the fatalities due to immediate blast, fire, and close-in fallout. But while sheltering in place is the plan that would be optimal for most people, it would run counter to their strong impulse to flee the area. For a comparatively few people just downwind of the detonation, moreover, sheltering would not in fact offer enough protection, and their only chance would be to leave as soon as possible, as fallout takes a finite time to reach the ground .

Two distinct fallout regions can be expected. In the smaller, close-in "hot" fallout region the dose over time will be so high that most sheltering will not be effective and evacuation, dangerous as it is, should be attempted. That area is limited, however, to a few square miles in addition to the area affected by blast and fire. People in the hot zone should be advised to leave as soon as possible, preferably during the time before most of the fallout settles. But the great majority of the people will be outside the hot zone, and for them sheltering in place will be the safest course of action.

In view of these facts, a new type of fallout shelter program – very different and much more practical than the 1950s-style civil defense program – should be promoted by the federal government as a cheap and effective way to minimize the radiation exposure of most people downwind of a nuclear terrorist attack. The Cold War "civil defense" shelter program was mocked because it could not offer realistic protection against an attack of thousands of warheads from the Soviet Union. But against one or a few terrorist nuclear weapons, sheltering in place is the best way for most people to protect themselves. The rate at which people are exposed to radiation (the dose rate) subsides in inverse proportion to the time after the blast. People outside the immediate downwind hot zone will receive a smaller dose of radiation if they shelter themselves for a period of three days or so (the recommended sheltering period can be determined and communicated by federal authorities at the time). If they try to leave on the first day when the radiation is strongest, they will receive a larger dose because they will be exposed to intense radiation

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[10] See *A National Strategy for Integrated Public Warning Policy and Capability,* The Partnership for Public Warning and The MITRE Corporation, May 16, 2003, available at www.PartnershipforPublicWarning.org. The authors are indebted to Robert Mikelskas and Darrell Ernst of The MITRE Corporation for their input to this recommendation.

as they walk or wait in traffic on clogged roads to evacuate. Shelters that will only be occupied for a few days do not need to be equipped with large stocks of food, water, and other supplies.

The absence of the sheltering population from the highways will have another benefit: it will permit emergency workers and those who need to evacuate from the hot zone to move freely. A mass and confused exodus from the city will expose the fleeing population to unnecessarily high doses of radiation and impede the movement of emergency personnel. To avoid this, federal and state officials and first responders should work out ahead of time plans for determining which roads in the affected area should be closed to the public for three days and which should remain open and for how long.

One way to persuade people to stay in shelters and off the roads would be to ascertain the direction of the fallout "plume" from the blast so citizens can be informed whether they are truly in the hot zone or not. Models at the Department of Energy's national laboratories and the Defense Threat Reduction Agency, coupled with the daily weather forecast from the National Weather Service, can predict where the plume will drift and settle. A federal shelter in place program therefore should be accompanied by a rapid plume prediction capability. It should also be accompanied by a program of education for emergency workers and, to the extent possible the press, on the effects of radiation (for example, the fact that the dose rate subsides in proportion to the passage of time after the blast, see Recommendation 4 below). Even given better plans than now exist, putting those plans into practice will clearly be difficult and will require constantly updated communications to the public and all media as well as to first responders. Large-scale panic could lead to subsequent loss of life on a par with that in the detonation zone itself. Experience with previous wartime catastrophes shows that, with leadership and training, this unnecessary additional loss of life can be avoided.

4. **LONG-TERM RADIATION EXPOSURE. A sensible approach to response, recovery, rebuilding, and decontamination after a nuclear detonation will require emergency responders and some citizens in the affected area to accept a greater exposure to radiation than is permitted by normal day-to-day occupational guidelines.** This is a sensitive subject, since beyond small doses no amount of radiation exposure is entirely safe. But the amount of risk varies drastically between high and low doses, and occupational guidelines are based on a different set of tradeoffs between exposure and other risks than are appropriate to the Day After scenario. Emergency responders, health workers, and troops need to understand these tradeoffs in order to accept the exposure that will be necessary in order for them to carry out their life-saving tasks. Citizens willing to accept added exposure will be able to move back to the fallout region and resume normal life more quickly and cheaply than those who are not.

Every person in the city bombed would have been exposed, like the rest of us, to about 0.2 rems of radiation every year of their lives from the natural environment around them. Each of them would also have on average about a 20% chance of dying of cancer of one form or another and another 80% probability of dying instead from other causes (heart disease, infections, accidents, etc.). Depending on where they are and what they do, people in the bombed city on the Day After will receive a certain dose on the Day After and an accumulating but subsiding dose rate thereafter. If their accumulated dose in the immediate aftermath is a few hundred rems or more, they will probably die since the specialized and elaborate medical care required to give a severe radiation exposure victim any chance of survival could only be made available to a very few people. But if their dose on the Day After and the days following (the dose rate would decrease with time) was between a large, lethal dose and the naturally occurring exposure, they would survive the exposure itself but have a greater chance of getting cancer over their lifetime than they would have had if the terrorists had not bombed their city. Most would experience a less than 1% increase in their chances of dying of cancer (i.e., an increase from 20% to 21% or less); those who suffered large doses and survived would see their chances of dying of cancer increase from 20% to 30%; those with still larger doses would not survive. A person or policy might reasonably choose to trade off a small increase in average cancer rate against other factors – for a responder, the chance to save lives by entering the radiation zone; for a citizen, the chance to return home earlier.

The key to a rational approach to the dilemmas of radiation exposure will require informed consent, which in turn depends on education – of responders and the public. First responders and other personnel critical to effective recovery can and should receive education in the effects of radiation on human health. This could be done through the creation (by the Department of Homeland Security in association with the Department of Energy) of a self-education website that emergency workers would be encouraged to visit. Many emergency workers, National Guard personnel, and others whose decisions would be critical to the overall response effort are highly motivated to carry out their professional tasks and accustomed to continuing professional education and self-training. Many of them would therefore avail themselves of such a website. A second target for education in the effects of radiation exposure would be the press. Many local and national media have one or more reporters who cover terrorism, homeland security, and disaster response: if they are educated in advance regarding radiation effects, they might be able to interpret the actions and advisories of public authorities for the public. Education of the public at large poses a more difficult problem, since it is unlikely that the public's attention will be fully engaged until after the Day After. Nonetheless it is crucial that the government invest more resources towards educating local community leaders about immediate actions that can be taken in the aftermath of a nuclear attack. On the Day After, well trained public officials operating from a response plan whose radiation exposure aspects are well thought out and communicating through a press corps that contains knowledgeable members is the best hope for informed choices by the public.

5. **FOLLOW-ON ATTACK. If one nuclear weapon goes off, there are likely to be more to follow: the response plan for the Day After should assume follow-on attacks.** If terrorists have stolen or bought one bomb or enough fissile material to make one nuclear weapon, there is no reason to suppose they won't have obtained two or three more. Even if they only have one, they are likely to claim they have more. Americans

will therefore expect that the Day After is merely the day before the next city or cities are destroyed, and the U.S. government is highly unlikely to be able to prove otherwise. **This fact – that nuclear terrorism will appear as a syndrome rather than a single episode – has major consequences.** For example, if San Francisco is hit, the U.S. government will be forced to conclude that Washington could be next and will have to decide whether and to what extent to relocate the government. For the same reason, residents of other cities may understandably want to evacuate their city. In short, on the Day After all citizens and cities in the country, and indeed perhaps the world, will be torn between helping the city bombed and preparing for the same in their locale. Borders, ports, and airports will be closed and a frantic search for terrorists and more nuclear weapons will ensue. **The federal government's response plan should assume a multi-threat scenario and a continuing state of crisis until it has been ascertained that the terrorists have used or surrendered all the weapons they are capable of delivering.**

Much will depend on the public's cooperation and therefore on continuing leadership and communication from all levels of government. As one example, provisions such as the evacuation of children from some cities together with their necessary support and school facilities and of some essential hospital staff should be considered. England during World War II and other historical models may be useful here.

Searching for the second and third nuclear weapons without cues from intelligence, law enforcement, foreign governments, or the terrorists themselves will be extremely difficult. Uranium weapons emit little radiation, and plutonium weapons are easily shielded by a container of lead. The United States is developing and deploying a variety of radiation sensors at ports and airports and around sensitive landmarks and buildings. While each of these sensors in itself is limited in sensitivity and might also have a high rate of false alarms because other items in normal commerce also emit radioactive signals, a well-designed sensor *network* consisting of detectors connected by communications and smart data processing has a better chance of detecting a nuclear weapon than an array of individual sensors, since the signals from each sensor can be correlated with signals from others in space and time. The technical reality remains that even such networks will not by themselves give a high probability of detecting the location of follow-on nuclear weapons on the Day After, but at a minimum they will pose a risk to terrorists that their plans for follow-on attack will be detected and foiled. Additionally, such sensors have a much better chance (individually and collectively) of detecting radiological ("dirty") bombs, and therefore their deployment would have a double purpose. The U.S. government should therefore continue to deploy ever-improving radiation detection sensor networks via the program coordinated by the Department of Homeland Security's Domestic Nuclear Detection Office (DNDO).

6. **RETALIATION AND DETERRENCE. The source of the weapon or material detonated by a non-governmental terrorist group will eventually be traced back to a government – Russia, Pakistan, another foreign source, or even the United States.** Even the most sophisticated terrorist groups will not be able to enrich uranium or reprocess plutonium; only relatively few governments possess these materials. Some weeks after the nuclear weapon goes off, and maybe sooner, the source of the weapon

material will become known. Radiochemical forensic analysis of the weapon debris, ordinary police and intelligence work, and perhaps the statements by the terrorists themselves will reveal who did it and where they got the bombmaking material. **While there will be a strong urge to punish the government responsible for the leakage, on the Day After it will probably be more in the U.S. interest to seek its cooperation than to punish it – unless the leakage was deliberate.** It is unlikely that the leaders of, say, Russia or Pakistan will have deliberately transferred fissile materials or nuclear weapons to terrorists. If they did so deliberately, obviously retaliation would be justified. The threat of such retaliation might in fact deter North Korea or, in the future perhaps Iran, from using terrorists as a way to deliver nuclear weapons to U.S. soil. But in the more likely case where the nuclear weapon or material was stolen or bought from a government's stockpile without the leadership's knowledge, the U.S. will need the full cooperation of that government to find out how many more nuclear weapons the terrorists might have, where they are, and who the terrorists are. Threatening to attack the country that was unwittingly the source of the nuclear weapon will be an understandable but counterproductive urge on the part of a U.S. population angered and frightened by the first detonation. **Deterrence through threat of punishment, while a familiar concept that is comforting to many strategists, will therefore only have utility in scenarios when the government ultimately responsible for the bomb acted knowingly and willfully.** For example, if North Korea sold fissile material or bombs to third parties, it should be held accountable for the ultimate use of those ingredients of nuclear terrorism; the United States should make this clear to North Korea in advance. But if, to take a different example, Pakistan unwittingly became the source of "loose nukes," retaliation by the United States on the Day After would not serve U.S. interests in locating other bombs and putting an end to the campaign of nuclear terror.

While deterrence through retaliation will play a limited role in most nuclear terrorism scenarios, the United States should have the capability to assure, with a high degree of certainty and in a manner credible to the world community, that it would eventually find out the source of the fissile material or nuclear weapons used against it. No government should believe it could attack the United States by using a terrorist group as a proxy and not be found out eventually and held accountable. Police and intelligence investigation could be powerfully augmented by radiochemical forensics, in which the debris from the detonation would be analyzed and compared to models of various U.S., Russian, Pakistani, and other nuclear weapon compositions and designs. This would allow the U.S. government to determine quickly, for example, whether the weapon was a uranium or plutonium design. Tracking down the exact source of the weapon, however, could take weeks of analysis under the best of circumstances and would be impossible unless the governments of Russia, Pakistan, etc. shared sensitive data about the design of all their weapons and the composition of all their supplies of fissile materials.[11] Such data sharing is unlikely in the advance of the Day After, though it might suddenly become easier on

[11] See Michael May, Jay C. Davis, and Raymond Jeanloz, "Preparing for the Worst," *Nature* 443:26 (26 October 2006), 907-08; "Nuclear Forensics Support," *IAEA Nuclear Security Series,* no.2 (2006); and M.J. Kristo, D.K. Smith, and S. Niemeyer, "Model Action Plan for Nuclear Forensics and Nuclear Attribution." Draft Product for the International Technical Working Group. Lawrence Livermore Laboratory, U.S. Department of Energy, 3 March 2004.

the Day After as these governments strive to show they are cooperating with an angry America. **The U.S. should aspire to have the capability to attribute a nuclear detonation to its source – credibly and unambiguously – and state clearly as a matter of national policy that it will demand the cooperation of governments that might have been the source in proving or disproving their complicity. The United States should also state clearly that it reserves the right to retaliate against governments that knowingly transfer nuclear weapons or fissile materials to non-governments.**

7. CONTINUITY OF THE AMERICAN FORM OF GOVERNMENT. Even in the terrible circumstances of the Day After, the underlying situation would continue to be that of a handful of terrorists acting against everyone else. Contingency plans for the Day After must tend to the needs of those affected but also to everyone else – people and cities not bombed and above all the institutions and spirit of collective governance of the American people through the Constitution. This means two things – continuity of constitutional government, and continued confidence by the population that their government's response is well thought-out and competently executed. They will need to know that their system of government is doing its best to restore their security and wellbeing to what it was before the Day After.

The physical security of the President and his successors should not be in doubt. The chain of succession if the President is killed is prescribed by the Constitution and law. Contingency plans for the so-called "continuity of government" were in place during the Cold War to ensure retaliation to an attack by the Soviet Union (and thus ensure deterrence of attack in the first place), were amended in the early 1990s to encompass terrorist attacks on Washington, and were further urgently updated after September 11, 2001 when the reality of terrorism suddenly became evident to all. The physical survival of all three branches of U.S. Constitutional government is presumably therefore beyond doubt, though its mechanisms are necessarily secret.

It would be advisable to add two additional ingredients to the continuity of government plans for the uniquely destructive and frightening circumstances of the Day After a nuclear detonation on a U.S. city.

First, plans should provide to make it true in fact and appearance that extraordinary measures taken to respond to a first detonation and to prevent follow-on detonations are the result of deliberation and balance among all three branches of American Constitutional government. A council of, say, the President, Vice President, Speaker of the House, Majority Leader of the Senate, and Chief Justice of the Supreme Court could be specified as a "consultative body" to determine important aspects of the government's response that touch law and the Constitution – without in any way impeding existing and long-established authorities of the Executive, Legislative, and Judicial branches. The resulting framework should be effective against terrorists and also be fair and seen as fair in the United States and throughout the world.

Second, contingency plans should stipulate that any extraordinary measures taken to respond to the Day After – even if taken through due Constitutional and balance of powers mechanisms – are temporary, have a specified "sunset date," and will be reviewed when the campaign of terror subsides or ends.

* * *

Dealing with the Day After a nuclear attack on a U.S. city is a contingency no government or citizen ever wants to face. Through wise policies of prevention, this day may never come. But the reality is that the probability of nuclear terrorism, while it cannot be quantified, is not zero and is surely increasing as the number of sources of fissile material multiplies.

A serious risk requires serious and thoughtful contingency planning, however small or remote the probability may seem. The Preventive Defense Project's Day After Workshop was inspired by this requirement.

This Report suggests that well thought-out measures embedded in serious contingency plans can save lives and promote recovery. This contingency planning therefore deserves sober attention. On the Day After, moreover, the destruction of buildings and lives in the cities bombed could be accompanied by a wider destruction of the sense of safety and well-being of each and every citizen. While thoughtful preparation in advance won't change a catastrophe into something less, it will nevertheless save thousands of lives and billions of dollars, prevent unnecessary panic, help maintain trust in the government, and help preserve democratic institutions in a time of emergency. Carefully considered action by government on the Day After will also help the citizenry avoid overreaction and panic and allow them to restore through their Constitutional government the American way of life that they have built over centuries. Terrorists – even armed with nuclear weapons – should never be allowed to take that away.

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Dr. Ashton B. Carter
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Professor Ashton Carter is chair of the International Relations, Security, and Science faculty at Harvard's Kennedy School of Government. He is also Co-Director (with former Secretary of Defense William J. Perry) of the Preventive Defense Project, a research collaboration of Harvard and Stanford Universities.

Dr. Carter served as Assistant Secretary of Defense for International Security Policy during President Clinton's first term. His Pentagon responsibilities encompassed: countering weapons of mass destruction worldwide, oversight of the U.S. nuclear arsenal and missile defense programs, policy regarding the collapse of the former Soviet Union (including its nuclear weapons and other weapons of mass destruction), control over sensitive U.S. exports, and chairmanship of NATO's High Level Group. He directed military planning during the 1994 crisis over North Korea's nuclear weapons program; was instrumental in removing all nuclear weapons from the territories of Ukraine, Kazakstan, and Belarus; directed the establishment of defense and intelligence relationships with the countries of the former Soviet Union when the Cold War ended; and participated in the negotiations that led to the deployment of Russian troops as part of the Bosnia Peace Plan Implementation Force. Dr. Carter managed the multi-billion dollar Cooperative Threat Reduction (Nunn-Lugar) program to support elimination of nuclear, chemical, and biological weapons of the former Soviet Union, including the secret removal of 600 kilograms of highly enriched uranium from Kazakstan in the operation code-named Project Sapphire. Dr. Carter also directed the Nuclear Posture Review and oversaw the Department of Defense's (DOD's) Counterproliferation Initiative. He directed the reform of DOD's national security export controls. His arms control responsibilities included the agreement freezing North Korea's nuclear weapons program, the extension of the Nuclear Nonproliferation Treaty, the negotiation of the Comprehensive Test Ban Treaty, and matters involving the START II, ABM, CFE, and other arms control treaties.

Dr. Carter was twice awarded the Department of Defense Distinguished Service Medal, the highest award given by the Department. For his contributions to intelligence, he was awarded the Defense Intelligence Medal. In 1987 Carter was named one of Ten Outstanding Young Americans by the United States Jaycees. He received the American Physical Society's Forum Award for his contributions to physics and public policy.

A longtime member of the Defense Science Board and the Defense Policy Board, the principal advisory bodies to the Secretary of Defense, Dr. Carter continues to advise the U.S. government as a member of Secretary of State Condoleezza Rice's International Security Advisory Board, co-chair of the Senate Foreign Relations Committee's Policy Advisory Group, a consultant to the Defense Science Board, a member of the National Missile Defense White Team, and a member of the National Academy of Sciences

Committee on International Security and Arms Control. In 1997 Dr. Carter co-chaired the Catastrophic Terrorism Study Group with former CIA Director John M. Deutch, which urged greater attention to terrorism. From 1998 to 2000, he was deputy to William J. Perry in the North Korea Policy Review and traveled with him to Pyongyang. In 2001-2002, he served on the National Academy of Sciences Committee on Science and Technology for Countering Terrorism and advised on the creation of the Department of Homeland Security. He has testified frequently before the armed services, foreign relations, and homeland security committees of both houses of Congress.

In addition to his public service, Dr. Carter is currently a Senior Partner at Global Technology Partners and a member of the Board of Trustees of the MITRE Corporation, and the Advisory Boards of MIT's Lincoln Laboratories and the Draper Laboratory. He is a consultant to Goldman, Sachs and Mitretek Systems on international affairs and technology matters, and speaks frequently to business and policy audiences. Dr. Carter is also a member of the Aspen Strategy Group, the Council on Foreign Relations, the American Physical Society, the International Institute of Strategic Studies, and the National Committee on U.S.-China Relations. Dr. Carter was elected a Fellow of the American Academy of Arts and Sciences.

Dr. Carter's research focuses on the Preventive Defense Project, which designs and promotes security policies aimed at preventing the emergence of major new threats to the United States.

From 1990-1993, Dr. Carter was Director of the Center for Science and International Affairs at Harvard University's John F. Kennedy School of Government, and Chairman of the Editorial Board of International Security. Previously, he held positions at the Massachusetts Institute of Technology, the Congressional Office of Technology Assessment, and Rockefeller University.

Dr. Carter received bachelor's degrees in physics and in medieval history from Yale University, *summa cum laude,* Phi Beta Kappa. He received his doctorate in theoretical physics from Oxford University, where he was a Rhodes Scholar. In addition to authoring numerous articles, scientific publications, government studies, and Congressional testimonies, Dr. Carter co-edited and co-authored eleven books, including *Keeping the Edge: Managing Defense for the Future* (2001), *Preventive Defense: A New Security Strategy for America* (1997), *Cooperative Denuclearization: From Pledges to Deeds* (1993), *A New Concept of Cooperative Security* (1992), *Beyond Spinoff: Military and Commercial Technologies in a Changing World* (1992), *Soviet Nuclear Fission: Control of the Nuclear Arsenal in a Disintegrating Soviet Union* (1991), *Managing Nuclear Operations* (1987), *Ballistic Missile Defense* (1984), and *Directed Energy Missile Defense in Space* (1984).

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Michael May is Professor Emeritus (Research) in the Stanford University School of Engineering and a Senior Fellow with the Freeman-Spogli Institute for International Studies at Stanford University. He is the former Co-Director of Stanford University's Center for International Security and Cooperation, having served seven years in that capacity through January 2000.

Dr. May is Director Emeritus of the Lawrence Livermore National Laboratory where he worked from 1952 to 1988, with some brief periods away from the Laboratory. While there, he held a variety of research and development positions, serving as Director of the Laboratory from 1965 to 1971.

Professor May was technical adviser to the Threshold Test Ban Treaty negotiating team; a member of the US delegation to the Strategic Arms Limitation Talks; and at various times has been a member of the Defense Science Board, the General Advisory Committee to the AEC, the Secretary of Energy Advisory Board, the RAND Corporation Board of Trustees, and the Committee on International Security and Arms Control of the National Academy of Sciences. He is a member of the Council on Foreign Relations and the Pacific Council on International Policy, and a Fellow of the American Physical Society and the American Association for the Advancement of Science.

May received the Distinguished Public Service and Distinguished Civilian Service Medals from the Department of Defense, and the Ernest Orlando Lawrence Award from the Atomic Energy Commission, as well as other awards.

May's current research interests are in the area of safeguarding the nuclear fuel cycle, nuclear terrorism, energy, security and environment, and the relation of nuclear weapons and foreign policy.

Dr. William J. Perry
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William Perry is the Michael and Barbara Berberian Professor at Stanford University, with a joint appointment at FSI and the School of Engineering. He is a senior fellow at FSI and serves as co-director of the Preventive Defense Project, a research collaboration of Stanford and Harvard Universities. He is an expert in U.S. foreign policy, national security and arms control. He was the co-director of CISAC from 1988 to 1993, during which time he was also a professor (half time) at Stanford. He was a part-time lecturer in the Department of Mathematics at Santa Clara University from 1971 to 1977.

Perry was the 19th secretary of defense for the United States, serving from February 1994 to January 1997. He previously served as deputy secretary of defense (1993-1994) and as under secretary of defense for research and engineering (1977-1981). He is on the board of directors of several emerging high-tech companies and is chairman of Global Technology Partners. His previous business experience includes serving as a laboratory director for General Telephone and Electronics (1954-1964); founder and president of ESL Inc. (1964-1977); executive vice-president of Hambrecht & Quist Inc. (1981-1985);

and founder and chairman of Technology Strategies & Alliances (1985-1993). He is a member of the National Academy of Engineering and a fellow of the American Academy of Arts and Sciences.

From 1946 to 1947, Perry was an enlisted man in the Army Corps of Engineers, and served in the Army of Occupation in Japan. He joined the Reserve Officer Training Corps in 1948 and was a second lieutenant in the Army Reserves from 1950 to 1955. He has received a number of awards, including the Presidential Medal of Freedom (1997), the Department of Defense Distinguished Service Medal (1980 and 1981), and Outstanding Civilian Service Medals from the Army (1962 and 1997), the Air Force (1997), the Navy (1997), the Defense Intelligence Agency (1977 and 1997), NASA (1981) and the Coast Guard (1997). He received the American Electronic Association's Medal of Achievement (1980), the Eisenhower Award (1996), the Marshall Award (1997), the Forrestal Medal (1994), and the Henry Stimson Medal (1994). The National Academy of Engineering selected him for the Arthur Bueche Medal in 1996. He has received awards from the enlisted personnel of the Army, Navy, and the Air Force. He has received decorations from the governments of Albania, Bahrain, France, Germany, Hungary, Japan, Korea, Poland, Slovenia, Ukraine, and the United Kingdom. He received a BS and MS from Stanford University and a PhD from Penn State, all in mathematics.

PREVENTIVE DEFENSE PROJECT

A RESEARCH COLLABORATION OF STANFORD & HARVARD UNIVERSITIES
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The Day After: Action in the 24 Hours Following a Nuclear Blast in a U.S. City

A Workshop of the Preventive Defense Project
Thursday, April 19, 2007

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Dr. Ashton B. Carter
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President and Chief Operating Officer, Nuclear Threat Initiative

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