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THESIS

ASSESSING THE EFFECTIVENESS OF CURRENT NYC RADIOLOGICAL EMERGENCY RESPONSE STRATEGY IN PROTECTING RESPONDERS IMMEDIATELY AFTER DETONATION OF AN IMPROVISED NUCLEAR DEVICE

by

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September 2011

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Intelligence and nuclear experts believe that the probability of a terrorist detonation of an improvised nuclear device (IND) in a major urban environment in the United States is low, but all agree that the consequences of such an attack are high and that plans should be developed. No U.S. city to date has developed and completed a comprehensive IND plan that addresses initial and long-term consequences. Long-term issues, such as re-occupancy, population monitoring, and food and water contamination, are similar to issues planned for in nuclear power plant disasters. They develop over hours to days or even weeks, and are being addressed by emergency responders in Japan today. An improvised nuclear detonation is sudden; it has devastating immediate consequences over a wide geographical area; and it does not allow emergency responders time to prepare to safely address them. Existing emergency response plans, including radiological dispersion devices (RDDs) in major U.S. cities like New York City, do not adequately prepare emergency responders to protect themselves from these immediate consequences in the first few hours. A change in traditional response strategies and public expectations is necessary in order to save the most responder lives and the most civilian lives.

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ABSTRACT

Intelligence and nuclear experts believe that the probability of a terrorist detonation of an improvised nuclear device (IND) in a major urban environment in the United States is low, but all agree that the consequences of such an attack are high and that plans should be developed. No U.S. city to date has developed and completed a comprehensive IND plan that addresses initial and long-term consequences. Long-term issues, such as re-occupancy, population monitoring, and food and water contamination, are similar to issues planned for in nuclear power plant disasters. They develop over hours to days or even weeks, and are being addressed by emergency responders in Japan today. An improvised nuclear detonation is sudden; it has devastating immediate consequences over a wide geographical area; and it does not allow emergency responders time to prepare to safely address them. Existing emergency response plans, including radiological dispersion devices (RDDs) in major U.S. cities like New York City, do not adequately prepare emergency responders to protect themselves from these immediate consequences in the first few hours. A change in traditional response strategies and public expectations is necessary in order to save the most responder lives and the most civilian lives.

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TABLE OF CONTENTS

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LIST OF FIGURES

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LIST OF ACRONYMS AND ABBREVIATIONS

ARA	Applied Research Associates
BAD	Biological Agent Drill
CBRNE	Chemical, Biological, Radiological, Nuclear, Explosive
CIMS	Citywide Incident Management System (NYC)
CRC	Community Reception Center
DEP	New York City Department of Environmental Protection
DHS	U. S. Department of Homeland Security
DNDO	Domestic Nuclear Detection Office
DOHMH	New York City Department of Health & Mental Hygiene
DoD	Department of Defense
DFZ	Dangerous Fallout Zone
EAP	Emergency Action Plan
EMP	Electro Magnetic Pulse
EPA	Environmental Protection Agency
ESF	Emergency Support Function
FDNY	Fire Department, City of New York
FEMA	Federal Emergency Management Agency
FOUO	For Official Use Only
HERO	Harbor Emergency Radiological Operations
HEV	Highly Enriched Uranium
HSIN	Homeland Security Information Network
IAEA	International Atomic Energy Agency
ICE	Interagency Chemical Exercise

IED	Improvised Explosive Device
IND	Improvised Nuclear Device
KG	Kilogram
KT	Kiloton
LDZ	Light Damage Zone
LLNL	Lawrence Livermore National Laboratory
MDZ	Moderate Damage Zone
mR/hr	Milli-roentgens per Hour
MT	Megaton
NARAC	National Atmospheric Release Advisory Center
NCR	National Capitol Region
NCRP	National Council on Radiation Protection & Measurements
NLE	National Level Exercise
NPP	Nuclear Power Plant
NYC	New York City
NYPD	New York City Police Department
OEM	New York City Office of Emergency Management
R/hr	Roentgens per Hour
RED	Radiological Exposure Device
RDD	Radiological Dispersion Device (aka “Dirty Bomb”)
RRRP	Radiological Response and Recovery Plan NYC
SDZ	Severe Damage Zone
SNM	Special Nuclear Material
TEPCO	Tokyo Electric Power Company

UASI	Urban Area Security Initiative
WMD	Weapons of Mass Destruction

EXECUTIVE SUMMARY

Research into the radiological and nuclear response plans that are available from the key emergency response agencies in New York City shows that these plans do not address the specific issues of a 10 kiloton (KT) (low yield) nuclear detonation at ground level, which is one of the current threat scenario concerns of the federal government and its intelligence community. Similar research from other U.S. Tier I Urban Area Security Initiative (UASI) cities show that not one has a completed comprehensive improvised nuclear device (IND) response and recovery plan, and radiological dispersion device (RDD or dirty bomb) plans have a serious gap in emergency responder protection against the effects of radioactive fallout. New federally funded modeling and planning information available in the last two to three years make this effort achievable.

Still considered a lower probability than the use of conventional improvised explosive devices, commercial chemicals and biological agents, the rise in global instability is raising the risk, and the consequences are severe enough to warrant planning. In April 2010, it was the focus of President Obama, in his 47-nation summit, to prevent terrorist groups from acquiring materials to develop an improvised nuclear device. It remains a concern of the International Atomic Energy Agency (IAEA) and nuclear community. The IAEA Director General, Yukiya Amano, during the World Economic Forum in Davos Switzerland in January 2011 reported that the IAEA receives information about illicit trafficking of nuclear or radiological materials every two days (NYPD Counterterrorism Bureau, 2011, p. 2). The Department of Homeland Security (DHS) Domestic Nuclear Detection Office Joint Analysis Center Report for January 2011 further states that U.S. nuclear experts and IAEA officials are “much alarmed over the constant cases of radioactive material from a number of Indian defense and civilian nuclear facilities that have gone missing” (Domestic Nuclear Detection Office, 2011, p. 7).

Compared to the consequences of a 10KT nuclear detonation (National Planning Scenario 1), it is my determination that the current guidance is inadequate in protecting emergency responders. It addresses the necessary protective actions that the public needs

to take but does not recognize the fact that responders often see themselves separately and must have specific guidance. Responders in the moderate and light damage zones and beyond may have only seconds to tens of seconds to take protective actions against the prompt blast, thermal, initial ionizing radiation, and flash blindness, but they need to recognize the unfolding detonation in order to act on training and instinct.

Guidance in the existing radiological plans and improvised explosive response plans has emergency personnel that survived the initial blast responding in toward the detonation site to assist civilians and manage the incident. The dangerous levels of radioactive fallout that begins to return to the ground simultaneously to the emergency response places the responders at severe risk to fatal exposures. This fallout can continue for hours and days, depending on the winds and amount of dirt, dust, and debris carried upward by the detonation and thermal column. Until the dangerous fallout zone can be tracked and plotted, emergency responders should shelter-in-place with civilians in adequate shelters for at least 60 minutes, possibly 12 to 24 hours. With planning, this time can be used to combine ground-level readings with federal projections and generate recommended evacuation routes and guidance for emergency responders as well as civilians. This is not a part of the guidance currently available.

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I am thankful and humbled by the national experts I have worked with the past three years on committees developing guidance for emergency responders in preparing for, responding to, and recovering from an improvised nuclear device detonation. The committee members of the NCRP 165 Report, ASTM E54.02.05, and ANSI N42.33 thru 36 series, DHS National Planning guidance document and the NYC Radiological Response and Recovery Plan all provided me an opportunity through direct participation or document review to expand my knowledge in this field that is critical in protecting emergency responders. Specifically, I want to single out Brooke Buddemeier (LLNL), Dr. Tammy Taylor (LANL), and Dr. Stephen Musolino (BNL) for their efforts in the emergency responder community preparedness and guiding me.

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I. INTRODUCTION

A. PROBLEM STATEMENT

Terrorist use of an improvised nuclear device (IND) is not thought to be high on the probability list by the U.S. Intelligence Community, but the consequences can be so severe that preparation by local, state, tribal, and federal levels of government should be a higher priority than it is at the state and local level. The Department of Homeland Security (DHS) in partnership with the Homeland Security Council (HSC) developed a list of National Planning Scenarios to "illustrate the potential scope, magnitude, and complexity of a range of major events" that all government levels should plan for (Department of Homeland Security [DHS], 2007). Scenario one recognizes the use of an improvised nuclear device by terrorists against a medium or large American city.

New research modeling of the immediate consequences of the detonation of an improvised nuclear device in a major metropolitan city projects prompt blast effects on people and structures that one would expect from a large explosion. Tens to hundreds of thousands of people will be injured or killed and scores of structures destroyed or damaged. Additionally, there would be initial radiation and dangerously high levels of radioactive fallout that is expected to begin descending 15 to 20 minutes after the detonation.

New York City (NYC) is considered to be a premier target for terrorists and does not currently have a planning document that establishes a response strategy to address the challenges created by the detonation of an IND. NYC response times to emergencies average five to eight minutes for fire, medical, and police resources, and this average is similar to those of other large, Tier I UASI cities. This places responders near and around the detonation site just prior to the expected radioactive fallout to begin descending, potentially exposing them to serious or fatal exposures.

A draft NYC *Radiological Response and Recovery Plan* (RRRP) (New York City Emergency Management [OEM], 2010) that focuses on RDDs remains incomplete after three years. The *Radiological Response and Recovery Plan* outlines the operational strategies that support a coordinated citywide response to a radiological incident and is similar to RDD plans in other large metropolitan cities (OEM, 2010). It is intended to provide a framework for the individual agencies to develop their specific strategic and tactical plans to meet their assigned responsibilities while protecting the emergency responders and the public. These agency specific plans cannot be completed and exercised until the RRRP is complete and approved in order to ensure interagency coordination. Agency commitments to develop an IND plan are delayed until completion of the RDD plan.

Emergency responders' health and safety may be at serious risk if current response strategies for radiological releases are not appropriate to protect them against the serious consequences of the prompt effects from an improvised nuclear detonation. The RRRP draft must be reviewed to identify the strategy and tactics developed, followed by an analysis to determine whether they are sufficient to protect emergency responders against the prompt effects of a nuclear detonation as described in recent reports, guidance documents, and modeling. Follow-up research must be conducted to monitor the response planning efforts of other cities, such as the National Capitol Region, to determine if they can be used as a template for NYC and other large metropolitan cities.

B. NUCLEAR THREAT

The threat of a large-scale nuclear attack during the Cold War between Russia and the United States has declined enormously since the breakup of the U.S.S.R. No longer are intelligence agencies viewing the deployment of hundreds of nuclear warheads by one nation state against another as a likely threat scenario. Intelligence agencies today and the international nuclear community have grave concerns that terrorists may escalate their violent actions to include nuclear terrorism. With ever tightening security and international agreements protecting intact nuclear weapons, the possibility of terrorists seizing a nuclear weapon is not likely. On the other hand, as Joseph Cirincione (2007) writes in his book *Bomb Scare*:

> It is common sense that national security policy should be oriented toward the main danger to the U. S. and other nations. Today that does not come from a nation intentionally attacking with nuclear weapons. The most urgent threat is a terrorist attack using a nuclear weapon. (2007, pp. 139–140)

Charles D. Ferguson and William C. Potter (2008), in their work at the Monterey Institute of International Studies, believe like many other nuclear experts that terrorists "may instead decide to acquire fissile material by purchase, diversion, or force for the purpose of fabricating a crude nuclear bomb, known more formally as an 'improvised nuclear device.' "

In 2008, a video entitled *Nuclear Jihad, The Ultimate Terror* was released by jihadist supporters calling for the use of weapons of mass destruction (WMD) against civilians. Charles D. Ferguson and William C. Potter (2008) write in their report for the WMD Commission that "the amount of fissile material that might theoretically be accessible to terrorists is staggering" and in the millions of tons range. The International Atomic Energy Agency (1993) defines the significant amount of fissile material necessary to form a nuclear weapon equivalent to the atomic bombs used on Hiroshima and Nagasaki in the 25 kilogram (kg) range for U^{235} (1993). Security on highly enriched fissile material in weapons programs is good, but civilian storage may provide the opportunity terrorists need to acquire what they need for an improvised nuclear weapon.

In May 2007, the Department of Defense's (DoD) Defense Science Board released a summer study titled *Reducing the Vulnerabilities to Weapons of Mass Destruction* (2007). DoD recognizes that it has a mission to protect its forces and support civil communities against attacks and other catastrophes, particularly since its domestic bases rely heavily on civil infrastructure. It recognizes the need to be "prepared in advance of an attack to lead and train a national mitigation and recovery operation" (Defense Science Board, 2007). To do this, it needs to develop detailed catastrophic plans now—analogous to classis war planning" (2007, p. 13).

The Defense Science Board contracted the Lugar survey on proliferation threats and responses. One hundred and thirty-two national security and non-proliferation experts responded to the Lugar survey with their thoughts on the threats faced by the nation (Defense Science Board, 2007, Figure 2). Results show that "over half of those responding believe that the probability of a nuclear attack on the homeland within the next ten years is greater than thirty (30) percent" (2007, p. 14) The survey results (shown in Defense Science Board, 2007, Figure 2) also present the "relative likelihood of the mode of WMD attack" as: nuclear (22 percent), radiological (42 percent), biological (21percent), and chemical (15 percent) (Defense Science Board, 2007,p. 13). With the consequences of a nuclear detonation so high (and although the probability is still low, it appears to be rising based on expert opinions), there is a strong need to plan for such an attack.

The National Academies of Science published *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism* in 2011. The authors, the Committee on Science and Technology for Countering Terrorism, National Research Council, addressed a section in the book to each of the weapons of mass destruction. In the nuclear and radiological research, they identify three categories of threats to homeland security here in the U.S. from nuclear and radiological terrorism:

C. THE NUCLEAR AND RADIOLOGICAL THREAT MATRIX

1. Stolen state-owned nuclear weapons or weapons components, modified as necessary to permit terrorist use.
2. Improvised nuclear devices (INDs) fabricated from stolen or diverted special nuclear material (SNM) plutonium and, especially, highly enriched uranium (HEU).
3. Attacks on nuclear reactors or spent nuclear fuel or attacks involving radiological devices. (Committee on Science and Technology for Countering Terrorism, 2011, p. 39)

The Academy committee defines an IND as "a nuclear weapon fabricated by terrorists, with or without state assistance, using stolen or diverted special nuclear material (SNM)" (Committee on Science and Technology for Countering Terrorism, 2011, p. 40). They go further to state, "The basic technical information needed to construct a workable nuclear device is readily available in the open literature" (2011, p. 40). Of the three identified nuclear threats, the work in this assessment will stay focused on the improvised nuclear device attack. The committee further states, "The probability of the occurrence of a nuclear detonation by terrorists in the next five years is low to moderate" (2011, p. 43). This is an increase from the estimation of most terrorism experts in the years immediately after September 11, 2001, and supports the Lugar survey results mentioned above.

NYC clearly remains a target for domestic and international terrorists. The consequences from such a device in a medium to large city are significant and would quickly overwhelm local resources. Certain component parts of various NYC emergency response plans already developed (e.g., evacuation and sheltering, emergency messaging), and one currently under development, the *Radiological Response & Recovery Plan* (RRRP), may provide limited structure to an IND plan. However, there are key challenges presented by an IND attack for which capabilities are not developed and will be essential in effectively managing an incident of this magnitude. One challenge, found by DHS sponsored modeling research, is that very high levels of radiation from the fallout can contaminate a geographic area 10–20 miles downwind with very dangerous levels in the first hour. Immediate sheltering of the public ***and emergency responders*** will be necessary to protect them from fatal radiation exposures.

To jumpstart the IND planning process, experts from the Department of Homeland Security, National Laboratories, and other technical organizations were requested to present their research on the consequences of a 10 kiloton (KT) improvised nuclear device being detonated at ground level in midtown Manhattan (Buddmeier, 2009). The consequences are dramatic and costly in terms of lives, infrastructure and the economy but manageable and survivable when the levels of government are prepared to address the challenges. The audience of high-level emergency response, environmental, and health officials in attendance from NYC agencies were subdued by the projected fatalities and injuries if this were to occur during an average workday population but understood the value in developing plans. This includes providing the public with realistic actions to take to protect themselves until emergency services personnel can assist them.

Brooke Buddemeier led this presentation and was instrumental in helping coordinate the DHS research to model the consequences of a 10 KT nuclear detonation in major U.S. cities (2009). His work supports the DHS Risk and Consequence Management Division in its efforts to evaluate the potential risk and consequences of radiological and nuclear terrorism. His research is referenced often in this work, and is recognized by the scientific community and has influenced the federal *Planning Guidance for Response to a Nuclear Detonation* (National Security Staff, Inter-agency Policy Coordination Sub-Committee for Preparedness and Response to Radiological and Nuclear Threats, first edition (2009) and second edition, 2010), [This document will be referred to as the *Federal Planning Guidance* for brevity] and NCRP Commentary 19*: Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism* (2005) and NCRP Report 165: *Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers* (2010). The results of this recent research and modeling indicate that a modern urban environment can greatly mitigate some of the effects of a low-yield nuclear detonation (Buddemeier, 2010).

Since the DHS presentation in the late summer of 2009, NYC has experienced some changes in key administrative positions following the federal and city elections. This requires informing new officials of the need to commit resources in this difficult budget period to developing an IND plan that we hope is never used at the same time as resources are dedicated to the RRRP.

In addition to the response gaps discussed already, many more exist. The decline in the Cold War nuclear threat has created a generation of Americans who are no longer familiar with protection factors of facilities such as fallout shelters or even what a fallout shelter is. They are not informed on the effects of fallout created by a ground burst of a nuclear device or the devastating health effects that can occur when exposed in the first few hours when levels are extremely high. Public awareness campaigns and emergency messaging systems must be developed to control the expected actions of untrained civilians. Protection factors for public facilities must be determined to ensure that emergency responders and other public employees are safe in those critical first few hours.

Tactical procedures for emergency response must be revised to reflect the position that a response to an improvised nuclear device will come from outside the effected jurisdiction while responders inside remain in shelters until fallout levels decrease. Training programs will require revision or development to inform responders of these changes.

Accurate plume modeling gaps must be addressed with new technologies in order to initiate "informed evacuations of civilians and responders from the dangerous fallout zone" (Buddemeier, 2009). Long-term population monitoring and environmental recovery resources must be identified and leveraged to address these significant challenges.

These activities will require coordinated action from all levels of government and should be pre-planned for each jurisdiction or region. They are very different than most of the disasters that have been managed by NYC agencies up to this point in history. Developing a plan that identifies IND challenges and assesses current capabilities to meet them will be critical in determining NYC's ability to effectively manage the effects of an improvised nuclear device detonated in the middle of Manhattan.

During the researching and writing of this thesis, a magnitude 9.0 earthquake and devastating tsunami hit the coast of Japan, creating a potentially catastrophic national and global disaster. A nuclear power plant disaster at the Tokyo Electrics' Fukushima Dai-ichi plant has been a serious possibility and incredible efforts have been made to continue cooling the reactor's fuel rods while repairs are planned to the cooling systems and containment pools. A wide area with a radius of 12 miles from the power plant has been evacuated and hundreds of thousands of Japanese people were displaced and many housed in shelters (AP, 2011). The population residing in a second ring, the area from 12 miles out to 20 miles from the plant, was directed to shelter-in-place to minimize exposures (AP, 2011). Radiation was detected in milk, water, produce, and other consumables, and it has leaked into the ground and ocean and spread contamination, for several weeks now, at detectable levels as far as the west coast of the United States.

The issues faced by the Japanese government now are similar to the long-term consequences of a nuclear device detonation. Some of these include containment and mitigation of the radioactive materials, recovery of critical infrastructure and services, long-term population monitoring, health treatment, decontamination of people and facilities, re-occupancy, and many others. According to an IAEA report in June 2011, the government of Japan announced in April that "protective actions to reduce the external exposure to the population beyond a distance of 30 km from the Fukushima-Daiichi Nuclear Plant. NISA has reported that the evacuation of the 'Planned Evacuation Zones' within Iitate village and Kawamata town commenced on 15 May" (IAEA 2011). On September 11, 2011, President Toshio Nishizawa of the Tokyo Electric Power Company (TEPCO), Inc. released a statement on the status of their roadmap towards restoration from the accident. He reported, "Step one whose goal was to secure the steady decline of radiation dose is almost fully accomplished as of July and they are working on step two to control the release of radioactive materials" (TEPCO, 2011).

The key differences between a nuclear detonation and the Fukushima Dai-ichi power plant catastrophe are the initial prompt blast effects and fatal levels of radioactive fallout that are associated with a nuclear detonation. A nuclear detonation creates fallout in a single, no notice event. The "plume" of material goes downwind and deposits on the ground, leaving behind a large contaminated "footprint" that initially decays rapidly, but remains at some level over a long period of time. There is generally not enough time to manage an immediate evacuation without being caught in the fallout.

A nuclear power plant (NPP) accident generally has a buildup of events leading to an expected release, but it is often hours or days before there is a major release. When releases do occur, they tend to come in cyclic bursts of releases with the potential for a continual release similar to a "smokestack effect," recently observed and reported by the IAEA in the 2011 Japanese emergency.

It is these areas of concern that occur within the first minutes to two hours after a nuclear detonation that can have a more devastating impact on emergency responders, if they are not prepared to address them. My research and recommendations identify and work toward planning for the protection of emergency responders so that then they may be able to assist the public that will be in need of services.

Although different, the Japanese power plant disaster can play a powerful role in supporting development of response plans in major U.S. cities. It has pushed radiological safety and health issues to the forefront of global daily news. Already, we see advocacy groups calling for reviews of nuclear power plant emergency response plans and increased evacuation distances and the subsequent large numbers of people involved. We are receiving information on sheltering and service needs; difficulties in repairing and restoring critical infrastructure and utilities; food and water health concerns; and how to deal with the large number of fatalities and injured persons. The prompt effects of a nuclear detonation in a major U.S. city will cause significantly more deaths and injuries, disrupt more services, destroy or seriously damage more infrastructure, and give no warning to emergency response services allowing them to initiate actions to protect their personnel. The loss of local emergency responders from a nuclear detonation will have a major, negative impact on our ability to protect and save civilians and recover quickly. Emergency managers need to leverage this information, particularly in this period of dangerous budget deficits and service cuts, in order to use current consequence modeling to develop realistic improvised nuclear detonation response plans that will protect the most civilians and emergency responders.

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II. LITERATURE REVIEW

In 1996, New York City's emergency service agencies developed their first citywide radiological response plan that established a strategy for radiological dispersion devices (RDDs, commonly referred to as dirty bombs). Previous editions addressed only the accidental releases of radiological material in licensed facilities or during transportation. This 1996 plan was subsequently used to guide independent agency strategic and tactical plans to complete their responsibilities, but it was never exercised. A 1997 interagency exercise in New York Harbor known as Harbor Emergency Radiological Operation (HERO) was stopped weeks before it was scheduled. The new draft plan, referred to above as the Radiological Response and Recovery Plan (RRRP) is nearing completion but still only addresses accidental releases and RDDs.

A. PROMPT EFFECTS

The prompt effects from the detonation of a 10 KT improvised nuclear device include direct blast effects and secondary effects from building collapses and glass projectiles, thermal and over-pressure effects, blinding light, and radiation. In their paper *Key Response Planning Factors for the Aftermath of Nuclear Terrorism*, Buddemeier and Dillon describe prompt effects as "those that radiate outward from the detonation location, i.e., ground zero, usually within the first minute after detonation" (2009, p. 2). DHS sponsored modeling of the prompt effects developed by Lawrence Livermore National Laboratory, Los Alamos, Sandia, other national labs and private sector corporations provide strong supporting evidence to the extent of the damage and land mass impacted. Information from the reports produced by these organizations and presented at a Federal Emergency Management Agency (FEMA)-sponsored seminar held June 15, 2010, featuring modeling projections of the prompt effects in an urban environment, identified the hazards and consequences of a 10 KT detonation. This will provide the basis on which an analysis can be completed on the effectiveness of existing emergency responder strategies and tactics to protect them from the immediate hazards and consequences of the prompt effects.

B. EARLY EVACUATION

The *Federal Planning Guidance for Response to a Nuclear Detonation* provides one recommendation for early shelter, and as information on the hazards is collected, it is followed by another recommendation for an informed, delayed evacuation (National Security Staff, 2010). The document further recommends an outside in, zoned approach strategy for emergency responders and identifies four zones: severe damage, moderate damage, light damage and dangerous fallout (National Security Staff, 2010). This guidance recommends prioritizing the moderate damage zone as the one where the most effective actions can be deployed to save victims. This is drastically different from the current response model of deploying directly to the seat of the detonation site.

Buddemeier and Dillon (2009) state, "Seeking adequate shelter (Protection Factor [PF] of 10 or more) for at least the first hour is the most critical lifesaving action for both the public and the emergency responders." This recommendation is in direct conflict with the existing response strategy of immediate response to a confirmed explosion for search and rescue missions that would place emergency responder's lives in potentially fatal exposures. A protection factor for buildings is not a new discovery, but one that, in fact, has been around since the Cold War. During the Cold War, FEMA maintained lists of infrastructure in most cities where designated fallout shelters were identified for the safety of the public for the threat of nuclear war. These lists have not been updated, the public has not sustained knowledge of these locations nor their value, and new lightweight constructed buildings are unaddressed in these lists with their identified protection factors against radiation from nuclear fallout in order to effectively shelter in place the public and emergency responders.

C. EARLY RESEARCH

Early research shows only two jurisdictions have developed extensive plans for response procedures after the detonation of an improvised nuclear device. These include plans from Ventura County, California, (preparing for a detonation in adjacent Los Angeles County) and the state of Oregon. Others in development that become available during this study may be included in the research work. Tier I UASI contacts in Chicago, Boston, Los Angeles, Houston, and the National Capitol Region (NCR) all replied that IND plans are either nonexistent or in early draft stages.

Articles such as Musolino and Harper's *Emergency Response Guidance for the First 48 Hours after the Outdoor Detonation of an Explosive Radiological dispersal Device* also provide clear and practical information for agencies to implement quickly (2006). The National Council on Radiation Protection and Measurements (NCRP) Commentary 19 identifies key elements for emergency responders in radiological and nuclear incidents, and NCRP Report 165, *Key Decision Points and Information Needed by Decision Makers in the Aftermath of a Nuclear or Radiological Terrorism Incident*, (2010). Both highlight critical actions for pre-event and the early phase immediately after an incident begins and will be invaluable identifying recommended actions.

FEMA's *National Response Framework* (NRF) (FEMA, 2008a) and particularly the NRF *Nuclear/Radiological Incident* Annex (FEMA, 2008b) describe the policies, concepts of operations and mission responsibilities for all federal agencies in the response and recovery phases for incidents involving the release of radiological or nuclear materials. State and local emergency managers should integrate this information into their assessment of the challenges they will be faced with, and the resources available in planning their state and local response plans.

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III. METHODOLOGY

This thesis will review existing local policies of response, academic literature and modeling projections to answer the question: Do current NYC radiological response strategies protect emergency responders against the consequences that result in the first two hours after detonation of a nuclear device?

The introduction will lay out the current United States threat matrix for terrorist weapons that use chemical, biological, radiological, nuclear, and explosive (CBRNE) materials in order to provide the correct probability potential of a nuclear detonation. It will also define the problem(s) our emergency responders face protecting themselves against the prompt effect consequences in order to have their capabilities available to save those victims who will require their services in order to survive this type of incident.

The literature review will provide a synopsis of the current literature, plans, and modeling projections available to planners tasked with developing recommendations in both strategy and tactics for responding to the detonation of a nuclear device in a major metropolitan city.

Newly released models projecting the prompt and long-term consequences of a 10 KT nuclear device detonation will be reviewed to identify the health effects to responders during the first two hours of the incident. This is a critical period for potentially hundreds of emergency responders whose health and safety may be at risk if they follow existing strategies of immediate deployment to the detonation site. DHS and its national laboratory partners research supports immediate sheltering-in-place for the public and emergency responders in the area impacted by the detonation. This may result in critical exposures due to extremely high levels of radiation that will be produced by a ground burst.

The existing NYC Radiological Response and Recovery Plan (RRRP), the recently completed *Nuclear Response Plans* from Ventura County, California (*Nuclear Explosion Response Plan,* Department of Public Health, 2007), and the states of Washington (*Initial Response Planning for Improvised Nuclear Device Explosions,* WA

Department of Public Health, 2007) and Nevada (Office of Emergency Management, 2010) will be reviewed specifically for emergency response procedures in the immediate two hours after a radiological incident is identified. Research of international planning, specifically of Israel and the United Kingdom, if available, will be included. These procedures will be compared to the newly projected consequences for detonation of a 10 KT nuclear device in the NYC or other urban environment for their effectiveness in protecting the health and safety of responders.

Recommendations from this analysis will focus on immediate strategies that can be developed and implemented by emergency response planners to significantly improve the health and safety of emergency responders during the first two hours after a nuclear detonation. In a time frame of budget deficits and limited complex and comprehensive emergency response plans development capabilities, development of short term, easily implemented protective actions will potentially save hundreds of responders, allowing them to provide essential services in later phases of a nuclear response and recovery program.

IV. CONSEQUENCE MODELING DATA REVIEW

Basic nuclear weapons effects or consequences have been known for decades, since testing and wartime use was conducted in the 1940s. Glasstone and Dolan, writing their book *The Effects of Nuclear Weapons* in 1977, captured these effects in detail and their work is still used as a basis for current modeling research. The breath of their work covers weapons in the kiloton and megaton size, as well as air, high-altitude, surface, and sub-surface detonations. The U.S. Department of Homeland Security's number one national planning scenario focuses on a surface detonation (ground level), in the 0.1, 1.0, or 10 KT size by a terrorist or terrorist organization. The assessment in this document will mirror the national planning scenario using a 10 KT device, detonated at ground level after being moved into a major metropolitan city.

A. ACADEMIC LITERATURE

In his document Reducing the Consequences of a Nuclear Detonation, Brooke Buddemeier separates the effects of a 10 KT into "two categories: prompt and delayed" (2007, p. 3). The recently released second edition of the Federal Planning Guidance for Response to a Nuclear Detonation, (National Security Staff, 2008) and other federal agency representatives, identify these same effects as primary and secondary (National Security Staff, 2010, p. 14). We will incorporate the latter terms as they both occur within the first two-hour window post detonation and will impact the effectiveness of existing NYC response strategy in protecting the health of fire fighters and other emergency responders. The two-hour period is based on several criteria:

- New DHS models predicting optimum evacuation times from poor shelters,
- This time period will be the most volatile in determining where the most radioactively hazardous areas will be (dangerous fallout zone),
- Average response times for NYC responders to other emergencies,
- Time it will take local NYC agencies to organize, coordinate activities, collect, analyze, and share environmental data in order to make informed decisions on lifesaving missions,

- It has the most potential to negatively affect the health of emergency responders as a result of radioactive fallout dropping to the surface after being carried up several miles in the thermal plume (mushroom cloud).
- Fifteen minutes to one hour is the expected time for local response organizations to begin receiving plume modeling from the Department of Homeland Security (DHS) lead Interagency Modeling and Atmospheric Assessment Center (IMAAC) (National Security Council Subcommittee, 2010, p. 42).

1. Primary Effects

Primary effects occur immediately after detonation and can last from seconds to a minute or two. These include: blast, thermal, initial ionizing radiation, and flash blindness. Secondary effects will include electromagnetic pulse (EMP) and radioactive fallout. As a result of these effects, there will be areas of complete destruction, and further away areas with decreasing levels of destruction that will have collapsed buildings, fires, and ruptured utility lines; particularly natural gas and water, air-rail-highway vehicle accidents, and more.

Nuclear blast effect is defined in the *Federal Planning Guidance* as "The impacts caused by the shock wave of energy through air that is created by detonation of a nuclear device" (National Security Staff, 2010, p. 3). The blast wave "is a pulse of air in which the pressure increases sharply at the front, accompanied by winds" (National Security Staff, 2010, p. 3). This overpressure and the high winds or dynamic pressure is very destructive to buildings, other infrastructure, vehicles, and people. Overpressure of only five to eight psi above normal pressure is strong enough to damage all but very substantial and reinforced buildings. Table 1.1 in the *Federal Planning Guidance Document* shows extrapolated overpressures of 50 psi and wind speed over 900 mph within one-fifth of a mile from the site of a 10 KT detonation (National Security Staff, 2010, p. 16). Overpressures of five psi can extend out to more than one-half mile from the epicenter with winds still exceeding 160 mph (National Security Staff, 2010). This information indicates that at one-half of a mile from the detonation site, most buildings will be either destroyed or severely damaged and there will be very few survivors, if any. The authors of the *Federal Planning Guidance* identify this zone as the "severe damage zone" for purposes of response planning (National Security Staff, 2010, p. 18). Moving out and away from ground zero, from approximately one-half mile to approximately one mile is identified as the “moderate damage zone” (National Security Staff, 2010, p. 17). Blast effects damage in this zone will “include significant structural damage, blown out building interiors, blown down utility lines, overturned automobiles, caved roofs, some collapsed buildings, and fires” (National Security Staff, 2010, p. 17). The “light damage zone” is described as extending outward to approximately three miles, and observations will include windows, gutters and doors blown in, window shutters, roofs, and lightly constructed buildings will have increasing damage. There will be extensive glass damage, with accompanying injuries, and many traffic accidents, hindering any effective response ((National Security Staff, 2010, p. 17).

2. Glass Injury Effects

Glass breakage from this overpressure can occur for several miles from the detonation epicenter. This damage will be obvious and expected in the severe and moderate damage zones where many structures will be either completely destroyed or seriously damaged or collapsed. It will be the cause of many injuries found in the light damage zone as well and out to areas more than five miles away where larger, older, or less insulated and reinforced glass panes are in place. Buildings in the dangerous fallout zone whose windows are shattered will also have higher levels of radiation exposure near the outer skin of the structure from fallout.

3. Ionizing Radiation

Tests from the Nevada desert indicated that initial ionizing radiation can cause serious exposures to those individuals caught out doors during the detonation, for distances up to a mile from ground zero. These exposures can occur directly from being in line of sight from the detonation or reflected from the atmosphere if the individual is shielded by a building or other structure. This initial radiation burst continues further away, but it decreases in intensity quickly. The exposure, to those outside but within the severe and moderate damage zones, would be enough to be fatal to most within one or more weeks from the time of exposure, even if this was their only injury. Shielding decreases the exposure but is dependent on the building construction and materials used or conveniently positioned between individuals and the blast site.

Models developed at Applied Research Associates (ARA) and Los Alamos National Laboratory indicate that the ambient radiation levels from a low-yield, ground-level nuclear detonation in a major urban environment could be significantly reduced by the shielding effects of dense urban landscape (Bergman, Kramer, Sanchez, Madrigal, Millage, & Blake, 2011). This has the potential to reduce initial radiation injuries that would potentially occur in a less densely developed environment.

Figure 1 is one model developed at ARA and Los Alamos National Laboratory. Developed by Bergman, Kramer, Sanchez, Madrigal, Millage and Blake, it was presented at the 56th Annual Meeting of the Health Physics Society on June 29, 2011. In it, the left side of the image represents an unobstructed exposure from a low-yield 10 KT surface detonation compared to the reduction of outdoor radiation levels indicated in the right side of the image.

Experts believe, however, that most people in this area immediately around the detonation site will suffer other more serious injuries and complications from collapsing buildings, direct blast effects or shrapnel from building debris in addition to the radiation exposure, and die as a result of those injuries much sooner than from the radiation.

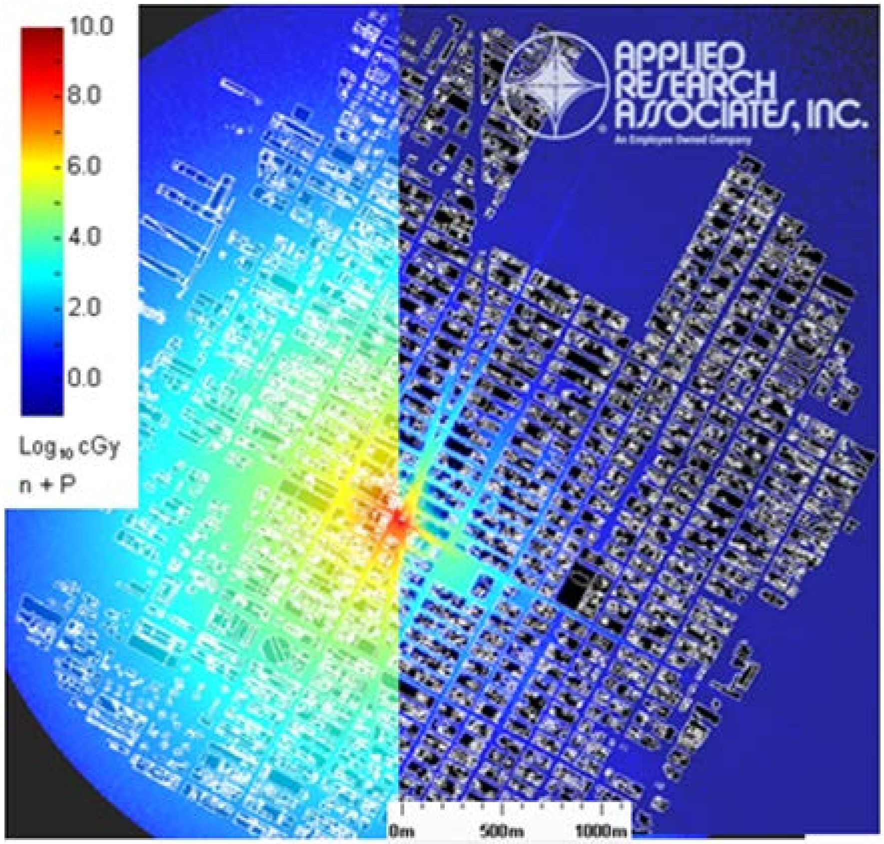

Figure 1. Analysis of the Reduction of Prompt Radiation in the Urban Environment (From Bergman et al., 2011)

4. Thermal Effects

Thermal effects produced by a 10 KT nuclear detonation ground burst produces less thermal energy than an air burst and what is produced can be absorbed by building materials and the ground. It still can produce heat energy in the millions of degrees and extend out approximately one-quarter of a mile, decreasing in temperature as the thermal pulse moves further away from the detonation site. This can ignite fires in combustible materials and ruptured gas lines, and cause serious injuries and fatalities to those unprotected from the pulse. *Federal Planning Guidance* information on injuries from this thermal pulse say they will vary depending on such factors as distance away, shielding, clothing worn, weather, environment etc., and will range from incineration in close proximity to line of sight burns up to two miles away (National Security Staff, 2010, p. 20).

5. Flash Blindness Effects

The energy released from the detonation will produce a blinding flash of light, which if not shielded from it, will cause eye injuries to those exposed ranging from temporary blindness to permanent injury or loss of sight. Factors such as weather, clear skies, cloud cover, use of eye protection, or a detonation at night may increase the damage caused by exposure to this flash. The impact that this effect may have on people in hazardous positions, driving vehicles or possibly even pilots flying near or within the flash is unknown, but it is expected to result in many accidents with the potential for serious injuries, all requiring levels of assistance.

These primary effects are typical of conventional explosives, except for the initial radiation, but to a significantly greater degree and distance. RDDs (or dirty bombs) add the initial radiation component to the blast and thermal effects produced but again to a much smaller scale than a nuclear device. These effects are not significant response model busters when assessing them against current radiation accident and explosive device emergency plans. Existing improvised explosive device (IED), radiation detection equipment deployed, and radiological accident response plan strategies will protect responders from the consequences of an RDD unless caught in the immediate blast.

6. Delayed Effects

The use of the word delayed here to characterize the effects of fallout is deceptive. It refers to the delay in health effects to exposed individuals compared to the immediate effects from the blast, heat, shrapnel, building collapse, and other secondary causes. Fatalities and serious injuries due to radiation exposure alone will not present for hours to days in even the most severely exposed.

7. Fallout

Buddemeier identifies fallout in *Reducing the Consequences of a Nuclear Detonation* as “the primary delayed effect, generated by the dust and debris excavated by the explosion combined with radioactive fission products and drawn upward by the heat of the event” (2007, p. 4). It is this plume, drawn upward by the thermal effects, that forms the characteristic shape of a mushroom cloud and can reach heights of several miles. The exposure to radioactive fallout will begin within minutes for those closest to the detonation site and who have survived the immediate effects described above. Heavier radioactive particles modeled in recent studies begin falling within 15 minutes as they descend from the plume, while lighter ones continue to fall for hours and days (National Security Staff, 2010). The *Federal Planning Guidance* states, "Fallout that is immediately hazardous to the public and emergency responders will fall to the ground within about twenty-four hours" (National Security Staff, 2010, p. 28). Depending on the low and high altitude winds that carry the fallout, this *dangerous fallout zone* can "extend a few tens of miles with a width of several miles" have radiation levels in the hundreds of R/hr, and contradict the traditional Gaussian cigar-shaped plume models (Figure 2) used in hazardous materials responses (Mars, 2007, p. 3).

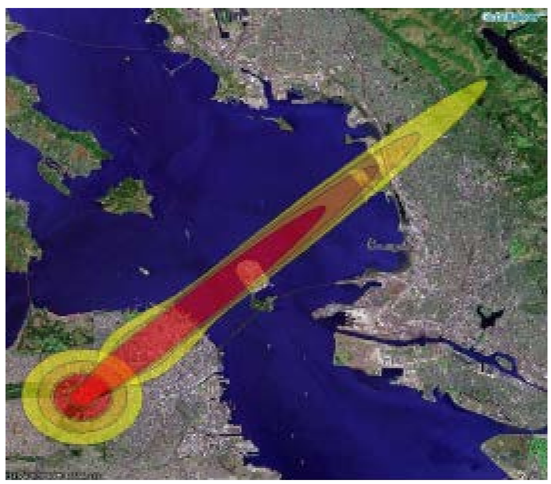

Figure 2. Typical Gaussian "Cigar-Shaped" Plume Model (From Mars, 2007)

Figure 2, from R. E. Mars's work, *Radioactive Fallout from Terrorist Nuclear Detonation*, depicts a 10 KT surface burst in San Francisco with a five mph wind from the southwest and was modeled by a simple Gaussian plume model, HotSpot Health Physics Codes (2007). More advanced models are able to include additional atmospheric data that changes the footprint of the dangerous fallout zone and changes response strategies. Key to protecting the public and responders from fallout is early sheltering in adequate shelters. Fallout created by a ground burst detonation, carried upward, and then deposited back on the ground decays very quickly. Harmful levels of radiation decrease rapidly over the first 24 hours and modeling of the shrinking footprint of the dangerous fallout zone will support safe, informed evacuation, and response efforts.

8. Electro Magnetic Pulse (EMP)

The *Federal Planning Guidance* defines EMP as "an electromagnetic field generated from the detonation that produces a high-voltage surge" (National Security Staff, 2010, p. 36). EMP does not present direct health effects to the public or emergency responders, but the high-voltage surge may cause potentially significant damage to electronics equipment, including power generating equipment, vehicles, computers, and communications devices. EMP effects are expected to be less with a surface burst than evidenced in the aerial bursts over Hiroshima and Nagasaki and directly opposite than the predicted larger fallout effects from a surface burst. Experts today, however, "do not understand how EMP will radiate outward from a ground level burst (with modern high-rise urban environments) and to what degree it will damage the electronic systems that permeate modern society" (National Security Staff, 2010, p. 36).

Researchers are working to further develop the EMP effects models to support planning efforts at all government levels. Current predictions lean toward limited EMP effects in a modern urban landscape from a ground level burst, blocked by building congestion and heights, extending out only a couple of miles. Electronics equipment outside of this area and those transported in after the detonation may function as expected, providing support systems such as communications towers, repeaters, and other key infrastructure is intact.

B. MODELING

Significant consequence modeling data, useful to researchers, policymakers, and emergency planners has been published in the past three years. Much of this effort comes from work sponsored by the U. S. Department of Homeland Security, the Homeland Security Council, and other federal agencies with responsibilities in the radiological and nuclear fields. A key to this productive research has been the coordinated effort among the various agencies and a core group of researchers, contracted from the national laboratories, that have contributed too many of the studies and projects. It has resulted in complimentary and supportive information, eliminating many of the conflicts that hampered previous, disparate studies. It has also included emergency planners and responders at all levels of government, creating an opportunity to make this information useful to and understood by, local agencies; the first line of defense responding to and recovering from a terrorist nuclear detonation.

1. Prompt Effects

Modeling of the prompt effects: blast, thermal, overpressure, and radiation for the 10 KT ground detonation significantly changes the Cold War perception of overwhelming devastation from a nuclear attack. It puts into perspective for planners, that although there will still be many fatalities and injuries and long-term recovery issues for health and the environment, there are many actions that can be effective in saving lives.

2. Damage Zones

Damage to the structures and injuries to exposed individuals in the areas surrounding a 10 KT detonation site were instrumental in identifying and defining four zones for planners and modelers. Figure 3, modeling work completed by Brooke Buddemeier in Lawrence Livermore National Laboratory depicts the severe, moderate, and light damage zones of prompt effects, and dangerous fallout zone of delayed effects based on a 10 KT ground burst detonation overlaid on a map of midtown Manhattan.

Figure 3. Severe, Moderate, Light Damage Zones Modeling (From Buddemeier, 2010)

It is said a picture is worth a thousand words, and this modeling view supports this statement. Describing in words that the inner ring, or severe damage zone (SDZ), is completely destroyed and the typical workday population of 80,000 people who will most certainly be fatalities paints a grim picture. Add to that the 600,000 people within the moderate damage zone (MDZ) who are deceased or seriously injured, many light weight constructed buildings destroyed, on fire, or severely damaged and over one million people within the light damage zone (LDZ) who may be injured by accidents, glass breakage, or frame buildings that have collapsed. These population figures are based on weekday figures that include residents, workers and visitors. This is truly a catastrophic emergency.

3. Delayed Effect Dangerous Fallout Zone

The dangerous fallout zone (DFZ) is depicted by the red contour in (Figure 4). It covers an area of Manhattan, a portion of the borough of Queens (possibly extending into

Nassau and Suffolk Counties on Long Island) and impacts several hundreds of thousands more citizens and responders. This modeling view shows more detailed information on the effects of low and high altitude winds and changes the Gaussian cigar-shaped plume models previously mentioned. The radiation levels within the DFZ develop within 15 minutes after detonation and reach expected levels in the several hundreds of R/Hr but decrease rapidly over time, changing the DFZ shape. Adding environmental data readings to the modeling as the incident progresses will tremendously assist federal resources and emergency responders in re-shaping the radiation footprint quickly. This will support decisions personnel in what areas should remain sheltered in place and which ones can be provided a safe, informed evacuation route.

The positive perspective that planners can glean from this modeling is that it identifies contaminated areas and can support safe response actions in those that are not. In this particular wind pattern, areas that are still functional include parts of southern Manhattan, upper Manhattan, and Brooklyn, a large portion of Queens, the Bronx, and Staten Island. There will be many emergency responders in these outer areas that will be available to support the missions of monitoring for the DFZ and initiating lifesaving actions from areas of safety.

In Figure 4, Brooke Buddemeier marked the locations of NYC fire stations and overlays them with the SDZ, MDZ, and DFZ. This modeling information provides great opportunity for field commanders to provide protective actions to specific fire companies based on levels of radiation in their location. The delayed effects of the fallout created by a ground level burst in the first two hours after detonation pose serious risks to emergency responders' health. Changes in initial response strategies can provide prevent many deaths and serious injuries.

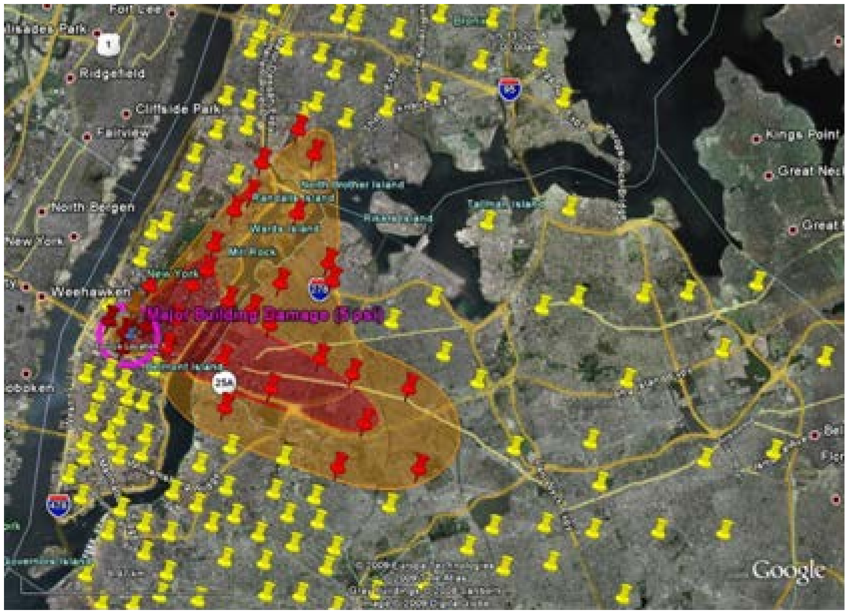

Figure 4. 10 KT Model in Midtown Manhattan with NYC Firehouse Locations (From Buddemeier, 2010)

4. Sheltering-in-Place

The *Federal Planning Guidance* states "the most effective life-saving opportunities for response officials in the first 60 minutes following a nuclear explosion will be the decision to safely shelter people in possible fallout areas" (National Security Staff, 2010, p. 14). Brooke Buddemeier and Dr. Sara Klucking used historical weather data for the fifteenth day of each month in 2006 to model the direction of the low and high altitude wind effect on fallout. The resulting plumes of the DFZ varied considerably and were observed in 360 degrees of direction. This makes pre-incident predictive modeling unreliable until actual weather data is integrated into the program. This unknown direction of dangerous fallout travel supports the recommendation of the *Federal Planning Guidance* to immediately shelter people after detonation (National Security Staff, 2010, p. 14).

Federal resources such as the "DHS led Interagency Modeling and Atmospheric Assessment Center (IMAAC) will begin to provide plume and fallout projections within fifteen minutes to one hour after detonation" (National Security Staff, 2010, p. 42). Supplemented by ground level readings detected and communicated by emergency responders from their fire stations or other adequate shelters, IMAAC maps will provide a more accurate radiation footprint from which to make life-saving decisions. One critical key to this life-saving opportunity recommended by the *Federal Planning Guidance* (National Security Staff, 2010) is a clear understanding that the guidance to shelter people includes emergency responders as well as residents and visitors. This will stop all responses to render aid to those injured and require a change in the publics' perception that help will be coming.

5. Incident Recognition

Research findings for a 10 KT ground level detonation will produce dangerous levels of fallout that can travel 10 to 20 miles or more and heavier particles will begin to fall within 15 minutes close to the detonation site. Lighter particles, traveling further, will take longer to return to the ground as radioactive fallout, or contamination. Emergency responders outside of their facilities working, or those assigned to respond to calls for assistance, must be trained to recognize the characteristics of a nuclear detonation. The traditional mushroom cloud may not be observed in urban environments with skyscrapers or low cloud weather conditions. The *Federal Planning Guidance* (National Security Staff, 2010) identifies observable conditions in infrastructure damage that can be used to recognize such an incident. The extent of damage and the possible loss of electronics equipment, including communications capabilities are indicators. Public service agencies should be providing radiation detectors to emergency responders and have policies in place requiring activation of these detectors for specific trigger events, such as a response to a report of an explosion. As soon as a nuclear incident is recognized, emergency responders must seek adequate shelter immediately to avoid serious to fatal exposures of radioactive fallout. Assisting the people that they encounter on the way to adequate shelter should be accomplished, but prolonged outside activity increases the risk to their own safety and will potentially hinder their ability to render aid in the longer response and recovery phases. First responders should plan to be inside adequate shelter within 15 minutes from detonation and remain there for a minimum of one to two hours, or until communications are established and informed evacuation routes are determined.

6. Adequate Shelter Protection Factors

During the Cold War years federal, state, and local government agencies identified safe fallout shelters and marked them with recognizable signs. The general public and emergency responders knew their locations and exercised “duck and cover” drills prior to moving toward designated shelters. Some shelters still exist, but younger generations of the public no longer are trained in the appropriate actions to take after a nuclear detonation. In addition, buildings have changed in construction design and materials used. Heavier weight construction techniques using brick and cement, offering good protective factors to those sheltered within, are no longer in use. Local emergency service agencies need to address informing responders (and the public) of the protective factors of their government facilities and that of current construction types in order to make informed decision on which buildings to take shelter in.

Several new documents and models provide updated building protective factor figures with information on shielding from the effects of radioactive fallout. Figure 5 is used by Brooke Buddemeier and Dr. Sara Klucking in their DHS Modeling of Tier I presentation and by the *Federal Planning Guidance* document (National Security Staff, 2010). This information on building types, height, and building materials used and their shielding factors should be included in local planning documents and training programs to support adequate shelter decisions. Other factors apply to supporting this decision and include, but are not limited to, condition of the building, fires and other imminent hazards nearby, proximity to current location, power and communications capabilities, etc.

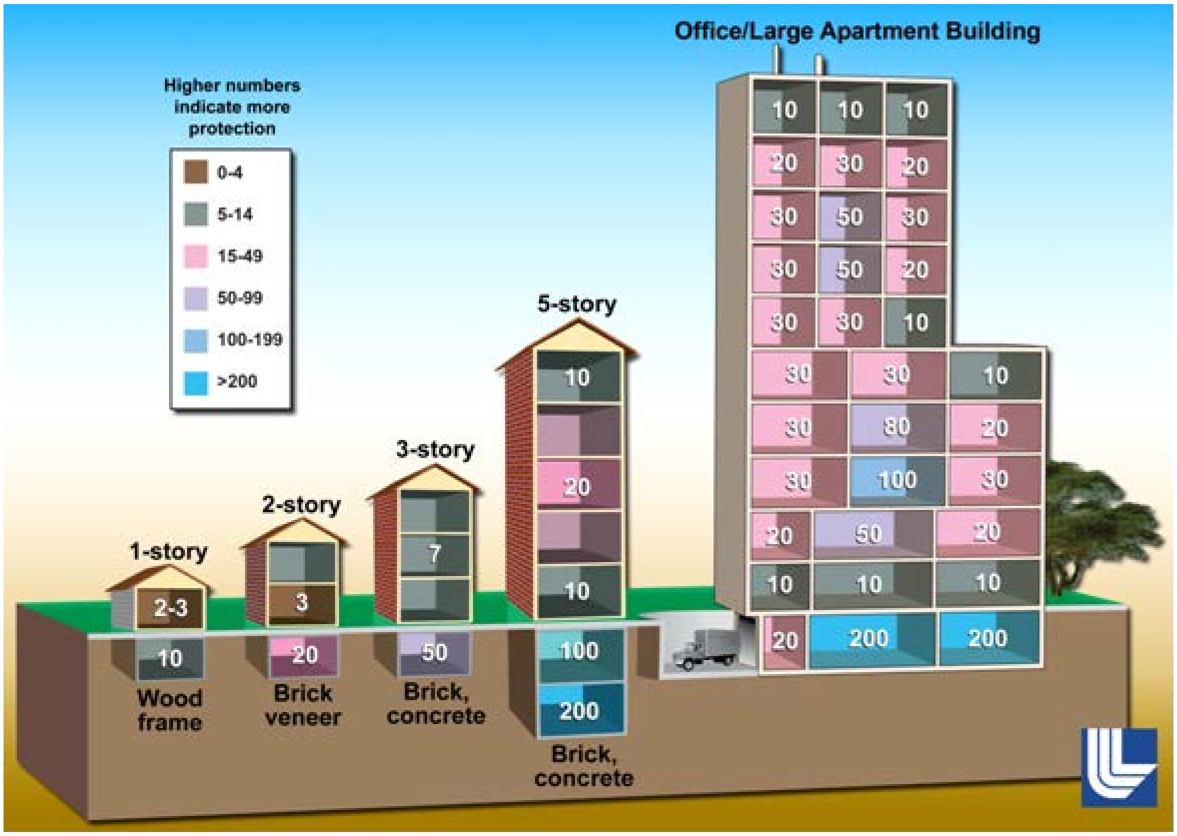

Figure 5. Building Protection Factors (From Buddemeier, 2009)

Additional pre-incident shelter work should be implemented by local planners to determine protective factors of government and emergency service facilities. Responders should know the shielding factors of their stations and if nearby structures are better, know to move to them within that 15-minute window prior to fallout arriving. Figures 6 and 7 are representative FDNY firehouse designs and estimate protection factors based on locations within the structures and building materials used.

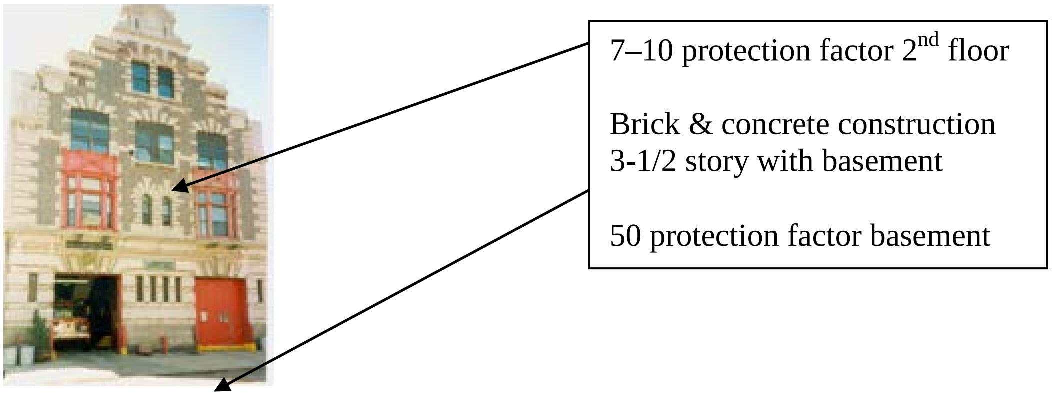

Figure 6. NYC Firehouse, Heavy Construction, 3-1/2 Stories. (From FDNY Mand Library Collection, 2010)

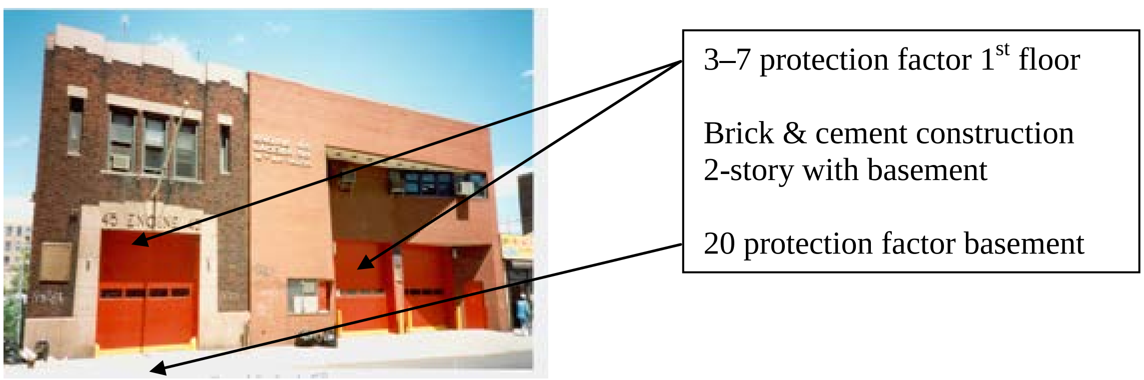

Figure 7. NYC Firehouse, Adjacent and Different Styles, 2-Story, (From FDNY Mand Library Collection, 2010)

7. Summary of Consequences Impacting Responders Immediately after Detonation

The research and modeling data clearly predict that there will be fatalities to emergency responders from the prompt effects of blast, thermal, and initial radiation hazards. These will occur mainly in the SDZ and MDZ but the potential for additional casualties in the LDZ from the prompt effects does exist and are unavoidable as they occur within the first minute or two. This does not allow protective actions to be implemented by responders working in these zones. Training responders to have an awareness of the indicators of a nuclear detonation in order to recognize it quickly is a critical pre-incident mission.

High levels of radioactive fallout are projected to begin within 15 to 20 minutes of the ground level improvised nuclear detonation and will continue from the blast site along the path of low and high altitude winds for hours to days. The potentially serious or fatal exposures that would occur to emergency responders unsheltered in that area can be avoided or significantly decreased with appropriate actions. Sheltering in place for a minimum of 60 minutes to two hours is strongly recommended in stable, safe structures until radiation levels can be monitored and mapped and informed evacuation routes identified. The sheltering time for emergency responders depends on several variables pointed out in modeling and research literature: the time it takes to model the DFZ using real time weather data, shelter conditions and protective factors, establishment of communications, information available, and monitoring capabilities for exposure rates and doses.

Although dramatically more catastrophic than an RDD or accidental release of radioactive material, an IND is survivable and manageable if comprehensive planning is completed up front, the public informed, and emergency responders trained to protect themselves and then coordinate an outside in response. Once communications capabilities are re-established, emergency operations centers functioning, the DFZ mapped and outside resources deploying, risk-based decisions with pre-determined exposure dose action guides will support optimization of emergency responders. It is the actions taken by emergency responders in the first two hours that can provide the benefit to their survival and long-term health.

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V. REVIEW OF CURRENT RESPONSE PLANS

At the time of this research, NYC does not have a response plan that specifically addresses managing and recovering from an improvised nuclear device detonation. Considered by many terrorism experts to be the number one or two, target city for terrorists, this has the potential for catastrophic results. NYC is not alone. A survey conducted by researchers working for DHS's Lessons Learned Information Sharing (LLIS) network in December of 2010 found only two local plans: White County, Arkansas and Ventura County, California. The state of Washington Department of Health, Office of Radiation completed an *Initial Response Planning for Improvised Nuclear Device Explosions* in 2007 and most recently, the state of Nevada completed a more extensive *Improvised Nuclear Device Operations Plan* in September 2010 in conjunction with the U. S. Department of Homeland Security, Federal Emergency Management Agency Region IX office. No Tier I Urban Area Security Initiative (UASI) city/region has completed a plan, comprehensive or not, for responding to and recovering from the consequences of a nuclear detonation. The city of Chicago is currently beginning this process, but it is still in the research phase. The following plan reviews will look at the current radiological response guidance provided to NYC emergency responders to protect themselves in the first 60 minutes to two hours from the exposure to radioactive fallout and existing IND plans for possible use as a template.

A. NYC RADIOLOGICAL RESPONSE AND RECOVERY PLAN HISTORY

Prior to September 11, 2001, NYC's Office of Emergency Management had completed a series of emergency response plans for chemical, biological, and radiological incidents. The chemical plan was exercised in 1997 in a drill titled "ICE" or Interagency Chemical Exercise. In 1998, city agencies tested the biological plan with the "BAD" tabletop exercise or Biological Agent Drill. Both of these plans have been updated, revised, and exercised since 9/11 with each agency developing specific plans to meet their mission responsibilities.

The Harbor Emergency Radiological Exercise (HERO) scheduled for 1999–2000 was never tested. The scenario included the use of an RDD on a vessel in NY Harbor but was cancelled due to conflicts in operational concepts. This plan remained "on the shelf" until 2003–2004 when an interagency committee was formed with federal grant funds to renew this effort for radiological planning. Close to completion in 2006, this effort was stopped and funding was transitioned into the new Domestic Nuclear Detection Office (DNDO).

NYC today does not have a completed and authorized citywide response plan for radiological emergencies that include accidental releases, intentional releases such as an RDD or dirty bomb, or an improvised nuclear detonation. Five key local agencies in NYC have primary and supportive roles in radiological emergencies, each having their own agency response plan that lacks the coordinating guidance of a citywide plan. A city plan goal would be to determine agency responsibilities, coordinate local resources, eliminate duplication and gaps, integrate regional, state and federal resources when needed and provide the best service to the public and protection to emergency responders. It can be exercised, evaluated, and improved upon.

In 2007, a NYC funded committee with representatives from the five key response agencies established the Radiological Response and Recovery Plan (RRRP) working group. As of January 2011, it remains an untested, unauthorized draft plan, although the main body of the document is close to completion. Several appendixes remain working projects but will benefit both RDD and IND planning efforts. These include: Shelter-in-Place guidance, Community Reception Center (CRC) and Re-occupancy plans, and several others.

The purpose of the RRRP includes:

> …developing operational guidance for NYC agencies to prepare for, conduct, and assess response and recovery activities following the release of radiological materials, describing agency roles and responsibilities in accordance with the Citywide Incident Management System (CIMS), and providing a framework for agency-specific plans, tactical manuals, exercises and training. (OEM, 2010)

The scope of the RRRP includes the release of radiological materials from accidental or deliberate causes including radiological dispersal devices (RDDs), dirty bombs, and radiological exposure devices (REDs) but does not include improvised nuclear devices.

The focus of this research is on protecting the emergency responders adjacent to the blast site from the serious or fatal delayed health effects resulting from exposure to the high levels of radiation from fallout that begins to occur within fifteen minutes of detonation. Response times for career, urban emergency responders averages in the range of five to seven minutes. If these responders are not trained to recognize the observable damage from a nuclear detonation, are not equipped with radiation alarming detectors, and do not seek immediate, adequate shelter within the first several minutes of operations, they potentially will be exposed to lethal levels of radiation. The NYC RRRP consists of 10 operational strategies: activation and implementation, life safety, site management, intelligence/investigations, public information, triage, treatment, and transport, decontamination and public screening, environmental assessment, public health protection, and, recovery and restoration.

1. RRRP Response Strategy

The activation and implementation strategy, strategy I, initiates a response to the location of the blast, which for an RDD will be much smaller than an IND and follows city wide and agency-specific improvised explosive device (IED) plans. All NYC Fire Department responders are assigned personal radiation detectors and are directed to confirm they are on any time they leave their station, especially if responding to a report of an explosion. Many New York Police Department (NYPD) officers, Department of Health personnel, members of the Department of Environmental Protection specialists and city emergency management personnel are assigned personal radiation alarming instruments and also directed to have them in the on position while on duty.

The RRRP informs responders to assess the scene, request additional resources, initiate life safety operations, and site management activities. They are to establish a hot zone boundary at a radiation exposure rate of two mR/hr, or up to 10mR/hr if the first boundary is too remote from the blast site and begin collecting environmental measurements. They are to facilitate evacuations, establish entry/egress control points, and establish a command element in a unified command post. All of these actions cause responders to remain unsheltered and unprotected from the high levels of radiation from fallout caused by a nuclear detonation that will descend while they are performing the plan strategy and tactical missions. If the first responders are beyond the 0.5 mile radius of the severe damage zone and beyond the 1.0 mile radius of the moderate damage zone, initial radiation from the blast may still be above the two to 10mR/hr exposure rate. Retreating to an area further away will still expose them to radioactive fallout if they are traveling the path of the plume.

The life safety, site management, intelligence/investigations, triage-treatment-transport, decontamination and public screening, environmental assessment, public health and recovery and restoration operational strategies provide good guidance for RDD incidents. These strategies can be incorporated into nuclear detonation plans but only safely after the coordinated local, state, and federal resources have identified the severe, moderate, least severe, and dangerous fallout zones. These RRRP strategies provide no guidance to protect emergency responders from the fallout during those first 60 minutes to two hours when the radiation zone is being developed. All of the strategies are designed to initiate response activities for a small explosives detonation with the release of radioactive materials.

2. Radiological Advisory Committee

During the implementation strategy the RRRP establishes the Radiological Advisory Committee, staffed with personnel knowledgeable in radiation concepts and plans. The primary mission of this committee is to provide technical guidance to the command element to protect emergency responders and the public from the harmful effects of radiation. It is expected that this committee will take up to 30 minutes or more to begin assembling, and one to two hours to gather field collected environmental measurement data and provide guidance, predicated on the fact that these designated representatives are still available. This time frame is again unacceptable for responder safety in the first 60 minutes to two hours after a nuclear detonation. The new research and federal guidance calls for the public sheltering-in-place prior to the fallout beginning its descent to the ground but falls short of stating that this must include emergency responders as well.

3. Public Messaging

The *Federal Planning Guidance* and NCRP Report 165 both recommend and provide suggested pre-scripted messaging for the general public that can be transmitted as soon after recognition that a nuclear detonation has occurred through whatever communications channels are still functioning (National Security Staff, 2010, p. 120; National Council on Radiation Protection & Measurements, 2011, p. 128). It does not make any distinction between the public and emergency responders and therefore lacks specific direction for responders to protect themselves. The RRRP has the same gap; providing annex material for public warnings, targeted outreach, specialized communications channels, press templates, and frequently asked questions for public information officers and officials. It does not provide pre-scripted messaging that directs the public and emergency responders to shelter-in-place as soon as a nuclear detonation is recognized.

4. RRRP Summary of Protection

The NYC RRRP as written does not provide guidance to adequately protect emergency responders from the briefly delayed fallout effects of a nuclear detonation. An RDD using explosive materials (dirty bomb) and nuclear detonations will cause fatalities and serious injuries from the prompt effects of the blast. These cannot be prevented by any plan for those unfortunate enough to be within the range of these effects. The RRRP provides good guidance for smaller RDD, dirty bomb, and RED incidents where radiation detection instruments will allow adequate warning of the radiation hazards associated with these devices and because of the smaller footprint, they will be more easily managed. It does not take into consideration the dangerous fallout hazard associated with a 10 KT ground level detonation and its delayed descent to the ground where responders will be operating to provide life safety missions and site management.

5. Future Plan Development

The intent of the RRRP committee is to complete the plan as scoped, addressing RDDs, dirty bombs, and REDs. Agency planners would use the plan to development agency-specific tactical plans to complete the responsibilities they are tasked with. Staff from the Office of Emergency Management (NYC-OEM) will assume a mission of incorporating the NYC Radiological Response and Recovery Plan into a UASI regional plan with New York and New Jersey state partners. The NYC committee members will proceed to develop an IND addendum or separate IND Response and Recovery Plan.

In April of 2010, the RRRP committee hosted DHS and Brooke Buddemeier from LLNL to present their latest modeling research describing the consequences of a 10 KT nuclear detonation on NYC's urban landscape. Subsequent work with DHS's Office of Health Affairs and FEMA's National Preparedness Directorate has supported initial planning activity, but a completed plan remains distant.

6. NYC Agency-Specific Plans

Five key agencies comprise NYC's emergency response group: FDNY, NYPD, Department of Health and Mental Hygiene, Department of Environmental Protection, and Office of Emergency Management. Each agency has strategic and tactical plans to address responsibilities from the consequences of an accidental or intentional (RDD, dirty bomb, RED) release of a hazardous material. All plans direct emergency responders to move toward the detonation site and initiate life-saving activities while protecting themselves from the hazards with appropriate protective equipment and deploying radiation monitoring instruments. No agency has yet addressed the scale of a nuclear detonation and the effects of radioactive fallout that require all responses around the blast site to stop and allow responders to protect themselves by sheltering in structurally safe facilities with adequate protection factors.

The current FDNY Radiological Operations Document was published in February of 2006. It contains background information on radiation as a training manual in addition to operational tactics found in a response plan. It introduces RDDs, REDs, radiological incendiary devices (RIDs) and INDs as specific types of radiological emergencies that responders can be faced with, but it makes only a small distinction in response strategies for INDs incident.

The plan instructs fire commanders to:

> …establish incident command according to CIMS and designate an Operations Chief to direct all search & rescue, structural evacuation, fire suppression, pre-hospital emergency medical care, Haz-Mat life safety and decontamination operations. It informs the field commander to consider security issues if the incident is intentionally initiated and locate the command post in a safe area out of the hazardous environment. (FDNY, 2006, p. 9)

In the event of a nuclear detonation, current guidance states:

> …radiation fallout from an IND does not occur for approximately 15 minutes after the detonation, units responding to an IND should not enter the area of the detonation for at least 15 minutes post-detonation when (the) presence of radiation can be detected and monitored. (FDNY, 2006, p. 11)

Accurate on the projected time frame for heavier fallout to begin descending near the blast site, it falls short of providing direct guidance to shelter against the dangerous levels of this radioactive fallout and misses entirely the fact that it will travel for miles with the high and low altitude winds, well beyond the blast site. It also disregards new planning guidance that identifies the moderate damage zone as the primary area to deploy rescue missions, where the most victims will require immediate assistance for life threatening but survivable injuries and exposures. The severe damage zone, nearest to the blast site, is not expected to have many survivors as a result of the prompt blast effects, would require large numbers of rescuers, and place too high a risk on them with little benefit. This zone should be given a low priority in initial phases of the operation. New plans must inform the responders that the path this fallout follows cannot be predicted on ground level wind direction alone and must be mapped by a combination of state and federal remote monitoring resources and ground level measurements before response routes are determined. Until that is completed with enough accuracy, plans and training should direct responders that are within two to three miles of the detonation site to find adequate shelter within 15 minutes, taking with them radiation measuring instruments and communications equipment.

FDNY Protective Actions Guides (PAGs) are more extensive than previous radiological operations documents and include a 50 Rem exposure as a new dose decision point for field commanders to use in the risk-benefit analysis for actions to save large populations in catastrophic emergencies. This is in addition to lower, five, 10 and 25 R dose decision points for property and smaller numbers of population groups. This new dose decision point was in consideration of the higher levels of radiation expected in some RDD and IND intentional releases. It informs the Operations Chief that they may need to adjust dose guidance for first responders based on the high number of lives at risk during a nuclear detonation versus the risk they would be willing to accept for an accidental transportation release with no lives at immediate risk. Responders in high benefit life saving missions may take higher dose risks before being removed from the radiation zone. The current document uses 50 Rem as a dose decision point for removal from the radiation hazard zone in this risk-based analysis, which would in fact rise higher due to continued exposure while exiting the area. Providing information in a new document with examples of risk-benefit decisions will give field commanders and responders better guidance in the dose decision point equations that will be associated with a nuclear detonation.

The current FDNY radiological operations document falls short of protecting emergency responders in the MDZ, LDZ, and DFZ during the first 60 minutes to two hours while the radiation hazard from fallout is mapped. No information is provided as to the levels of radiation that will be present in both initial and delayed fallout. There is no guidance as to how adequate shelter is defined, or for the protection factors relative to building design, construction, and materials used. The existing plan considers “sheltering-in-place a viable option if rapid evacuation is impeded and/or is not feasible” (FDNY, 2006, p. 12). RDDs have limited spread of radioactive material; they are dependent on the physical state of the material, amount of explosives, ground level winds, and other factors. There may only be damage to buildings and vehicles over a few square blocks, and it may be possible to rapidly evacuate in a safe direction. New DHS modeling for a 10 KT nuclear detonation projects initial radiation out to at least a mile from the blast site and fallout will travel tens of miles. Modelers anticipate hundreds of vehicular accidents caused by drivers suffering flash blindness and losing control. Buildings will be collapsed in all three damage zones depending on proximity and construction type. Evacuation routes will clearly be blocked leaving sheltering-in-place as the only viable option.

The present FDNY document further states, "sheltering-in-place may also be a viable option to protect civilians in nearby buildings if a plume is generated by the radiological release" (FDNY, 2006, p. 12). Models today realize that a ground level 10 KT nuclear detonation will create a cloud of dust, dirt, and debris that will be carried upward in the thermal column as high as five miles and then picked up by high altitude winds travel for many tens of miles as a plume. Until the footprint of this plume, the DFZ, is measured and mapped, all civilians and responders under it should be directed to find adequate shelter and remain there until radiation levels drop to safe levels or informed evacuation routes are communicated to them by knowledgeable resources.

In researching other NYC local plans, NYPD officials speaking off the record, state that they have not addressed this issue beyond viewing the federal DHS presentation of consequences. Their existing radiological patrol guide plan is more focused on LE detection and interdiction procedures for illicit materials. The concept of operations developed for the federal DHS DNDO Secure the Cities program, which NYPD is the host agency for NYC and lead principle partner, does include some protective actions for LE officers when dealing with suspicious materials. This limits actions of officers to levels of exposure based on their training and equipment assigned but does not address the consequences of a nuclear explosion, particularly the fallout dangers.

The NYC Department of Health and Mental Hygiene (DOHMH) developed a Radiation Emergency Operations Plan that is still in effect but undergoing changes to integrate internal incident command revisions developed in 2010. The stated purpose of the document is to address radiological and nuclear scenarios, but it is, in reality, similar to the FDNY plan and only specifically addresses the consequences of radiological incidents. It does not address shelter-in-place versus evacuation decisions for its own personnel to protect them against the dangerous fallout conditions of a 10 KT ground detonation.

B. U.S. IMPROVISED NUCLEAR DEVICE PLANS

Incidents provide high-level strategy for federal agencies with roles and responsibilities in the 15 Emergency Support Functions (ESF) (FEMA, 2009). The DHS Strategy for Improving the National Response and Recovery from an IND Attack (FOUO) lists seven capabilities that must be achieved to successfully manage an IND response: manage the response, characterize the incident, mass evacuation and/or in-place protection, medical triage, casualty and evacuee care, stabilize and control impacted area, perform site cleanup, and recovery and restore essential functions (DHS, 2010, p. 3). The document identifies specific objectives or tasks that must be completed for each capability to be achieved. All of these tasks require response to acquire situational awareness, collect environmental measurements, characterize the site (mapping), manage the public movement, etc. It is not until Annex A, page A-5, in Gap 3 that it states, "the most lifesaving action for both the public and first responders is to seek shelter for at least the first hour" (DHS, 2010, p. A-5). Until the footprint of the fallout created by the ground level detonation can be modeled at least remotely, preferably supplemented by actual field measurements, responders should remain sheltered if within two to three miles of the detonation site or in the DFZ. This gap is not receiving the attention it requires to change the perception of the public that a responder will arrive to help them, nor the mindset of response at all costs that most emergency responders have. Local resources in the attacked jurisdiction, or in adjacent ones but not affected, will be overwhelmed with those civilians who have self-evacuated. State resources will be hours out and the bulk of federal resources will be at least 72 hours from estimated arrival. If we do not plan to protect the immediately exposed local emergency responders, the attacked jurisdiction will lose a large capability to manage this incident in all phases of the incident.

1. Other Local Plans

Stated previously, searches for other existing local plans in large metropolitan cities for response to a nuclear detonation revealed a tremendous gap for this incident type. It was hoped that one or more comprehensive plans would be available to use as a template for analyzing existing radiological plans and determining their effectiveness in protecting responders from the consequences now available in models.

White County, Arkansas has an annex to its emergency operations plans for nuclear terrorism response. Planners considered four types of events in their planning; they include:

1. Dispersal of radioactive material other than plutonium and uranium,
2. Detonation of a conventional bomb salted with radioactive materials (plutonium, strontium, or other known radioactive isotope),
3. Detonation of an improvised nuclear explosive device, and
4. Detonation of a nuclear weapon. (White County, Arkansas Emergency Management, 2007, p. 1)

The concept that planners had for operations for all of these events centered on the resources of the federal government coming in and assuming all responsibility for managing the consequences from investigating the threat of a weapon or release to final recovery.

In regards to “first responders at the local and state government level, they will be responsible for carrying out their normal emergency responsibilities as defined in the White County EOP and state EOP” (White County, Arkansas Emergency Management, 2007, p. 1). Normal emergency operations call for responders to respond to the scene of the incident and perform law enforcement, fire service, and medical treatment missions. Planners in White County expect that local responders will in fact provide support to federal agencies that will manage the full response as well as provide their normal missions. They have not written strategic and tactical mission specifics for the local agencies that may be directly or indirectly involved. Experience shows this is more the norm with plans at the county, state, or federal level than not. Local officials should develop the planning details based on their available resources and hazard assessments.

The Arkansas County, however, does not provide protective action guidance for the safety and health of the responders against the hazards of the initial detonation, nor those of the fallout that will follow within minutes and probably is better equipped to develop this guidance than smaller local agencies.

Ventura County, California has viewed the consequences of a nuclear detonation from a different but very practical and realistic position. Adjacent to Los Angeles County, a Tier I UASI target city, Ventura County officials assessed Los Angeles as the target of an IND attack and developed their plan accordingly. They would be in a supportive role to Los Angeles but unable to provide mutual assistance in the early phase after detonation. They anticipate and plan for managing possible fallout hazards to limited areas of Ventura but realistically dealing with mass numbers of evacuees from Los Angeles, many of whom will be contaminated and/or injured.

The planners looked at and considered the effects to all critical infrastructure and population areas in need of assistance. A key mission identified by Ventura planners within the first three hours is to develop accurate plume maps and track the path of radioactive fallout. They expect to integrate this information into broadcasted public messaging and order initial protective actions including sheltering-in-place downwind in the DFZ within buildings with adequate protective factors. In fact, they plan to ask for predictive models of the plume location 6, 12, 18, and 24 hours out from the time of detonation to be ahead of public messaging, evacuation, and sheltering issues. The plan points out that in most situations, with structures out of the damage zones and not knowing the extent of the DFZ, sheltering-in-place for the citizens of Ventura County will be safer than evacuation

As already noted in the White County plan, county, state, and federal plans generally do not detail the actions that local government agencies will initiate. It is up to each local agency and jurisdiction to assess their capabilities for different incident types and plan accordingly. The Ventura County plan follows this pattern as well. Officials have made assumptions based on the detonation occurring in Los Angeles City, historical data on wind direction, the distance from Los Angeles City, and that limited areas of Ventura County will be impacted by fallout directly. This may have guided their decision to not specifically include a distinction that some Ventura County responders may be included in the general population that will be ordered to shelter-in-place to avoid exposures to dangerous fallout. The plan provides very good information on what provisions the public should consider when sheltering. It does fall short in specific guidance to emergency responders who must shelter in those DFZ areas including: the use of monitoring instruments, other PPE, and communications devices at a minimum in order to protect themselves and still provide a service to the overall management of the incident.

2. State Plans

The Washington State Department of Health, Office of Radiation Protection's Initial Response Planning for Improvised Nuclear Device Explosions is simply what it states; an initial attempt to recognize the consequences of an IND and inform state and local responders (2007). This report is not a response plan but can be helpful to local planners developing one. The authors recognize up front that "radiation fields from fallout are the primary source of radiation hazard following a nuclear explosion" (Office of Radiation Protection, 2007, p. 4). They further write "in the case of INDs, very high radiation doses and deterministic risks are likely and should represent the primary short-term concern for planners and responders" (Office of Radiation Protection, 2007, p. 5). The Washington State Health planners agree with the guidance to shelter until the dangerous fallout zone is known and the shelters are adequate to minimize exposure.

The planners do not detail how local responders will map the DFZ, nor do they mention there may be communications problems due to EMP and blast damage from the nuclear detonation. More importantly, as a state agency with technical expertise in radiation, they should be providing more specific guidance for emergency responders. Leaving them lumped as a group within the larger "public" guidance of sheltering for at least the first hour is not direct enough to change the "respond to everything" mindset of responders.

Nevada's Improvised Nuclear Device Operations Plan (FOUO) is well conceived and incorporates much of the new national guidance literature and modeling efforts to describe the consequences of a 10 KT nuclear detonation. It is a state plan that comprehensively provides tasking to state assets to support the urban areas of Nevada, particularly the densely populated areas of Las Vegas and Reno. It integrates federal assets into the state plan to fill gaps and considers the time frame for arrival of these resources once requested and authorized. As a state plan, it does not detail those decisions that must be determined at the local level, including initial action guidance for emergency responders. It does make critical assumptions that drive state actions; these include:

- Less than half of local responders will be available for initial response;
- The majority will be directly affected either self-evacuating or ***sheltering-in-place***;
- Local and state resources will be overwhelmed quickly; and
- That EMAC, mutual aid, and federal support is available to Nevada because there has been no second IND detonation in the country that would divert resources.

The Nevada plan's concept of operations has four phases: phase 0-prevention and preparedness, phase 1-coordination of threat information, phase 2-response (immediate, build-up, and sustained), and phase 3-recovery. From the point of view of guidance for emergency responders in the first 60-minutes to two hours, this plan is conflicting and does not provide adequate guidance to protect them. The plan recognizes the high radiation hazard associated with the fallout generated by the detonation and states, "the fallout pattern is highly dependent on weather conditions, with the most dangerous concentrations occurring within twenty miles downwind of the event" (Nevada Division of Emergency Management, 2010, p. 6). The plan lists nine response objectives, none of which includes "site characterization" or identifying the DFZ. In fact, there does not appear to be a state mission to map the DFZ; yet, sub-phase 2A, immediate response calls to "formulate a deployment plan based on the fallout pattern and available staging areas; activation of key teams and resources, immediate response of local first responders (emphasis added) and deployment of Rapid Reaction Forces." (Nevada Division of

Emergency Management, 2010, p. 9). Until the DFZ is initially mapped in that first hour (whether by local and state resources outside the immediate area, or federal resources, such as NARAC or IMAAC,) the local responders within two to three miles of the detonation site should shelter-in-place. Supportive of this statement, the plan states in Appendix 8 to Annex C, Assess and Protect, that "there will be a significant shortage of local radiological measuring equipment during an IND incident" (Nevada Division of Emergency Management, 2010, p. 1). Without radiological measuring instruments, local responders are best directed to shelter in facilities with adequate protective factors until communications can be established providing informed evacuation routes, or until the shelter's protective factor is exceeded exposing the responder to higher levels of radiation than would be received if they evacuated at that time.

C. INTERNATIONAL NUCLEAR DEVICE PLANS

In 2006, the International Atomic Energy Agency published their Manual for First Responders to a Radiological Emergency. The intent of the manual is to "assist member states to adopt relevant standards, procedures and tools, and underline the need to provide appropriate training for dealing with ionizing radiation during nuclear and radiological emergencies" (IAEA, 2006, Foreword). The document provides excellent guidance for first responders, and in fact their concept of operations identifies the first two priorities of first responder objectives as:

1. Promptly perform all reasonable actions to protect the public in order to minimize the radiological and non-radiological (e.g., psychological) health effects.
2. Protect emergency personnel during rescue operations.

They make it a priority to protect first responders and identify many of the actions necessary to successfully meet this objective. The actual body of the manual only addresses radiological emergencies including RDDs and unshielded sources. It does not address improvised nuclear devices and the immediate consequences and effects on emergency responders.

Research outside of the United States has been understandably challenging when requesting response plans from other nation states. Israel has been under threat from many fronts and from various weapons including the threat of nuclear terrorism. In his report, The Armageddon Scenario: Israel and the Threat of Nuclear Terrorism, Chuck Freilich, writing in April 2010 for the Begin-Sadat Center for Strategic Studies at Bar-llan University, states, “nuclear terrorism has not been a foremost priority to date” for Israeli officials (Freilich, 2010). Although Israel has lived under the threat of nuclear attack for many years, many senior officials believe that their retaliatory capability has kept nation state attacks in check. Nuclear terrorism is an emerging threat for many nations and one that has not been addressed. In a similar rationale to local officials in the United States who address local crime issues first and nuclear terrorism tomorrow, Mr. Freilich finds that Israeli officials have not focused on the dire consequences of nuclear terrorism, but instead, deal with the higher probability daily issues. He recommends the appointment of a senior official to lead and coordinate consequence management preparedness. Mr. Freilich points out that years of living under constant attack or the threat of attack has pre-conditioned Israeli emergency services and the public to react quickly to many scenario events. Building requirements for new construction including shelter areas within the structure and to store provisions support Israel’s preparedness planning effort for its citizens and responders.

Emergency service counterparts in the London Fire Brigade inform me that a nuclear detonation from an IND would be handled as a radiation incident, but on a huge scale. Similar to NYC, the London Fire Brigade has a plan for RDDs and dirty bombs supported by assignment of personal dosimeters for every on duty member and survey instruments on every apparatus. These instruments would be deployed during an RDD or dirty bomb incident to identify the hazard zones, protect responders and civilians, and guide risk-based decisions. The London Fire Brigade plan, like the NYC RRRP draft, directs a response to the blast site and does not provide guidance on the high-risk/low-benefit for rescue in the severe damage zone of an improvised nuclear detonation, nor the dangerous hazard of the fallout that will travel unpredictably to initial emergency responders until it is measured and mapped.

The LFB and NYC plans provide no guidance on the difference in affected areas between an RDD and an IND. Based on explosives work with dispersion of radiological materials, completed by Fred Harper and Steve Musolino (2006), the smaller footprint and affected area of the RDD or dirty bomb incident can be managed by existing plans and equipment. The larger area of an IND detonation will include large numbers of responders, equipment, and emergency facilities. Responders who survive the prompt blast effects in the severe, moderate, and light damage zones and attempt to respond or evacuate instead of seeking adequate shelter may be exposed to dangerous levels of radiation from the descending fallout.

Harper and Musolino's RDD work estimates potentially high levels of radiation, particularly from deposited ground shine (depending on the strength of the source), but the low altitude plume depositing the contamination would be past the detonation site within 10–15 minutes. This is very different from IND models that suggest fallout will not begin until approximately 15 minutes after detonation or at the same time as responders would be arriving if not sheltering-in-place.

London Fire Brigade counterparts agree that the consequences of an IND, particularly the effects of the fallout and much larger area of hazards, will require a re-evaluation of current planned actions. A protective sheltering posture combined with environmental measurements data collection may be required to identify safe response routes into the moderate damage zone and provide an informed evacuation route out to those civilians and responders within the high hazard zones.

D. PLAN ANALYSIS SUMMARY

My research for this report, in parallel with similar efforts by FEMA personnel working in the Lessons Learned program, found no completed IND plans for Tier I, UASI target cities and very little planning work at the local level in progress. The few available are at the federal, state, and county levels and do not include detailed procedures for protecting local emergency responders against the effects of the radioactive fallout. Radiological response plans in place for accidental releases and RDDs follow traditional emergency plans and direct an emergency response into the affected area. Prompt blast effects from these incidents including RDDs are observable and the hazard area relatively small compared to an IND. The radiation disseminated by an RDD is spread primarily by the device and low altitude ground winds and have already dropped to the ground prior to the arrival of most responders. Buddemeier, Klucking and Blue, in their presentation *Modeling Improvised Nuclear Device (IND) Impacts to Tier I UASI Cities*, project that fallout produced by a ground level nuclear detonation will begin to fall 15–20 minutes after the blast (DHS-OHA, 2009, slide 61). This will occur shortly after average response times of responders, placing them on scene and in the hazard zone and exposed to potentially fatal doses.

New federal planning guidance falls short of informing local key leaders and planners about the hazards to responders and the need to protect them from serious exposure to the fallout hazard. Language that informs local leaders to message the public to shelter-in-place and does not include separate, clear sheltering guidance for emergency responders in the plan is not strong enough. Responders within two to three miles of the detonation site should be directed to shelter-in-place within a shelter that has an adequate protection factor for a minimum of one hour or until the DFZ can be mapped to protect them when evacuating the facility or responding.

Federal efforts to support local planning activities are beginning. NYC, LA, Washington, D.C., Houston, Boston, and several other Tier I UASI cities have received presentations on the latest modeling but budget deficits, staffing shortages, and a lack of urgency because of the sense of low probability have not advanced planning efforts enough. Recent federal efforts to support planning activities in Chicago show promise and, if completed, will become a template for other large urban cities; however, budget cuts now coming to light in the FY11 federal budget may stall this necessary effort.

A new FEMA effort to develop a training program to better inform key leaders at the local and state level of the consequences of the prompt effects of an improvised nuclear detonation, including radioactive fallout and the actions necessary to protect the public and responders has promise. The program is intended to be available online to reach a broad audience quickly, and work group participants are advocating strongly for detailed guidance to inform local leaders of the risk in delaying planning efforts to both the public and the emergency responder community. This effort may also suffer FY11 budget cuts, leaving local leaders and planners without the necessary federal support.

Pre-incident public disaster information programs must include practical guidance on protective actions. Responder training programs must be a part of this planning process and include information on the consequences and risks posed to them from a nuclear detonation. They require the knowledge and capability to determine adequate shelters with high protection factors, detection equipment to monitor exposure levels, communications equipment to implement environmental data information sharing efforts including mapping, and the strategic value of delayed and informed outside-in response after initial sheltering and zone determination.

Existing NYC and other UASI Tier I cities' radiological incident response plans fall short of providing the necessary guidance to protect emergency responders from the hazards of high radiation levels produced by a nuclear detonation and the subsequent fallout.

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VI. GAPS, RECOMMENDATIONS, AND FUTURE RESEARCH

Existing radiological plans at the local level, and IND plans at the county, state, and federal levels do not provide adequate guidance to protect emergency responders from the immediate effects of an improvised nuclear detonation in a large urban area such as NYC. Lacking specific guidance, many more emergency responders will be injured or killed in the first one to two hours implementing current radiological plans after a nuclear detonation than should be. This will have long lasting consequences in overall management of the incident and recovery for the city or urban area affected.

Recognizing that there are many intermediate and long-term consequences that emergency responders at all government levels must plan for, this research focused primarily on whether existing guidance protected them from the initial prompt effects of a nuclear detonation. New modeling and guidance at the federal research level identify prompt effects associated with the detonation: blast pressures, thermal radiation, flash blindness, and initial radiation, both prompt and residual fallout.

Blast, thermal, and flash blindness effects from a nuclear detonation are severe, cover an area much larger than traditional explosives or dirty bombs, and will injure or kill thousands of people including emergency responders within the damage zones. These effects will be instantaneous and devastating but only last for seconds to a couple of minutes, depending on the distance from the detonation site. Secondary effects from collapsing buildings and fires will continue for a much longer period of time, but by themselves they can be safely managed by emergency plans addressing them.

The potentially catastrophic effects of the high levels of initial radiation and subsequent fallout from a terrorist detonation of an improvised nuclear device in NYC or other local Tier I UASI target city demands a comprehensive plan to protect the public ***and*** emergency responder communities by providing clear guidance to those who survive the initial prompt blast effects. New York and other target city leaders, and consequently local agency planners, have not placed the necessary emphasis on developing such a plan 10 years after the attacks on September 11, 2001.

A. GAPS

Analyzing the current information on the consequences of a nuclear detonation and federal planning documents with existing local response plans for radiological and nuclear emergencies identifies the following gaps in protecting emergency responders from the immediate consequences of a nuclear detonation:

1. No major city in the U.S. has a comprehensive improvised nuclear detonation response and recovery plan. State plans are not detailed enough with actions to protect local emergency responders in the first two hours. International planning for this scenario appears to have a similar gap and does not provide a possible template.

2. Key local leaders have not prioritized development of an IND Response and Recovery Plan. They may not be fully aware of the consequences of a nuclear detonation in a densely populated U.S. city or limited funding has prevented them from doing so. They must be informed of the consequences, the different strategies necessary to protect emergency responders and the public and the necessary actions to be implemented. Federal programs and funding support are necessary to provide the emphasis to local key leaders.

3. Current radiological response plans in NYC and other U.S. cities do not provide the strategy and tactics necessary to protect emergency responders from the early consequences of a nuclear detonation, specifically the fallout hazard. In fact current plans direct responders to deploy to the seat of explosion, directly exposing them to the radiation hazard of the fallout.

4. Decreasing federal grants and budget deficits at the state and local levels will place higher emphasis on more likely disaster scenarios despite the high potential consequences of being unprepared for a nuclear detonation.

5. Federal guidance on the need to shelter-in-place to protect oneself from the dangerous hazards of the radioactive fallout does not emphasize that emergency responders are included in the public message to shelter.

6. Pre-incident planning information for nuclear detonation preparedness and public messaging on self-protective actions have not been posted to most local, state and federal all-hazard readiness sites. Officials have questioned how to post this information without misleading the public into thinking that a nuclear detonation is imminent. Without pre-incident protective actions available, large numbers of the public will be unaware of the need to shelter quickly. This will unnecessarily expose them to the harmful radioactive fallout and increase the risk to emergency responders who feel compelled to assist them instead of sheltering themselves.

7. Building protection factors critical to safely sheltering-in-place must be developed and emergency responders trained in determining the factors

for public facilities and private buildings that may become a shelter for them during normal outside activities in the first two hours or more.

8. Emergency responders are not trained to recognize the signs of a nuclear neither detonation nor do they understand the hazards of radioactive fallout to them when deploying into the physical damage zones and within the dangerous fallout plume.

9. The full negative effects of the electro-magnetic pulse to the communications and electronic equipment of emergency responders is not known. Loss of this equipment may affect public messaging, responder accountability, command and control issues, electronic monitoring of radiation levels, interagency information sharing, building systems including fire protection equipment and other critical resources in those first two hours.

Intermediate and long-term response and recovery gaps exist as well. They will not be addressed here but include: integration of federal and state resources into local incident management systems, long-term health and environmental monitoring issues, re-occupancy of residences and businesses, extended sheltering provisions, re-establishment of local government functions, restoration of utilities and services, fatality management, and many others. Some components of long-term recovery planning from natural disasters will be transferrable to the capabilities necessary to recover from a nuclear detonation, others will be unique.

B. RECOMMENDATIONS

1. Recommendation: Comprehensive IND Response and Recovery Plan

With international concerns to prevent nuclear materials from falling into the hands of terrorists or groups growing due to instability in nation states with nuclear programs and the proliferation of black market availability of nuclear materials, the earlier low probability views are changing. Still lower than the probability of other WMD threats, a new emphasis on planning for the possibility of an IND remains a serious gap. A comprehensive plan for response to a nuclear detonation in every major metropolitan city must be developed, trained on, exercised, and maintained current with changing conditions and technologies. NYC and other Tier I UASI cities considered to be primary targets of terrorist organizations that do not have an IND response and recovery plan are particularly at risk.

A comprehensive nuclear response plan may take a year or longer to complete in every city because of the complexities and differences in resources, government structures, and funding. I propose a two-phase approach to developing this capability: Phase I to protect emergency responders from the immediate effects of fallout in the early phase of nuclear detonation response operations, and phase II to successfully manage the events of the early, intermediate, and long-term stages of response and recovery operations by completing a comprehensive plan at the local level.

a. Phase I

Phase I would require NYC planners and those in other Tier I UASI cities to address the unique hazards to emergency responders from the initial prompt effects in the moderate and severe damage zones and from the radioactive fallout. The following actions should be developed and implemented quickly:

> i. Emergency Response Strategy Change.
>
> A response strategy change must be drafted that directs all responses into the damage zones (one to two miles from the blast site) to cease within 15 minutes of the detonation.
>
> ii. Recognizing a Nuclear Detonation.
>
> Emergency responders must be trained to recognize a nuclear detonation quickly enough to protect themselves and others by implementing protective actions such as sheltering. Training programs need to be developed and delivered that provides them the knowledge to identify the characteristics of a nuclear detonation and understand the critical importance to share that information through whatever communications channels are available.
>
> iii. Emergency Responder Sheltering within the Damage and Fallout Zones.
>
> All responders must be trained in the new response strategy for a nuclear detonation. This training must include the knowledge that if they have survived the prompt blast effects and are within the severe, moderate and light damage zones (out to two miles from the blast site) they must seek adequate shelter before the fallout descends as soon as 20 minutes after the blast.

iv. Protection Factors of Public Facilities.

Emergency service agencies should determine the protective factor of all their facilities and instruct all personnel assigned to them with this information. Responders in facilities with poor protection factors should be trained to identify shelters with higher protection factors in their response areas as alternatives.

v. Radiation Detection Equipment.

Emergency response vehicles and emergency responders should have radiation equipment available, either mounted on the vehicle or portable and carried. This capability is critical in providing them protection against the radiation hazards of dirty bombs and nuclear detonation fallout. If funding is too limited to equip every member, every emergency response vehicle should be equipped with radiation monitoring instruments. At a minimum, enough should be distributed geographically throughout a city to provide adequate protection and warning.

vi. Emergency Responder Actions when Sheltering-in-Place.

Emergency responders must be trained to deploy radiation detection instruments and communications equipment with them into the shelter to monitor their surroundings and share readings, personnel status and a situational awareness with the next level of command that can be established.

vii. Emergency Responder Actions outside the Damage and Fallout Zones.

Emergency responders outside the damage zones must be trained to deploy radiation detection instruments and communicate readings. All responders must understand that collecting environmental data and communicating it through their agency chain of command will be critical in mapping the fallout plume and identifying the dangerous fallout zone. This will be a positive action to protect them, support those sheltering inside the zones and protect those who self-evacuate without being informed of safe routes.

viii. Early Unified Command Post or Operations Center.

A unified command post (UCP) or operations center must be established early and outside of the damage and fallout zones to successfully and safely manage this type of emergency. Collecting, sharing, and mapping the radiation levels at this facility between local agencies and integration later with state and federal plume information will support the determination of informed evacuation routes and safe areas of response from outside emergency responders.

A current DHS/FEMA effort in the city of Chicago and the National Capital Region (NCR) provides a starting point. Federal emergency officials in DHS/FEMA realize the necessity to provide a stronger guidance structure to support cities that want to develop IND response plans after having observed the federally funded presentation on "Modeling the Consequences of a 10 KT Nuclear Detonation in a Tier I UASI City" (Buddemeier, Klucking, & Blue, 2009). The city of Chicago started its planning effort in late fall of 2010. The NCR began in April 2011. NYC should begin this effort quickly as it is a major target of terrorists.

The NCR effort drafted a six-month timeline for a requirements assessment. The objective is to determine the necessary capabilities for response and recovery from a nuclear detonation. It is based on the DHS *Strategy for Improving the National Response and Recovery from an IND Attack* released in April 2010. This document breaks down IND response planning activities into seven manageable capabilities, each with supporting objectives. During the six months of workshops the participants will view briefings and technical reports that evaluate potential courses of action available to emergency officials during the initial seventy-two hours after a nuclear detonation. This 72-hour framework represents the expected response time of federal resources that are requested and deployed to support local and state operations and will certainly address the serious gaps in the current strategies that do not protect local emergency responders in the first two hours after a nuclear detonation.

b. Phase II

Phase II would be development of a full comprehensive plan to define those capabilities necessary to respond to, mitigate, and recover from an improvised nuclear detonation during early, intermediate, and long-term operational phases and assign them to the appropriate local agency. It can and should be done simultaneously with phase I and incorporate the protective actions developed and implemented from that effort.

This phase may take an additional six months or more to complete with participation from every local and state agency with responsibility, facilitated by knowledgeable federal subject matter experts. I am basing this on my own 15 years of planning experience with the FDNY and working with dozens of local agency representatives in NYC. In addition, the complexity of issues such as re-occupancy of residences and businesses, long-term health concerns, environmental clean-up, legal issues, and others will require much thought and do not have a lot of historic data to support the effort. New research in these areas will come from the nuclear plant disaster in Japan as local, state, and federal experts who worked there return with data collected and the effectiveness of tactics implemented. Continuing studies from the Chernobyl accident conducted over the past 25 years, including those on long-term effects on the people, plant, and animal communities exposed, should prove to be helpful in the recovery phase of the planning process.

This two-phase process should be replicated in each of the Tier I UASI cities with the same federal support and funding. The process time frames will shorten with each city as they are able to use earlier plan templates to speed up the learning process.

2. Recommendation: Informing Key Leaders

The fact that not one U.S. city has developed a comprehensive IND response and recovery plan 10 years after 9-11 attests to the low prioritization assigned to this effort by key local leaders. With state resources not arriving until several hours after a detonation and federal resources taking up to several days to arrive, it will be the actions implemented by local emergency responders that will have the most immediate effect on protecting the public and their own emergency responders. Key local leaders must address this planning gap and place a high priority on IND Response and Recovery plan development. New consequence research, threat analysis, planning guidance, messaging information, and funding support must be made available to them to accomplish this quickly and effectively.

DHS/FEMA and other federal agencies have been working for several years now to conduct modeling research, develop IND response guidance, develop public information and messaging, and monitor the accessibility of nuclear material to terrorists and work to prevent this from happening, but it often appears to be haphazard and without a high level strategic plan. The nuclear and intelligence communities provide threat matrixes to the president and other federal agencies, but it is often not passed on to local leaders or linked to other federal activities. The Domestic Nuclear Detection Office works primarily with law enforcement agencies to prevent, detect, and interdict nuclear materials but often in a vacuum from other federal, state, and local response agencies. The DHS Office of Health Affairs arranged public focus groups to better understand the public's base level of radiation knowledge in order to develop messaging for pre- and post-incident three years ago. Nothing was ever released to the public or to many local and state agencies. In the past 12 months, DHS/FEMA and the EPA conducted new public awareness sessions in several cities across the U.S. In NYC, most local agencies were not even made aware that a public focus group occurred until after it was completed.

I would recommend a federal task force be organized and managed by DHS/FEMA with its main goal to support development of IND Response and Recovery plans in each of the Tier I UASI cities with a completion date of no more than three years. The task force would have the budget to complete the project and the authority to utilize the subject matter experts from each of the federal agencies working the disparate programs now. The Tier I cities would be prioritized by both target potential and what information they have already received. For example, Chicago and the NCR may be at the top of the list because they have programs already under way.

The steps in this program should include at a minimum:

1. A high-level briefing from DHS Intel and Analysis to the mayor, city manager, and agency heads in each of the target cities in the listed order. This would build into the program scheduling flexibility allowing use of the same briefing staff in each city. The goal will be to build awareness of the risk assessed by the intelligence community for an improvised nuclear device detonation or radiological dirty bomb.
2. Federal funding to each Tier I city dedicated to assign personnel from every local agency to the planning process without impacting daily operations and shrinking staffs. A copy of every DHS funded report with radiological and nuclear information developed in the last five years

should be provided electronically to each city team. It should not be up to the local team to develop this research list alone.

3. A briefing to the key leaders and local planning team members by DHS representatives detailing the modeled consequences produced by the detonation of a 10 KT improvised nuclear device in a major metropolitan city. The goal here will be to define the challenges that will be faced by the emergency service communities and local officials.

4. A presentation and facilitated discussion by a team consisting of authors of the June 2010 federal *Planning Guidance for Response to a Nuclear Detonation* (National Security Staff, 2010), to the local planning teams. This will introduce the capabilities and tasks that must be addressed by local, state, and federal resources to protect the public and emergency responders.

5. A task force team consisting of a representative from each federal agency having any responsibility to support local and state governments in a radiological or nuclear event that will provide a briefing of their agency capabilities, timelines, and a single point of contact for follow-up support during the plan development.

6. A DHS representative assigned to each of the Tier I cities who will support all activities, facilitate requests for information to all federal agencies point of contact identified in point 5, and provide status updates to DHS/FEMA officials.

7. A task force team consisting of DHS/FEMA and EPA personnel who have worked on the radiation knowledge assessment, pre-incident public information campaign, and post-incident pre-scripted messages will brief and provide support to local key leaders, planners, and public information officers. DHS funded projects such as NCRP report 165, FEMA/EPA draft info-scripts, and others providing messaging information should be provided as stated in point 2.

8. A DHS/FEMA Homeland Security Information Network (HSIN) community of practice site can be developed for Tier I planning groups to share information and expedite the learning curve with each succeeding city.

9. Templates of the first plans completed can be made generic and provided to Tier II or medium sized cities to support plan development there as well as build regional capabilities through standardization.

10. A new DHS/FEMA effort to develop an on-line awareness and operations training Course titled IND Response Training for Key Leaders should continue. The use of this program to share IND information to Tier II city leaders and planners may be a good way to transition from the task force teams used in Tier I cities back to their regular agency assignments while still providing necessary information to local planners. Lessons learned

from the Tier I city planning groups can be incorporated into the on-line training making it more effective and current.

11. National Level Exercises (NLE) can be developed from the completed plans, funded by DHS and after action reports with lessons learned shared through the HSIN community of practice and/or lessons learned site.

3. Recommendation: NYC Draft Radiological Response Plan

NYC leaders have not finalized their draft *Radiological Response and Recovery Plan* (RRRP) that includes the strategy for RDDs. Other Tier I cities do not have a completed RDD response and recovery plan either. Completion of the NYC plan and others would provide guidance for local emergency responders in an RDD attack and some capabilities will carry over into supporting an IND plan. The NYC RRRP has been in development for almost four years. Some of the delay has been caused by a gap in coordinating funding at the federal level—providing prevention funding but only limited response mission support—but NYC leaders share in this responsibility by not pushing for completion. Professing NYC's high target risk at the same time city leaders are not emphasizing plan development is contradictory and should be corrected. Key city agency officials should address the remaining plan issues, finalize the plan, and move toward agency training programs and interagency exercises.

Although this is a necessary step, it will not provide adequate guidance for emergency responders after a nuclear detonation. New modeling of a nuclear detonation in a major urban environment has significant differences in consequences than those previously planned for as a result of an RDD or dirty bomb.

Blast effects including tremendous overpressure from a 10 KT IND are expected to extend out over one mile from the detonation site, varying with building construction, number of buildings, weather, and other factors. An RDD will only impact several blocks depending on many factors. The crater created by the nuclear detonation will sever natural gas and utility lines creating additional hazards more numerous than an RDD. Secondary collapse of damaged and unstable buildings can occur with both types of incidents but will be much more extensive and widespread with an IND.

Thermal effects from a 10 KT nuclear detonation can potentially cause second degree burns to those outside and in line of sight of the explosion. Severe initial ionizing radiation exposure is possible from a nuclear detonation. Brooke Buddemeier in his work, *Reducing the Consequences of a Nuclear Detonation*, estimates that both the thermal and ionizing radiation effects will extend possibly to the outer edge of the moderate damage zone, or 1 mile from the blast site (2007, p. 3). These effects are much greater than what is expected from an RDD or dirty bomb.

A RDD or dirty bomb will create a plume of radioactive material different from the radioactive fallout that results from a nuclear detonation. The RDD utilizes a conventional explosive to disperse radiological or nuclear materials. The blast pressure and thermal energy created by the explosive will push the material out and away from the RDD detonation site. The distance the RDD plume will travel depends on the type of isotope, its physical state, the quantity of the radioactive material, and explosive charge and mainly low altitude winds that can swirl in urban canyons. It will be far less than that modeled for a nuclear detonation, where the thermal updraft can reach several miles in height and be carried by low and high altitude winds. The ground level nuclear detonation also creates radioactive fallout from the dirt, dust, and debris picked up as a result of the tremendous explosive force. The IND fallout is much larger in quantity because the explosive force creates particles that become radioactive and does not simply disperse the initial radioactive material within the device. Both the RDD plume and the IND fallout will impact the emergency responders during their response mode, but the RDD effect will be significantly smaller in size, levels of radiation, and duration.

4. Recommendation: Emergency Responder Sheltering

New guidance documents must clarify that sheltering-in-place after a nuclear detonation to protect against the radioactive fallout is for both the public and emergency responders, particularly within the one to two mile zone surrounding the blast site. We cannot accept ambiguous or grey language for this action. Too many responders will be severely or fatally exposed to high levels of radiation.

Local planning tactics should be developed to provide guidance for responders in those 15 to 20 minutes after detonation while preparing to shelter-in-place. They may include:

1. Monitoring radiation levels and establishing agency communications
2. Selecting adequate shelter locations for themselves and the nearby public
3. Assisting those injured and in need
4. Gathering situational awareness of building conditions, fires, other hazards nearby, personnel accountability, equipment readiness, etc.
5. Communication of this information internally within their local agency, and then shared at the unified command post or operations center. General awareness conditions will support damage and dangerous fallout zones assessments and identifications. This in turn will support decisions on informed evacuations, safe response routes, staging areas, community reception areas, mobile field hospitals, etc.
6. Actions that can be assigned to emergency responders outside the damage and dangerous fallout zone to establish the emergency facilities identified in point 5 that will provide services to the public evacuating and manage the emergency.

5. Recommendation: Adequate Shelter Guidance

DHS/FEMA focus group results of questions posed to the public find that many citizens no longer are familiar with the sheltering programs developed during the Cold War. Public pre-incident information must include guidance on the need to shelter, length of sheltering time factors and what types of buildings provide the best protection. Emergency responders today lack this knowledge and must be informed as well. Some recommended actions that I would include:

1. FEMA and local officials should revisit old fallout shelter lists. These sites should be inspected and the list made current. Building owners should be made aware of the shelter and maintain its use for building occupants.
2. NYC Local Law 26 requires high-rise commercial office buildings to develop Emergency Action Plans (EAP) for all hazards. A requirement of the EAP calls for identification of a shelter location within the building. This location should be reviewed during initial filing or in subsequent renewals for adequate protection factors against exposure to radiation from fallout. Similar laws can be researched for other types of building occupancies and in other municipalities.

3. Federal research on construction types designed since Cold War fallout shelters were identified can be updated further and shared with local city emergency managers. This information can be posted on "Ready.gov" sites for access by the general public for private residences along with guidance on what supplies should be available for the shelter.

4. Public agencies should be required to utilize current federal research to identify the protection factors of all public facilities and shelter locations within them. This must include emergency response facilities and the responders trained in identifying the safest locations within their stations and all structures.

5. Task force members briefing local leaders and planners can include research on building protection factors in general and for building designs that may be unique to that geographic area of the country.

6. Recommendation: Emergency Responder Training to Recognize a Nuclear Detonation

A key component to protecting emergency responders in NYC and other cities from the radioactive fallout hazard will be recognizing that a nuclear detonation has occurred. Modelers of nuclear detonations in urban environments are not certain that the "mushroom cloud" most people identify with a nuclear detonation may not be visible because of the blocking effect of high-rise structures in a major Tier I UASI city and combined with possible cloud conditions and the weather. All of effects of a nuclear detonation found in the modeling and recent guidance documents must be incorporated into responder training and public information programs. Key for responder programs are the descriptions of building damage and injuries to those in the severe, moderate, and light damage zones found in the federal *Planning Guidance for Response to a Nuclear Detonation* (National Security Staff, 2010, pp. 44–47). This information and training will support early recognition of the nuclear detonation allowing emergency responders to communicate this information to other responders and the public and the direction to shelter against the radioactive fallout.

7. Recommendation: Post-Incident Messaging

Emergency responders (and the public) need to be notified by any and all means available that a nuclear detonation has or may have occurred as soon as it is recognized. Cue cards and/or pre-scripted messages directing responders and the public to seek immediate and adequate shelter must be activated quickly utilizing multimedia channels; TV, radio, social media sites, texting, e-alert groups, etc. These messages should include directions for public and emergency responders to seek adequate shelter immediately and wait for information from officials. Responder missions and tasks that must be initiated while sheltering that will support incident management and personal survival can be communicated to personnel. Self-help messages for the public that include information on conditions, first aid, informed evacuations, locations of community reception centers, and other critical information to keep them safe until responders can safely reach them should be developed and ready to transmit.

The Planning Guidance for Response to a Nuclear Detonation document (National Security Staff, 2010, pp. 120–121), NCRP Report 165 (National Council on Radiation Protection and Measurements, 2010, pp. 124–128), and others include sample messages that local planners, emergency managers, and public information officers can work with to write pre-incident messages designed for their local conditions and officials.

C. FUTURE RESEARCH

Federal government agencies, national laboratories, and academia have provided troves of new information the past five years on modeling consequences, equipment, detection standards, treatment, and response guidance for a nuclear detonation. Still, we require more research and funding to develop capabilities and become more resilient as local, state, tribal, and national communities. Some detail is provided below in three critical areas of concern to the subject of protecting emergency responders in the first two hours: EMP, environmental mapping of collected radiation data points, and responder dose guidance for short- and long-term exposure effects. Other areas include but not limited to: effective public information programs, pre- and post-incident public messaging, more effective plume modeling in urban environments, protection factors of new lightweight building construction, and future work restrictions on emergency responders who are exposed to higher levels of radiation in life saving missions. This will require a long-term commitment in research and funding to continue to build our capabilities to manage a terrorist nuclear detonation. The good news is that this research will provide better preparedness in nuclear plant emergencies such as the recent Japanese Tokyo Electrics' Fukushima Dai-ichi plant.

1. Electro Magnetic Pulse

Research on the expected effects of EMP on electronics equipment from a ground-level nuclear detonation and the extent it will travel is largely unknown. Distances range from one mile to several from the detonation site and damage ranges from complete destruction to only those electronics that are "on" and operating. The damage that does result though is expected to occur within the first minute or two after the detonation. The resulting damage will be determined by emergency responders as they begin to react and implement response plans. This is not an expected effect from an RDD or dirty bomb.

Additional research at the federal level on the full range of effects of EMP on electronics equipment should be a priority project and funded sufficiently to produce results quickly. The results of this research can positively support current planning efforts that rely on communications equipment and other electronics working, or if the research identifies a great negative effect then plans may need to be completely revised.

2. Incident Mapping

A critical capability necessary to protect responders (and the public) from the harmful effects of the radioactive fallout will be to collect environmental measurements of the levels of radiation present in as many locations as possible, as quickly as possible. Identifying the severe, moderate, and light damage zones and particularly the dangerous fallout zone will support evacuation and sheltering decisions. This capability development has been started but remains incomplete. A system that can integrate federal plume predictions using real-time weather information with field collected, GPS tagged environmental measurement data and layer it on a map will provide commanders a picture of the full size of the affected area.

3. Responder Dose Guidance

For many years hazardous materials teams used the EPA *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents* (EPA 1992) for dose guidance in radiological releases, mainly dealing with accidents in transportation and facilities dealing with radiological materials in commercial ventures. The majority of national hazardous materials programs trained and operated with dose levels of 5, 10 and 25 R with hot zones being established at 1mR/hr. A dose of up to five R was within the risk-benefit equation for protecting property only. If viable lives were at risk, dose exposures of up to 10 R were considered and when many lives were at risk, or critical infrastructure that would impact many lives, then doses up to 25 R were within reason. Responders who were aware of the risks, understood them, and volunteered were considered for these missions when and if they arose. Public and private employers have been required by federal OSHA and EPA to provide hazardous materials training to emergency responders and employees under federal regulations. This training includes radiation basics and the health risks involved when the employees job will, or has the potential to, expose them to radioactive materials. There is still discussion in some areas of public service as to whether sworn personnel who have received this training are considered to having already volunteered to accept this risk of high exposure levels when the benefits warrant. But issues remain as to the continued duty status of these responders for future exposures. Fortunately, no nuclear plant or transportation accident in the United States has exposed emergency responders to these high levels to date.

New planning documents and recent modeling show that the levels of radiation following a nuclear detonation, both initial and fallout, will be much higher than transportation and industrial accidental releases. Use of INDs in an attack on a large metropolitan city will put hundreds of thousands of lives at risk from exposure to high radiation levels. The NCRP *Commentary No. 19* (2006) report recommends several considerations for change in two areas related to the emergency responder dose guides. The first recommends the hot zone, or inner perimeter, start at 10mR/hr. This addresses the concern that the two mR/hr mark may be a considerable distance from the areas that need to searched, (moderate damage zone) and would unnecessarily delay rescue missions. Secondly, they consider 50R exposure to be a dose decision point and chose not to consider hard and fast limits of exposure (NCRP, 2006). Each agency should consider all levels: 5, 10, 25, and 50, for example, as dose decision points, where the benefits to be gained must be weighed against the risk of exposure to emergency responders. The *Federal Planning Guidance* references the NCRP numbers and:

> …does not give strict dose or dose rate limits, but provides recommendations and decision points at which emergency responders should be made aware of the risks they are about to incur, have the training necessary to understand that risk, and consent to progressively higher radiation doses. (National Security Staff, 2010, p. 52)

This is a significant change for emergency responders and must be highlighted with emergency planners. It should be carefully considered as a necessary guide in large RDD and IND incidents in order to provide rescue services to large populations exposed or sheltered that require assistance. Extensive work must be done to include this in training programs that informs emergency responders what information is needed in order for them to make safe, informed risk-benefit live-saving decisions.

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VII. CONCLUSIONS

Research into the radiological and nuclear response plans that are available from the key emergency response agencies in New York City shows that they do not address the specific issues of a 10 KT nuclear detonation at ground level, one of the current threat scenario concerns of the federal government and its intelligence community.

Still considered a lower probability than the use of conventional improvised explosive devices, commercial chemical agents or biological agents, the consequences are severe enough to warrant planning. In April of 2010, nuclear terrorism was the focus of President Obama in his 47-nation summit to prevent terrorist groups from acquiring materials to develop an improvised nuclear device. It also remains a concern of the International Atomic Energy Agency and nuclear community. The IAEA Director General, Yukiya Amano, during the World Economic Forum in Davos, Switzerland in January of 2011, reported that the IAEA receives information about illicit trafficking of nuclear or radiological materials every two days (NYPD Counterterrorism Bureau, 2011, p. 2). The DHS Domestic Nuclear Detection Office Joint Analysis Center Report for January 2011 further states that U.S. Nuclear experts and IAEA officials are "much alarmed over the constant cases of radioactive material from a number of Indian defense and civilian nuclear facilities that have gone missing" (DNDO, 2011, p. 7).

The current NYC interagency radiological plan does not address the nuclear detonation scenario; its focus is on the RDD and dirty bomb issues that were absent in the pre-9/11 plan. To be fair, no major metropolitan Tier I UASI city has developed a response plan for a 10 KT nuclear detonation by a terrorist group. New federal modeling and planning information available in the last two to three years make this effort achievable.

The response actions in the NYC *Radiological Response and Recovery Plan* and the independent agency radiological plans provide sound information to emergency responders for RDDs. The smaller area impacted by an RDD of the size projected by experts in the nuclear field, combined with instrumentation deployed with many responders in NYC agencies and associated training, provide adequate protection to them if applied properly.

Compared to the consequences of a 10 KT nuclear detonation, the current response guidance is inadequate. Emergency responders lack the information to quickly identify the initial characteristics necessary to determine that a nuclear detonation has occurred. Responders in the moderate and light damage zones and beyond may have only seconds to tens of seconds to take protective actions against the prompt blast, thermal, initial ionizing radiation, and flash blindness, they but need to recognize the unfolding detonation in order to act on training and instinct.

Guidance in the existing radiological plans and improvised explosive response plans has emergency personnel that survived the initial blast responding in toward the detonation site to assist civilians and manage the incident. The dangerous levels of radioactive fallout that begins to return to the ground simultaneously to the emergency response, places the responders at severe risk of fatal exposures. This fallout is modeled to continue for hours and days, depending on the winds and amount of dirt, dust, and debris thrust upward by the detonation and thermal column. Until the dangerous fallout zone can be tracked and plotted, emergency responders should shelter-in-place with civilians in adequate shelters for at least 60 minutes to two hours; approximately the time it should take to combine ground level readings with federal atmospheric projections.

The absence of specific guidance for emergency responders in the event of a nuclear detonation will cause them to rely on the existing guidance for radiological accidents or RDD response plans. Exposures that result from the high levels of radioactive fallout and entry into the high-risk, low-benefit severe damage and dangerous fallout zones will have a cascading effect on the cities' ability to manage long-term response, mitigation, and recovery actions. Nuclear response planning in major metropolitan cities will be essential to be successful in these actions, protect emergency responders and provide the best service possible to the citizens.

LIST OF REFERENCES

Barnaby, F. (2004). *How to build a nuclear bomb*. New York: Nation Books.

Bergman, J., Kramer, K., Sanchez, B., Madrigal, J., Millage, K., and Blake, P. (2011, June 29). *The effects of the urban environment on the propagation of prompt radiation from an improvised nuclear device*. 56th Annual Meeting of the Health Physics Society. West Palm Beach, FL.

Buddemeier, B. (2007). *Reducing the consequences of a nuclear detonation.* Livermore, CA: Lawrence Livermore National Lab.

Brooke Buddemeier & Dillon, M. (2009). *Key response planning factors for the aftermath of nuclear terrorism*. Livermore, CA: Lawrence Livermore National Lab.

Buddemeier, B., Klucking, S., Blue, Charles, Office of Health Affairs, Department of Homeland Security. (2009). *Modeling improvised nuclear device (IND) impacts to Tier I UASI Cities* (LLNL-PRES-409771). Livermore, CA: Lawrence Livermore National Lab Presentation to DHS-OHA, 2009

Bunn, M., Weir, A., and Holdren, J. P. (2003). *Controlling nuclear warheads and materials: A report card and action plan.* Project on Managing the Atom, Belfer Center for Science and International Affairs, Harvard University. Retrieved November 2, 2010, from http://www.nti.org/e_research/cnwm/cnwm.pdf

Cirincione, J. (2007). *Bomb scare.* New York: Columbia University Press.

Defense Sciences Board, Department of Defense. (2007). *2005 summer study reducing vulnerabilities to weapons of mass destruction* (Vol. I). Retrieved October 15, 2010, from http://www.acq.osd.mil/dsb/reports/ADA471566.pdf

Department of Homeland Security. (2011, January). *Joint Analysis Center monthly open source report*. Washington, DC: author.

Department of Homeland Security. (2010). *Strategy for improving the national response and recovery from an IND attack.* Washington, DC: author.

Department of Homeland Security. (2006). Preparedness directorate: Protective action guides for radiological dispersal device (RDD) and improvised nuclear device (IND) incidents. *Federal Register*, *71*(1): 174–196. Retrieved June 1, 2010, from http://www.gpo.gov/fdsys/pkg/FR-2006-01-03/pdf/FR-2006-01-03.pdf

Federal Emergency Management Agency. (2008a). *National response framework.* Retrieved May 1, 2008, from http://www.fema.gov/pdf/emergency/nrf/nrf-core.pdf

Federal Emergency Management Agency. (2008b). *National response framework: Nuclear/radiological incident annex.* Retrieved August 15, 2008, from http://www.fema.gov/pdf/emergency/nrf/nrf_nuclearradiologicalincidentannex.pdf

Ferguson, C. D., Potter, W. C., Sands, A., Spector, L. S. & Wehling, F. L. (2005). *The four faces of nuclear terrorism*. New York: Routledge.

Ferguson, C. D. & Potter, W. C. (2008). *Improvised Nuclear Devices and Nuclear Terrorism*, (No. 2), 1. Retrieved April 1, 2010 from www.wmdcommission.org/files/No2.pdf.

Freilich, C. (2010). *The Armageddon scenario: Israel and the threat of nuclear terrorism*. Tel Aviv: Begin-Sadat Center for Strategic Studies, Bar-llan University. Retrieved November 3, 2010, from http://www.biu.ac.il/Besa/MSPS84.pdf

Glasstone, S. & Dolan, P.J. (1977). *The effects of nuclear weapons* (3rd ed.). Washington, DC: U.S. Government Printing Office. Retrieved June 1, 2010, from http://www.cddc.vt.edu/host/atomic/nukeffct/enw77b1.html

Harper, F. & Musolino, S. (2006). Emergency response guidance for the first 48 hours after the outdoor detonation of an explosive radiological dispersal device. *Health Physics Society Journal*, *90*(4).

Harper, F., Musolino, S., & Wente, W. (2007). Realistic radiological dispersal device hazard boundaries and ramifications for early consequence management decisions. *Health Physics Society Journal*, *93*(1).

International Atomic Energy Agency. (1993). *Limits to the safeguards system* (Pamphlet 93-04459, IAEA/PI/A38E), Retrieved August 26, 2011, from http://www.iaea.org/Publications/Booklets/Safeguards/index.html

International Atomic Energy Agency & World Health Organization. (2005). *Development of an extended framework for emergency response criteria*. Retrieved January 2, 2011, from http://www-pub.iaea.org/MTCD/publications/PDF/TE_1432_web.pdf

International Atomic Energy Agency. (2006). *Manual for first responders to a radiological emergency*. Retrieved September 25, 2010, from http://www-pub.iaea.org/MTCD/publications/PDF/epr_Firstresponder_web.pdf

International Atomic Energy Agency. (2011). *Fukushima nuclear accident update log* (staff report). Retrieved September 13, 2011, from http://www.iaea.org/newscenter/news/tsunamiupdate01.html

Mars, R.E. (2007). *Radioactive fallout from terrorist nuclear detonation*. Livermore, CA: Lawrence Livermore National Laboratory. Retrieved October 5, 2010, from https://e-reports-ext.llnl.gov/pdf/347266.pdf

Mlakar, Sr., P.F., Corley, W.G., Sozen, M.A., & Thornton, C.H. (1998). The Oklahoma City bombing: analysis of blast damage to the Murrah Building. *Journal of Performance of Constructed Facilities*, *12*(3): 113–119.

Musolino, S. V. & Harper, F. T. (2006). Emergency response guidance for the first 48 hours after the outdoor detonation of an explosive radiological dispersal device. *Health Physics*, *90*(4).

National Academies of Science, Committee on Science and Technology for Countering Terrorism. (2011). *Making the nation safer: The role of science and technology in countering terrorism*. Washington, DC: The Academy Press.

National Council on Radiation Protection and Measurement. (2006). *Key elements of preparing emergency responders for nuclear and radiological terrorism* (Commentary No. 19).

National Council on Radiation Protection & Measurements. (2011). *Responding to a radiological or nuclear terrorism incident: A guide for decision makers* (Report 165).

National Security Staff, Inter-Agency Policy Coordination Subcommittee for Preparedness and Response to Radiological and Nuclear Threats. (2010). *Planning guidance for response to a nuclear detonation* (2nd ed.). Retrieved June 30, 2011, from http://hps.org/hsc/documents/Planning_Guidance_for_Response_to_a_Nuclear_Detonation-2nd_Edition_FINAL.pdf

Nevada State Division of Emergency Management. (2010). *Nevada improvised nuclear device (IND) operations plan (OPLAN)*. Internal document, Nevada State Division of Emergency Management, Carson City, NV.

New York City, Office of Emergency Management. (2010). DRAFT Radiological Response and Recovery Plan. New York: New York Office of Emergency Management.

New York City Fire Department. (2004). *Hazardous materials emergency response plan for radiological incidents*. New York: New York City Fire Department.

New York City Fire Department. (2006). *Fire tactics & procedures/ EMSC OGP 105-01,ERP addendum 4, radiological operations*. New York: New York City Fire Department.

Nishizawa, T. (2011). *TEPCO President's comments on Fukushima nuclear power plant updates*. Retrieved September 13, 2011, from http://www.tepco.co.jp/en/index-e.html\

NYPD Counterterrorism Bureau. (2011). Terrorists may be getting access to nuke materials “every second day:” IAEA. *CBRN Weekly*, *5*.

Office of Radiation Protection, Washington State Department of Health. (2007). *Initial response planning for improvised nuclear device explosions*. Tumwater, WA: Washington State Department of Health.

Poeton, R., Glines, W., & McBaugh, D. (2007). *Planning for the worst in Washington state: Initial response planning for improvised nuclear device* explosions. Olympia, WA: Office of Radiation Protection, Washington State Department of Health.

U.S. Environmental Protection Agency. (1992). *Manual of protective action guides and protective actions for nuclear incidents* (EPA 400-R-92-001). Retrieved July 24, 2010, from http://www.epa.gov/radiationdocs/er/400-r-92-001.pdf.

United States Government Accountability Office. (2009). *Combating nuclear terrorism: Preliminary observations on preparedness to recover from possible attacks using radiological or nuclear materials, statement of Gene Aloise, Director, Natural Resources and Environment, Testimony before the Subcommittee on Emerging Threats, Cyber security, and Science and Technology, Committee on Homeland Security, House of Representatives*. Retrieved October 5, 2009, from http://www.gao.gov/products/GAO-09-996T

Ventura County Department of Public Health. (2007). *Ventura County nuclear explosion response plan-draft*. Ventura County, CA: Ventura County Department of Public Health.

Visser, V. P. (2006). *Preparing for response to a nuclear weapon of mass destruction: Are we ready?* Ft. Leavenworth, KA: U.S. Army Command and General Staff College, School of Advanced Military Studies. Retrieved November 20, 2010, from http://dodreports.com/pdf/ada450830.pdf

White County, Arkansas Emergency Management. (2007). *Emergency operations plan, Annex R: Nuclear terrorism response*. White County, AR: author.

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