Planning Guidance for Response to a Nuclear Detonation

Second Edition
June 2010

Developed by the National Security Staff Interagency Policy Coordination Subcommittee for Preparedness & Response to Radiological and Nuclear Threats

American Red Cross

This guidance was developed by a Federal interagency committee led by the Executive Office of the President (National Security Staff and Office of Science and Technology Policy) with representatives from the Departments of Defense, Energy, Health and Human Services, Homeland Security (DHS), Labor, Transportation, Veteran's Affairs, the Environmental Protection Agency, the National Aeronautics and Space Administration, and the Nuclear Regulatory Commission. Future editions and interagency coordination related to Planning Guidance for Response to a Nuclear Detonation will be coordinated by DHS, Federal Emergency Management Agency (FEMA).

Please refer comments and questions to the FEMA IND Response and Recovery Program Office (www.fema.gov/CBRNE).

FOREWORD FOR SECOND EDITION

The First Edition Planning Guidance focused on topics relevant to emergency planning within the first few days of a nuclear detonation including: 1) shelter and evacuation, 2) medical care, and 3) population monitoring and decontamination. There are a few notable changes in the Second Edition that are worth calling out in this foreword. The Second Edition will integrate new contributions seamlessly without making references to the differences between the First Edition and Second Edition.

The First Edition planning guidance summarized recommendations based on what was known about the consequences of a nuclear detonation in an urban environment extrapolating from the experience base of nuclear weapons testing. It provided recommendations based on existing knowledge and existing techniques. The Federal government immediately initiated ongoing studies that have provided more robust and comprehensive recommendations. Some recommendations in this Second Edition planning guidance are updated or expanded to capture recommendations that have been drawn from these studies. Most notably, a chapter has been added to address public preparedness and emergency public communications.

To provide planners the opportunity to think beyond the 10 KT nuclear yield as found in National Planning Scenario #1, the Second Edition provides additional information in Chapter 1 showing ranges of nuclear yield. Chapter 1 is updated with graphics that have been produced from assessment of nuclear explosion urban impacts conducted since January of 2009. You will notice some improvements in graphics and expected numerical predictions (e.g., distances, overpressures) associated with various effects and impacts. In Chapter 2, worker safety and health recommendations are briefly expanded relative to the First Edition; however, more extensive guidance is being developed by the Occupational Safety and Health Administration (OSHA) and should be anticipated within a year of publication of this second edition. It will be added to the FEMA website where this planning guidance will be maintained (www.fema.gov/CBRNE). Other expanded work in this present edition that is relevant to the first 72 hours of response includes: expanded zone management concepts (Chapter 1); selection of radiation detection systems (Chapter 2); response worker safety strategies and responder health-benefit concepts (Chapter 2); urban search and rescue guidance (Chapter 2), decontamination of critical infrastructure information (Chapter 2); waste management operation concepts (Chapter 2); expanded shelter, shelter transition, and evacuation planning guidance (Chapter 3); medical care scarce resource situation considerations (Chapter 4); behavioral healthcare guidance (Chapter 4), expanded fatality management recommendations (Chapter 4), self-decontamination guidance (Chapter 5); and pre-incident public education, including emergency public information (Chapter 6).

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Acronym List

AC	Assembly Center
AFRRI	Armed Forces Radiobiology Research Institute
ALARA	As Low as Reasonably Achievable
ARS	Acute Radiation Syndrome
ASPR	Assistant Secretary for Preparedness & Response
BHCP	Behavioral Healthcare Provider
CDC	Centers for Disease Control and Prevention
CONOPS	Concept of Operations
CRCPD	Conference of Radiation Control Program Directors
DF	Dangerous Fallout
DHHS	Department of Health and Human Services
DHS	Department of Homeland Security
DIME	Delayed, Immediate, Minimal or Expectant
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
EMAC	Emergency Management Assistance Compact
EMP	Electromagnetic Pulse
EPA	Environmental Protection Agency
ESAR-VHP	Emergency System for Advanced Registration of Volunteer Health Professionals
FEMA	Federal Emergency Management Agency
FRMAC	Federal Radiological Monitoring and Assessment Center
Hazmat	Hazardous Materials (designating specialty emergency response team)
IAEA	International Atomic Energy Agency
ICRP	International Council on Radiation Protection
IMAAC	Interagency Modeling and Atmospheric Assessment Center
IND	Improvised Nuclear Device
KT	Kiloton
LD	Light Damage
LD_{50}	Lethal Dose for 50% of the exposed population
MD	Moderate Damage
mph	miles per hour
NCRP	National Council on Radiation Protection and Measurements
NDMS	National Disaster Medical System
NPS	National Planning Scenario

OEG	Operational Exposure Guidance
OSHA	Occupational Safety and Health Administration
PAG	Protective Action Guide
PPE	Personal Protective Equipment
psi	pounds per square inch
RDD	Radiological Dispersal Device
REAC/TS	Radiation Emergency Assistance Center/Training Site
REMM	Radiation Emergency Medical Management
REP	Radiological Emergency Preparedness
RITN	Radiation Injury Treatment Network
RTR	Radiation TRiage, TReatment, and TRansport system
SAR	Search and Rescue
SALT	Sort, Assess, Life-saving intervention, Treatment/Transport
SD	Severe Damage
US&R	Urban Search and Rescue
TNT	Trinitrotoluene
US	United States
USG	United States Government

Definitions[1]

Adequate shelter – Shelter that protects against acute radiation effects and significantly reduces radiation dose to occupants during an extended period.

ALARA – (Acronym for 'As Low As Reasonably Achievable') **–** A process to control or manage radiation exposure to individuals and releases of radioactive material to the environment so that doses are as low as social, technical, economic, practical, and public welfare considerations permit.

Ambulatory – Victims who are able to walk to obtain medical care.

Beta burn – Beta radiation induced skin damage.

Blast effects – The impacts caused by the shock wave of energy through air that is created by detonation of a nuclear device. The blast wave is a pulse of air in which the pressure increases sharply at the front and is accompanied by winds.

Combined injury – Victims of the immediate effects of a nuclear detonation are likely to suffer from burns and/or physical trauma, in addition to radiation exposure.

Dose – Radiation absorbed by an individual's body; general term used to denote mean absorbed dose, equivalent dose, effective dose, or effective equivalent dose, and to denote dose received or committed dose.

Duck and Cover – A suggested method of personal protection against the effects of a nuclear weapon which the United States government taught to generations of school children from the early 1950s into the 1980s. The technique was supposed to protect them in the event of an unexpected nuclear attack which, they were told, could come at any time without warning. Immediately after they saw a flash they had to stop what they were doing and get on the ground under some cover, such as a table or against a wall, and assume the fetal position, lying face-down and covering their heads with their hands.

Electromagnetic Pulse (EMP) – A sharp pulse of radiofrequency (long wavelength) electromagnetic radiation produced when an explosion occurs near the earth's surface or at high altitudes. The intense electric and magnetic fields can damage unprotected electronics and electronic equipment over a large area.

Emergency Management Assistance Compact (EMAC) – A Congressionally ratified organization that provides form and structure to interstate mutual aid. Through EMAC, a

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[1] When available, definitions have been adapted from Glasstone and Dolan (Glasstone and Dolan 1977) or the Department of Homeland Security (DHS) Planning Guidance (DHS 2008).

disaster-affected State can request and receive assistance from other member States quickly and efficiently, resolving two key issues up front: liability and reimbursement.

Exposure Rate – The radiation dose absorbed per unit of time. Generally, radiation doses received over a longer period of time are less harmful than doses received instantaneously.

Fallout – The process or phenomenon of the descent to the earth's surface of particles contaminated with radioactive material from the radioactive cloud. The term is also applied in a collective sense to the contaminated particulate matter itself.

Fission Products – Radioactive subspecies resulting from the splitting (fission) of the nuclei of higher level elements (e.g., uranium and plutonium) in a nuclear weapon or nuclear reactor.

LD_{50} – The amount of a radiation that kills 50% of a sample population.

Morbidity – A diseased state or symptom, the incidence of disease, or the rate of sickness.

Mortality – A fatal outcome or, in one word, death. Also, the number of deaths in a given time or place or the proportion of deaths to population.

Personal Protective Equipment (PPE) – Includes all clothing and other work accessories designed to create a barrier against hazards. Examples include safety goggles, blast shields, hard hats, hearing protectors, gloves, respirator, aprons, and work boots.

Radiation effects – Impacts associated with the ionizing radiation (alpha, beta, gamma, neutron, etc.) produced by or from a nuclear detonation, including radiation decay.

rad – A unit expressing the absorbed dose of ionizing radiation. Absorbed dose is the energy deposited per unit mass of matter. The units of rad and Gray are the units in the traditional and SI systems for expressing absorbed dose.

1 rad = 0.01 Gray (Gy); 1 Gy = 100 rad

rem – A unit of absorbed dose that accounts for the relative biological effectiveness of ionizing radiations in tissue (also called equivalent dose). Not all radiation produces the same biological effect, even for the same amount of absorbed dose; rem relates the absorbed dose in human tissue to the effective biological damage of the radiation. The units of rem and Sievert are the units in the traditional and SI systems for expressing equivalent dose. 1 rem = 0.01 Sieverts (Sv); 1 Sv = 100 rem

Roentgen (R) – A unit of gamma or x-ray exposure in air. For the purpose of this guidance, one R of exposure is approximately equal to one rem of whole-body external dose.

- 1,000 micro-roentgen (μR) = 1 milli-roentgen (mR)
- 1,000 milli-roentgen (mR) = 1 Roentgen (R), thus
- 1,000,000 μR = 1 Roentgen (R)

Roentgen per hour (R/h) – A unit used to express gamma or x-ray exposure in air per unit of time (exposure rate).

Shelter – To take 'shelter' as used in this document means going in, or staying in, any enclosed structure to escape direct exposure to fallout. 'Shelter' may include the use of pre-designated facilities or locations. It also includes locations readily available at the time of need, including staying inside where you are, or going immediately indoors in any readily available structure.

Shelter-in-place – Staying inside or going immediately indoors in the nearest yet most protective structure.

Survivable victim – An individual that will survive the incident if a successful rescue operation is executed and will not likely survive the incident if the rescue operation does not occur.

References:

Glasstone, Samuel and Philip J. Dolan. 1977. *The Effects of Nuclear Weapons*. Washington, DC: US Government Printing Office.

US Department of Homeland Security. Federal Emergency Management Agency. 2008. *Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents*, Federal Register, Vol. 73, No. 149. http://www.fema.gov/good_guidance/download/10260.

Units of Measure

For the case of a nuclear detonation, persistent beta-gamma radiation levels will affect some response decisions. For the purpose of this planning guidance, the following simplifying assumptions about units used in measuring this radiation applies: 1 R (exposure in air) ≅ 1 rad (adsorbed dose) ≅ 1 rem (whole-body dose).[2]

For the purpose of this planning guidance, the rem unit is related to the Sievert unit and 1 rem = .01 Sv will be applied as the basis for comparison of traditional and SI units. Exposure rate (R/hour [R/h]) can be expressed in terms of Sv/hour (Sv/h). Therefore: 1 R/h ≅ 0.01 Sv/h

Radiation Measurement Units:

	Traditional Units Units	**SI Units**
Radioactivity	Curie (Ci)	Becquerel (Bq)
Absorbed dose	rad	Gray (Gy)
Dose equivalent	rem	Sievert (Sv)
Exposure	Roentgen (R)	Coulomb/Kilogram (C/kg)

Traditional/SI Unit Conversions:

1 Curie = 3.7 x 10^{10} disintegrations/second	1 Becquerel = 1 disintegration/second
1 rad	0.01 Gray (Gy) or 1 centiGray (cGy)
1 rem	0.01 Sieverts (Sv)
1 Roentgen (R)	0.000258 Coulomb/kilogram (C/kg)
1 Gray (Gy)	100 rad
1 Sievert (Sv)	100 rem
1 Coulomb/kilogram (C/kg)	3,876 Roentgens

Reference

National Council on Radiation Protection and Measurements (NCRP). 2005. *Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism,* Commentary No. 19 (Bethesda).

[2] NCRP 2005

Structure of this Document

The planning guidance is organized in a stepwise manner using terminology and concepts of the National Planning Scenario #1, the National Response Framework, and other technical and policy documents. The planning guidance presents general background information that builds a foundation for specific planning recommendations.

Bold text is used throughout the document to emphasize important material or concepts.

Italicized text denotes direct quotes of material from cited sources.

Bold and italicized text is used to emphasize a term defined in the Definitions section. Terms that appear very frequently are only emphasized in this fashion once at the beginning of each chapter.

Text boxes that run the width of the page have been generated to summarize key information following the presentation of information in the context of the guidance.

> Text boxes that run the width of the page have been generated following the delivery of key information.

This key information has been pulled to the beginning of each chapter as a summary of **KEY POINTS.**

> **KEY POINTS**
> 1. Key points summarize important information captured throughout each chapter.
> 2. The key points are presented at the beginning of each chapter.

Relevant supporting information that may be useful, but is not essential for planners, is included throughout the planning guidance. This additional information is useful for subject matter experts and for educational purposes. The information is captured in grey text boxes.

Finally, use of the Latin acronyms i.e., and e.g., is used throughout the document. The use of i.e., denotes “that is, or in other words” and e.g., “for example”.

> **Background Points are in Grey Boxes**
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> In each chapter appropriate background or additional information of a technical nature has been included in grey boxes to enable those who seek supporting information to have access, while those who wish to bypass it may do so. This is non-essential information and can be bypassed when using the planning guidance.

INTRODUCTION

One of the most catastrophic incidents that could befall the United States (US), causing enormous loss of life and property and severely damaging economic viability, is a **nuclear detonation in a US city**. It is incumbent upon all levels of government, as well as public and private parties within the US, to prepare for this incident through focused nuclear attack response planning. Nuclear explosions present substantial and immediate radiological threats to life and a severely damaged response infrastructure. **Local and State community preparedness to respond to a nuclear detonation could result in life-saving on the order of tens of thousands of lives.**

The purpose of this guidance is to provide emergency planners with nuclear detonation-specific response recommendations to maximize the preservation of life in the event of an urban nuclear detonation. This guidance addresses the unique effects and impacts of a nuclear detonation such as scale of destruction, ***shelter*** and evacuation strategies, unparalleled medical demands, management of nuclear casualties, and radiation ***dose*** management concepts. The guidance is aimed at response activities in an environment with a severely compromised infrastructure for the **first few days** (i.e., 24 – 72 hours) when it is likely that many Federal resources will still be en route to the incident.

The target audiences for the guidance are response planners and their leadership. Emergency responders should also benefit in understanding and applying this guidance. The target audiences include, but are not limited to, the following at the city, county, State, and Federal levels:

- Emergency managers
- Law enforcement authority planners
- Fire response planners
- Emergency medical service planners
- Hazardous material (Hazmat) response planners
- Utility services and public works emergency planners
- Transportation planners
- Medical receiver planners (e.g., hospitals)
- Mass care providers (e.g., American Red Cross)
- Other metropolitan emergency planners, planning organizations, and professional organizations that represent the multiple disciplines that conduct emergency response activities

The planning guidance recommendations are focused on providing express consideration of the following topics relevant to emergency planners within the first few days of a nuclear detonation: 1) shelter and evacuation, 2) medical care, 3) population monitoring and decontamination, and 4) public preparedness – emergency public information. As additional recommendations become available on issues that are identified as gaps by stakeholder communities, they will be incorporated into future editions of this planning guidance. Future editions of the planning guidance will be coordinated by the Department of Homeland Security (DHS), Federal Emergency Management Agency.

Since the events of September 11, 2001, the nation has taken a series of historic steps to address threats against our safety and security. This guidance represents an additional step in this continuing effort to increase the nation's preparedness for potential attacks against our nation. It was developed in response to gaps noted in the previously published DHS *Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents*[1,2] and hereafter referred to as the DHS Planning Guidance.[3] While the publication provides substantial guidance to Federal, State, and local planners for responding to such incidents, it concedes that it does not sufficiently prepare local and State emergency response authorities for managing the catastrophic consequences of a nuclear detonation as follows:

> *"In addition to the issuance of this Guidance, in response to interagency working group discussions and public comments, further guidance will be provided for the consequences that would be unique to an IND attack. This Guidance was not written to provide specific recommendations for a nuclear detonation (IND), but to consider the applicability of existing PAGs[4] to RDDs and INDs. In particular, it does not consider very high doses or dose rate zones expected following a nuclear weapon detonation and other complicating impacts that can significantly affect life-saving outcomes, such as severely damaged infrastructure, loss of communications, water pressure, and electricity, and the prevalence of secondary hazards. Scientifically sound recommendations for responders are a critical component of post-incident life-saving activities, including implementing protective orders, evacuation implementation, safe responder entry and operations, and urban search and rescue and victim extraction."*

This guidance does not replace the DHS Planning Guidance; however, it does provide specific guidance for response in the damaged region surrounding a 10 kiloton (KT) nuclear detonation (i.e., within approximately three miles) and the life threatening ***fallout*** region where fallout is deposited within 10 – 20 miles (16 – 23 km). The DHS Planning Guidance will continue to serve planners who are preparing for the protection of populations beyond these immediately life-threatening areas. The existing DHS Planning Guidance combined with this planning guidance provides more comprehensive direct for emergency response planners to prepare for responding to consequences of a nuclear detonation.

It is important to clarify that the Federal government does not anticipate the development of or the need for specific nuclear detonation protective action guides (PAGs) for the most heavily impacted zones described in this guidance. Existing DHS and EPA PAGs do not

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[1] Federal Register, Vol. 73, No. 149, Friday, August 1, 2008, http://www.fema.gov/good_guidance/download/10260.
[2] By agreement with the Environmental Protection Agency (EPA), the DHS Planning Guidance (DHS 2008) published is final and its substance will be incorporated without change into the revision of the 1992 EPA Manual of Protective Actions Guides and Protective Actions for Nuclear Incidents - the PAG Manual (EPA 1992). This notice of final guidance will therefore sunset upon publication of the new EPA PAG Manual (see, http://www.epa.gov/radiation/rert/pags.html)
[3] DHS 2008
[4] PAGs stands for Protective Action Guides

need to be altered for a nuclear detonation, but it is important to understand how they are useful to planners in the context of an extreme situation such as a nuclear detonation. The DHS and EPA PAGs provide decision points for sheltering and evacuation to minimize overall radiation dose. Implicit in the PAG decision process is the time and information necessary to make health protection decisions. The PAG principles apply to consideration of a nuclear explosion; however, the anticipated no-notice initiation of the scenario and the impractical nature of rapid evacuation of populations from fallout areas lead to the general recommendation that **everyone should seek shelter regardless of proximity to ground zero or orientation to the actual path of fallout**. In this situation, avoiding acute, potentially lethal radiation dose dominates other potential protective action decisions. However, survivors should use good judgment and should not seek shelter in buildings that are on fire or otherwise clearly dangerous. See Chapter 3 for further discussion and details. In summary, additional PAGs will not increase public or responder protection.

This guidance was developed by a Federal interagency committee led by the Executive Office of the President (see Committee Membership section at the end of the guidance). The guidance could not have been completed without the technical assistance provided by individuals summarized in the Acknowledgements section also at the end of the report. The planning guidance was developed through a process which included extensive stakeholder review that included Federal interagency and national laboratory subject matter experts, emergency response community representatives from police, fire, emergency medical services, medical receivers, and professional organizations such as the Health Physics Society and the Interagency Board resulting in 886 addressed comments and recommendations from over 65 individual reviewers representing 19 Federal departments and national laboratories and 10 communities and professional organizations. The nuclear weapons technical community was engaged throughout the development of the guidance through active interagency programs related to this topic.

The guidance is based upon DHS National Planning Scenario (NPS) #1 (Improvised Nuclear Device Attack), for use in national, Federal, State, and local homeland security preparedness activities. Scenario-based planning is a useful tool for Federal, State, and local planners, and, increasingly, departments and agencies are using the DHS NPSs to develop strategic, concept, and operational plans for designing response exercises and for other planning purposes. However, the NPSs have sometimes been applied as rigidly prescriptive scenarios against which planning should occur, not with the flexibility originally intended. This has often been the case with NPS #1. While it is impossible to predict the precise magnitude and impact of a nuclear detonation, this scenario provides a foundation for preparedness and planning efforts, as well as for initial response actions in the absence of specific measurements.

It is expected that planners and exercise designers will use this guidance, and the scenario on which it is based, and tailor them to their specific circumstances or to compare differing inputs and assumptions. Factors that planners and exercise designers may consider changing from parameters in NPS #1 may include the target city, specific location of detonation, size and type of weapon, date and time of day, population features, meteorological conditions, and assumptions about local, regional, or national response to the incident.

Target audiences should use this planning guidance in their preparedness efforts. They are encouraged to meet and work with their Federal, State, and local counterparts and partners, as each bring important knowledge to the design of implementation plans. Of special note are those planners with existing relationships with the Federal Emergency Management Agency (FEMA) Radiological Emergency Preparedness (REP) Program associated with communities in the vicinity of commercial nuclear power plants. Some processes and procedures from the REP Program are expected to be important tools in developing local response plans for nuclear detonations.

Finally, critical assumptions in the development of this guidance for response to a nuclear detonation include:

- **There will be no significant Federal response at the scene for 24 hours and the full extent of Federal assets will not be available for several days.** Emergency response is principally a local function. Federal assistance will be mobilized as rapidly as possible; however, for purposes of this document, no significant Federal response is assumed for 24 – 72 hours.

- **A nominal 10 KT yield, ground detonated nuclear device is assumed for purposes of estimating impacts in high-density urban areas**. Variation in the size and type of the nuclear device has a significant effect on the estimation of impacts, however, most homeland security experts agree on 10 KT as a useful assumption for planning.

- **The lessons from multi-hazard planning and response will be applicable to response to a nuclear detonation.** While ***fallout*** and the scale of the damage by a nuclear detonation present significantly complicating hazards, most aspects of multi-hazard planning and many of the response capabilities are still useful. Planners and responders bring a wealth of experience and expertise to nuclear detonation response. This guidance provides nuclear-detonation specific information and context to allow planners, responders, and their leaders to bring their existing capabilities to bear in a worst-case scenario.

- Although based on technical analyses and modeling of the consequences of nuclear explosions, the **recommendations are intentionally simplified to maximize their utility in uncertain situations where technical information is limited**. Recommendations are intended to be practical in nature and appropriate for use by planners in addressing actions for the general public and emergency responders.

- While it is recognized that the ***fallout*** from a nuclear detonation will reach across many jurisdictions, potentially involving multiple States, this **guidance is intended primarily for the target audience specified above with respect to the first few days in the physically damaged areas and life-threatening *fallout* zone.**

References

US Department of Homeland Security. 2008. *Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents*, Federal Register, Vol. 73, No. 149. http://www.fema.gov/good_guidance/download/10260.

US Environmental Protection Agency. Office of Radiation Programs. 1992. *Manual of Protective Actions Guides and Protective Actions for Nuclear Incidents.* http://www.epa.gov/radiation/docs/er/400-r-92-001.pdf.

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Chapter 1 - Nuclear Detonation Effects and Impacts in an Urban Environment

KEY POINTS

1. There are no clear boundaries between the representative damage zones resulting from a nuclear explosion, but generally, the light damage (LD) zone is characterized by broken windows and easily managed injuries; the moderate damage (MD) zone by significant building damage, rubble, downed utility lines and some downed poles, overturned automobiles, fires, and serious injuries; and the severe damage (SD) zone by completely destroyed infrastructure and high radiation levels resulting in unlikely survival of victims.
2. It is anticipated that some injuries (e.g., eye injuries, blast injuries — particularly from flying debris and glass) can be prevented or reduced in severity if individuals that perceive an intense and unexpected flash of light seek immediate cover. The speed of light, perceived as the flash, will travel faster than the blast overpressure allowing a few seconds for some people to take limited protective measures.
3. The most hazardous fallout particles are readily visible as fine sand-sized grains. However, the lack of apparent fallout should not suggest the lack of radiation; therefore, appropriate radiation monitoring should always be performed to determine the safety of an area. Fallout that is immediately hazardous to the public and emergency responders will descend to the ground within about 24 hours.
4. 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. Because of the unique nature of radiation dangers associated with a nuclear explosion, the most lives will be saved in the first 60 minutes through sheltering in place.
5. Blast, thermal, and radiation injuries in combination will result in worse prognoses for patients than only sustaining one independent injury.
6. EMP effects could result in extensive electronics disruptions complicating the function of communications, computers, and other essential electronic equipment. Equipment brought in from unaffected areas should function normally if communications towers and repeaters remain functioning.

Overview

A nuclear detonation would produce several important effects that impact the urban environment and people. In this discussion, the term ‘nuclear effects’ will mean those outputs from the nuclear explosion, namely primary effects including blast, thermal (heat), and initial radiation and secondary effects including ***electromagnetic pulse (EMP)*** and

fallout. All of these effects impact people, infrastructure, and the environment, and they significantly affect the ability to respond to the incident. The term 'nuclear impacts' will be used to describe the consequences to materials, people, or the environment as a result of nuclear effects, such as structural damage, fire, radioactivity, and human health consequences.

Generally, when considering nuclear explosion scenarios perpetrated by terrorists, experts assume a low-yield nuclear device detonated at ground level.[1] Low yield in this context ranges from fractions of a kiloton (KT) to 10 KT. The descriptions and planning factors provided in this document are based on the Department of Homeland Security (DHS) National Planning Scenario (NPS) #1, which describes a nuclear device yield of 10 KT detonated at ground level in an urban environment. The impacts of a nuclear explosion less than 10 KT would be less; however, the relation is not linear.

> Even a small nuclear detonation produces an explosion far surpassing that of conventional explosives. An explosion occurs when an exothermic reaction creates a rapidly expanding fireball of hot gas or plasma. The expanding fireball produces a destructive shock wave. In a chemical-based explosion (such as dynamite or trinitrotoluene (TNT), a common explosive), the heat produced reaches several thousand degrees and creates a gaseous fireball on the order of a few meters in diameter. While energy in a chemical explosion derives from reactions between molecules, the energy released in a nuclear explosion derives from the splitting (or fission) of atomic nuclei of uranium or plutonium (i.e., fissile material). Pound-for-pound, a nuclear explosion releases ~10 million times more energy than a chemical explosive. The heat in a nuclear explosion reaches millions of degrees where matter becomes plasma. The nuclear fireball for a 10 KT nuclear device has a diameter of approximately 1450 ft (~442 meters), and the shock wave and degree of destruction are correspondingly large.

Blast

The primary effect of a nuclear explosion is the blast that it generates. Blast generation is the same in any kind of explosion. The blast originates from the rapidly expanding fireball of the explosion, which generates a pressure wave front moving rapidly away from the point of detonation. Blast is measured by the overpressure[2] and dynamic pressure[3] that it produces. Initially, near the point of detonation for a ground detonation (also referred to as ground zero), the overpressure is extremely high (thousands of pounds per square inch [psi] expanding out in all directions from the detonation at hundreds of miles per hour [mph]). With increasing distance from ground zero, the overpressure and speed of the blast wave dissipate to where they cease to be destructive (see Table 1.1). After initial dissipation, the blast wave slows to about the speed of sound. After the first mile it travels, the wave takes approximately five seconds to traverse the next mile. This is enough time for a person with the right information to seek basic ***shelter*** for safety (e.g., ***duck and cover*** – see definition section).

[1] It should be noted that if a state-built weapon were available to terrorists, the presumption of low yield may no longer hold.
[2] Pressure over and above atmospheric pressure, and measured in pounds per square inch (psi).
[3] Manifested as wind, dynamic pressure is proportional to the square of wind velocity, and is measured in pounds per square inch. The dynamic pressure is, "*the air pressure which results from the mass air flow (or wind) behind the shock front of a blast wave. It is equal to the product of half the density of the air through which the blast wave passes and the square of the particle (or wind) velocity behind the shock front as it impinges on the object or structure*" (Glasstone and Dolan, 1977).

Accompanying the overpressure wave is dynamic pressure that is related to the wind generated by the passing pressure wave. A very high wind velocity is associated with a seemingly small amount of overpressure, as shown in Table 1.1. The dynamic pressure (wind) associated with the overpressure is extremely destructive to structures. For example, with an overpressure of 5 psi, the wind velocity may reach over 160 mph. The full impact of overpressure and associated dynamic pressure on structures common in a modern city is not currently known. However, past tests and computer models aid in impacts estimation.

The magnitude of a nuclear explosion is quantified in terms of the amount of conventional explosive it would take to create the same energy release. The amount of explosive power from a nuclear explosion, or the "yield," is measured relative to TNT, and is usually in the thousands of tons (kilotons, or KT) of TNT. A small nuclear device, for example, would be a 1 KT device, meaning it would produce an explosive yield equivalent to one thousand tons of TNT. For comparison, the size of the Murrah Federal Building bombing in Oklahoma City, OK (1995) was equivalent to 2 tons of TNT.

Table 1.1: Relation of wind speed to peak overpressure and distance for a 10 KT explosion; adapted from Glasstone and Dolan (Glasstone and Dolan 1977)

Peak Overpressure (psi)	Approximate Distance from Ground Zero (miles) [km]	Maximum Wind Speed (mph) [km/h]
50	0.18 [0.29]	934 [1503]
30	0.24 [0.39]	669 [1077]
20	0.30 [0.48]	502 [808]
10	0.44 [0.71]	294 [473]
5	0.6 [0.97]	163 [262]
2	1.1 [1.8]	70 [113]

Physical destruction of structures following an urban nuclear explosion at different overpressures is described as follows:

1. Approximately 0.1 to about 1 psi: Buildings sustain minor damage, particularly broken windows in most residential structures.

2. Between 1 psi and 5 psi: Most buildings sustain considerable damage, particularly on the side(s) facing the explosion.

3. Between 5 psi and 8 psi: Buildings are severely damaged or destroyed.

4. At higher overpressures, only heavily reinforced buildings may remain standing, but are significantly damaged and all other buildings are completely destroyed.

The amount of damage to structures can be used to describe zones for use in response planning. Each zone will have health and survival implications, although not as neatly as arbitrary zone delineations would indicate. The purpose of establishing zones is to help plan response operations and prioritize actions. The following zones are proposed for planning response to a 10 KT ground burst nuclear explosion in an urban environment:[4]

Light Damage (LD) Zone:

- ❒ Damage is caused by shocks, similar to those produced by a thunderclap or a sonic boom, but with much more force. Although some windows may be broken over 10 miles (16 km) away, the injury associated with flying glass will generally occur at overpressures above 0.5 psi. This damage may correspond to a distance of about 3 miles (4.8 km) from ground zero for a 10 KT nuclear explosion. The damage in this area will be highly variable as shock waves rebound multiple times off of buildings, the terrain, and even the atmosphere.
- ❒ As a responder moves inward, windows and doors will be blown in and gutters, window shutters, roofs, and lightly constructed buildings will have increasing damage. Litter and rubble will increase moving towards ground zero and there will be increasing numbers of stalled and crashed automobiles that will make emergency vehicle passage difficult.
- ❒ Blast overpressures that characterize the LD zone are calculated to be about 0.5 psi at the outer boundary and 2–3 psi at the inner boundary. More significant structural damage to buildings will indicate entry into the moderate damage zone.

Moderate Damage (MD) Zone:

- ❒ Responders may expect they are transitioning into the MD zone when building damage becomes substantial. This damage may correspond to a distance of about one mile (1.6 km) from ground zero for a 10 KT nuclear explosion. The determination is made by ground-level and/or overhead imagery.
- ❒ Observations in the MD zone include significant structural damage, blown out building interiors, blown down utility lines, overturned automobiles, caved roofs, some collapsed buildings, and fires. Some telephone poles and street light poles will be blown over. In the MD zone, sturdier buildings (e.g., reinforced concrete) will remain standing, lighter commercial and multi-unit residential buildings may be fallen or structurally unstable, and many wood frame houses will be destroyed.
- ❒ Substantial rubble and crashed and overturned vehicles in streets are expected, making evacuation and passage of rescue vehicles difficult or impossible without street clearing. Moving towards ground zero in the MD zone, rubble will completely block streets and require heavy equipment to clear.
- ❒ Within the MD zone, broken water, gas, electrical, and communication lines are expected and fires will be encountered.

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[4] In order to provide some basic parameters to describe the generic urban environment this document assumes a nominal 10 KT detonation in a modern city. While distances would vary, the zone descriptions apply to any size nuclear explosion. Building types will include a mix of high rise commercial structures of varying ages and design, with some residential high rises, and high daytime population density at the ground zero location. Building heights and population density are assumed to drop off with distance from the ground zero location in favor of low, lighter constructed buildings, and increased residential structures.

- Many casualties in the MD zone will survive, and these survivors, in comparison to survivors in other zones, will benefit most from urgent medical care.
- A number of hazards should be expected in the MD zone, including elevated radiation levels, potentially live downed power lines, ruptured gas lines, unstable structures, sharp metal objects and broken glass, ruptured vehicle fuel tanks, and other hazards.
- Visibility in much of the MD zone may be limited for an hour or more after the explosion because of dust raised by the shock wave and from collapsed buildings. Smoke from fires will also obscure visibility.
- Blast overpressures that characterize the MD zone are an outer boundary of about 2–3 psi and inner boundary of about 5–8 psi. When most buildings are severely damaged or collapsed, responders have encountered the severe damage zone.

Severe Damage (SD)[5] Zone:

- Few, if any, buildings are expected to be structurally sound or even standing in the SD zone, and very few people would survive; however, some people protected within stable structures (e.g., subterranean parking garages or subway tunnels) at the time of the explosion may survive the initial blast.
- Very high radiation levels from prompt and residual origin and other hazards are expected in the SD zone, significantly increasing risks to survivors and responders. Responders should enter this zone with great caution, only to rescue known survivors.
- Rubble in streets is estimated to be impassable in the SD zone making timely response impracticable. Approaching ground zero, all buildings will be rubble and rubble may be 30 feet deep or more.
- The SD zone may have a radius on the order of a 0.5 mile (0.8 km) for a 10 KT detonation. Blast overpressure that characterizes the SD zone is 5–8 psi and greater.

Figure 1.1 shows the 10 KT zones overlaid on a notional urban landscape.[6] Figure 1.2 provides a side by side summary of idealized damage zones to compare the distances projected for 0.1, 1, and 10 KT nuclear explosions.

[5] In the First Edition planning guidance the term No-go (NG) Zone was used for this third zone. Numerous responders and technical experts requested that severe damage zone be used for consistency with the theme of observable characteristic descriptors used for the first two zones presented as opposed to transitioning to an action oriented zone descriptor, as was the case for the NG Zone.

[6] Note that building damage is irregular; responders should expect to find many anomalies such as buildings collapsed where it seems they should be standing and standing where they should be collapsed and glass broken where nearby glass is still intact.

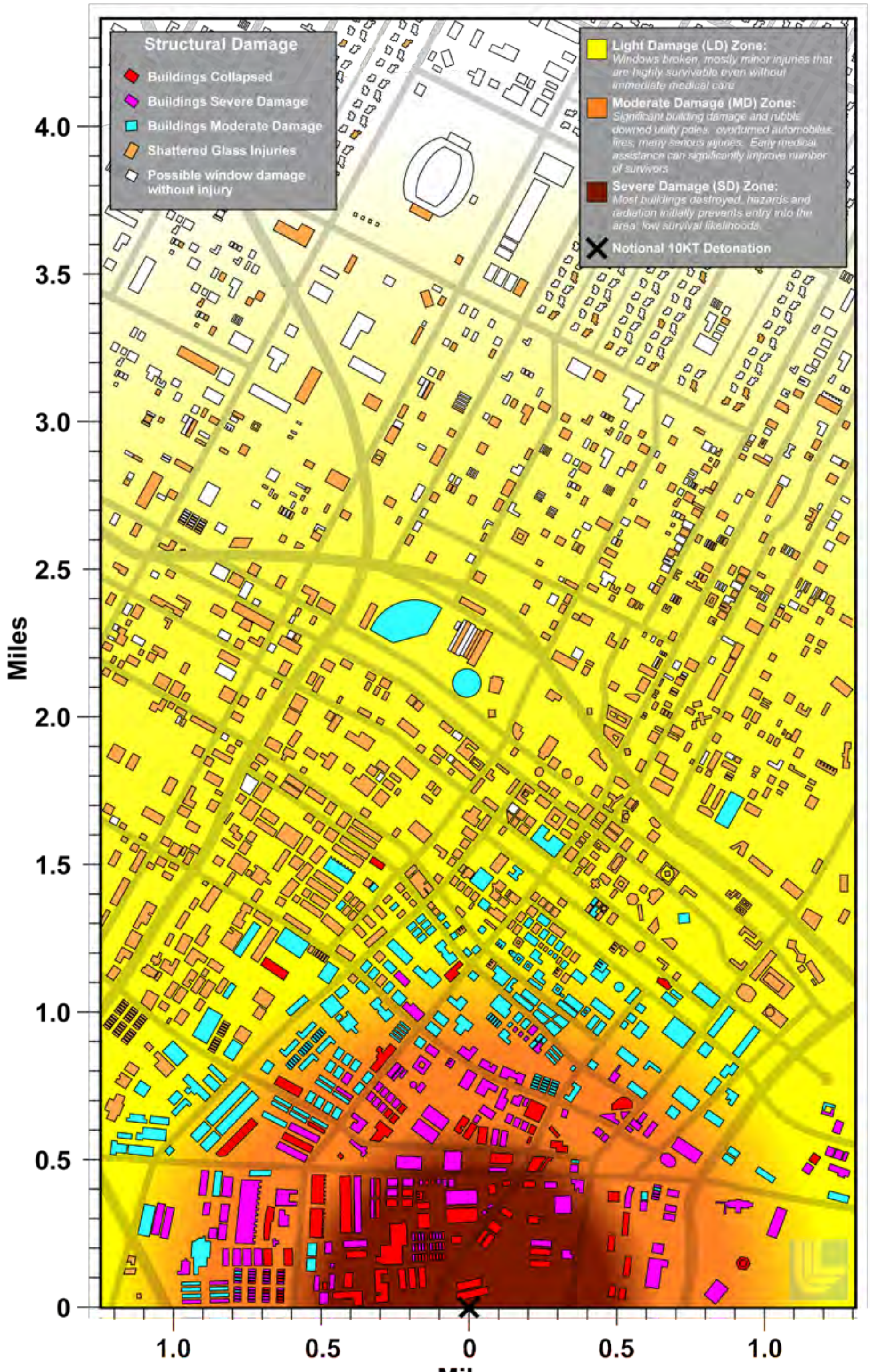

Figure 1.1: Representative damage zones for a 10 KT nuclear explosion overlaid on a notional urban environment.

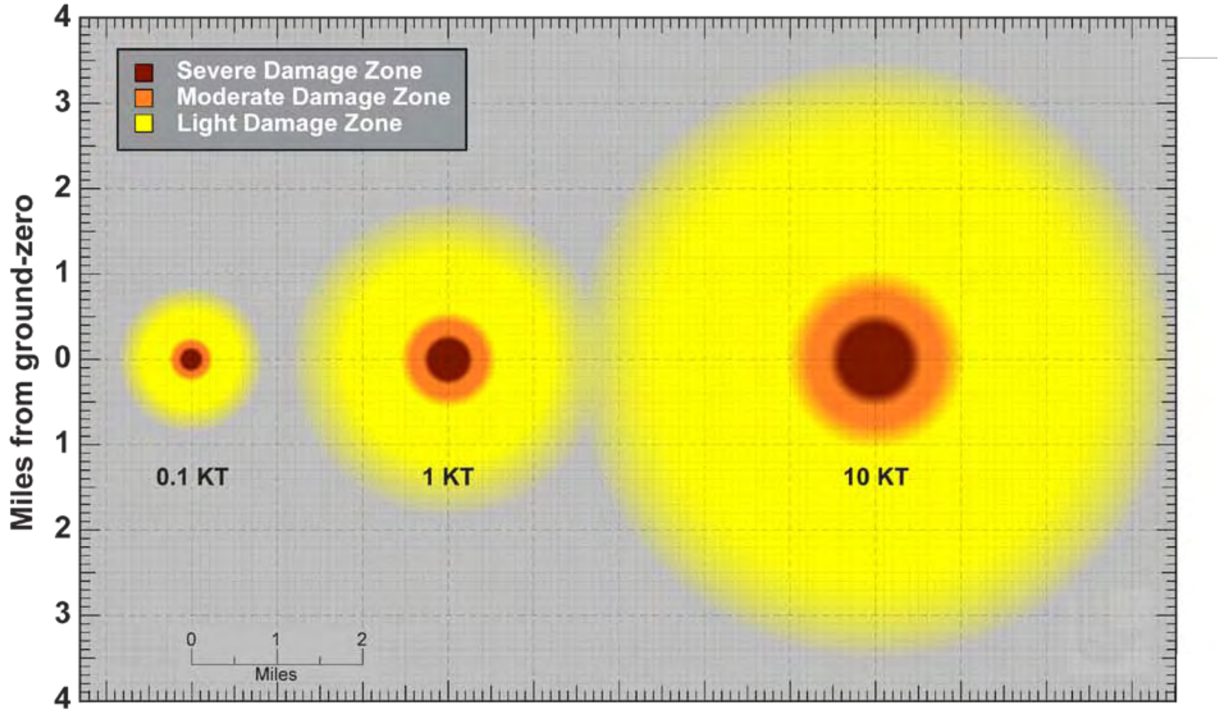

Figure 1.2: Representative damage zones for 0.1, 1, and 10 KT nuclear explosions (circles are idealized here for planning purposes)

The zone delineations are rough approximations that can assist response planners. They will be referred to during the remainder of Chapter 1 discussions and will be further developed for response planning in Chapter 2. There are no clear boundaries between the damage zones. The zones will need to be characterized based on observations by early response units and if possible by overhead photography.

There are no clear boundaries between the representative damage zones resulting from a nuclear explosion, but generally, the light damage (LD) zone is characterized by broken windows and easily managed injuries; the moderate damage (MD) zone by significant building damage, rubble, downed utility lines and some downed poles, overturned automobiles, fires, and serious injuries; and the severe damage (SD) zone by completely destroyed infrastructure and high radiation levels resulting in unlikely survival of victims.

It is important to recognize that the zones depicted in Figure 1.1 and 1.2 should be determined not by precise distances, but by the degree of observable physical damage. Nuclear weapon experts believe damage will be highly unpredictable; for example, some lighter buildings may survive closer to ground zero while robust structures may be destroyed under relatively low overpressure resulting from the complex way shock waves bounce off structures. Glass breakage is an important factor in assessing blast damage and injuries, but different kinds of glass break at widely varying overpressures. Some modern windows may survive within the MD zone, whereas others will shatter at distances far beyond the LD zone. The glass dimensions, hardening, thickness, and numerous other factors influence glass breakage. Zoned planning, however, will help officials estimate overall response needs and preplan the logistical support necessary for a response.

Although the description of effects and ranges used in this document is based on the 10 KT yield of NPS #1, it is important to emphasize again that the 10 KT ground burst provides a basis for planning purposes. Consideration of 0.1 and 1 KT yields in this chapter provides the planner an understanding of the range of physically damaged zones with smaller yields (Figure 1.2 and Figure 1.3). Table 1.2 provides approximate distances for LD, MD, and SD zones with the different yields.

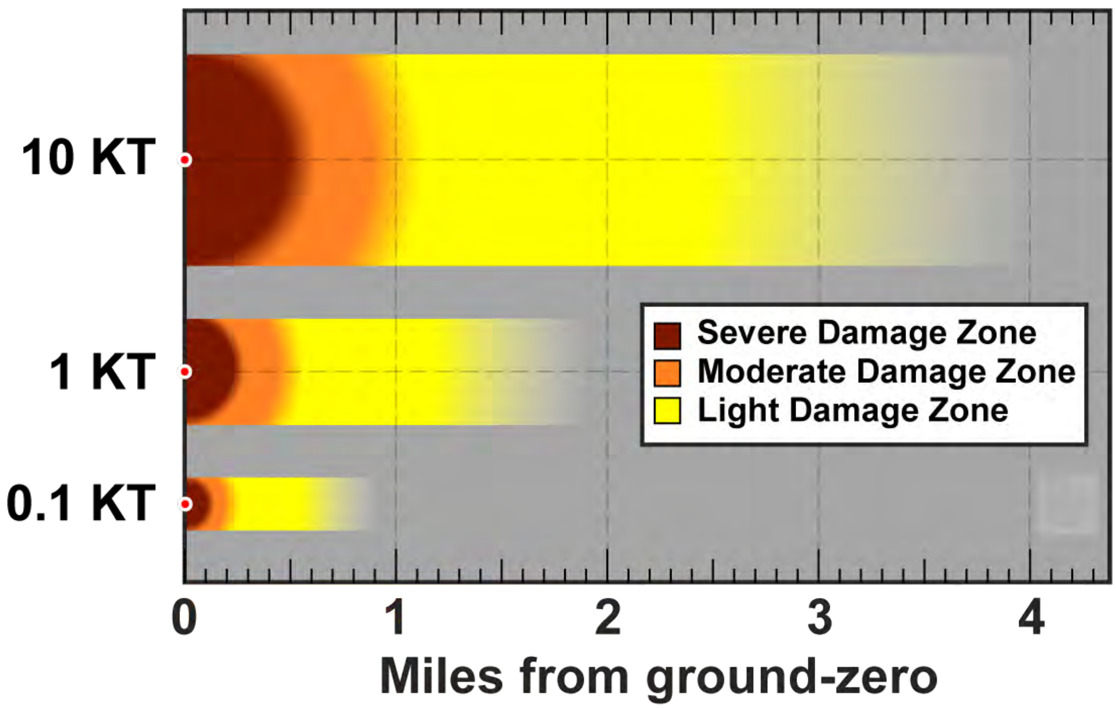

Figure 1.3 Zone distances for 0.1, 1, and 10 KT explosions are shown for zone size comparison.

Table 1.2: Approximate distances for zones with varying yield nuclear explosions.

10 KT Explosion • The Severe Damage Zone will extend to ~ ½ mile (0.8 km) • The Moderate Damage Zone will be from ~ ½ mile (0.8 km) to ~ 1 mile (1.6 km) • The Light Damage Zone will extend from ~ 1 mile (1.6 km) to ~3 miles (4.8 km)
1 KT Explosion • The Severe Damage Zone will extend to ~ ¼ mile (0.4 km) • The Moderate Damage Zone will be from ~ ¼ mile (0.4 km))to ~ ½ mile (0.8 km) • The Light Damage Zone will extend from ~ ½ (0.8 km) mile to ~2 miles (3.2 km)
0.1 KT Explosion • The Severe Damage Zone will extend to ~ 200 yards (0.2 km) • The Moderate Damage Zone will be from ~200 yards (0.2 km) to ~ ¼ mile (0.4 km) • The Light Damage Zone will extend from ~ ¼ mile (0.4 km) to ~1 mile (1.6 km)

Blast Injuries

Initially, blast causes the most casualties in a ground level urban nuclear explosion. As described earlier, ***blast effects*** consist of overpressure and dynamic pressure waves. Table 1.3 provides an overview of impacts on both structures and the human body relative to the peak overpressure of the blast wave. As shown in Table 1.3, the human body is remarkably resistant to overpressure, particularly when compared with rigid structures such as buildings. Although many would survive the blast overpressure itself, they will not easily survive the high velocity winds, or the crushing injuries incurred during the collapse of buildings (see Figure 1.4) from the blast overpressure or the impact of high velocity shrapnel (e.g., flying debris and glass).

Table 1.3: Impacts of peak overpressure of blast[7]

Peak Overpressure (psi)	Type of Structure	Degree of Damage
0.15-1	Windows	Moderate (broken)
3-5	Apartments	Moderate
3-5	Houses	Severe
6-8	Reinforced concrete building	Severe
6-8	Massive concrete building	Moderate
100	Personnel shelters	Severe (collapse)
Peak Overpressure (psi)	**Type of Injury to People in the Open**	
5	Threshold for eardrum rupture	
15	Threshold for serious lung damage	
50	50% incidence of fatal lung damage	

Blast wave destroys wood frame house
(16 KT, 0.6 miles away [1 km], ~6 psi, ~200 mph [320 km/h])

Figure 1.4: Blast wave effects on a house, indicating low survivability

Blast injuries, such as lung and eardrum damage, will likely be overshadowed by injuries related to collapsing structures. Many of these will be fatal injuries in the SD and MD zone. Further out, flying debris injuries will prevail. NATO medical response planning documents for nuclear detonations state that *"… missile injuries will predominate. About half of the patients seen will have wounds of their extremities. The thorax, abdomen, and head will be involved about equally."*[8] The American Academy of Ophthalmology noted *"Most injuries among survivors of conventional bombings have been shown to result from secondary effects of the blast by flying and falling glass, building material, and other debris. Despite the relative small surface area exposed, ocular injury is a frequent cause of* ***morbidity*** *in terrorist blast victims."*[9] The probability of penetrating injuries from flying debris increases with increasing velocity, particularly for small, sharp debris such as glass fragments. Single projectile injuries will be rare; however, multiple, varied projectile injuries will be common. Blast wave overpressures above 3 to 5 psi can produce flying debris and glass fragments with sufficient velocity to cause blunt trauma or deep lacerations resulting in injuries that require professional medical attention. For a 10 KT detonation, the range for these more serious impacts is about 0.5 – 1 mile (0.8 –1.6 km). However, broken and shattered windows will be observed at much greater distances. Large windows can break at blast wave pressures as low as 0.1 psi and people will be subject to injury from the glass falling from damaged tall

[7] Adapted from Glasstone and Dolan 1977; DOD 2001
[8] NATO – AmedP-6(b)
[9] Mines et al. 2000

buildings. For a 10 KT explosion, these lower pressure window breakages could occur more than 10 miles (16 km) from ground zero.

Thermal Radiation (or Heat)

An important effect of a nuclear detonation is the generation of an intense thermal pulse of energy (i.e., the nuclear flash). The thermal effect causes burns to people and may ignite certain flammable materials. The potential for fire ignition in modern cities from the nuclear thermal effect is poorly understood but remains a major concern. Fires may be started by the initial thermal effect igniting flammable materials. Secondary fires may be started by the ignition of gas from broken gas lines and ruptured fuel tanks.

Fires destroy infrastructure, pose a direct threat to survivors and responders, and may threaten people taking shelter or attempting to evacuate. If fires are able to grow and coalesce, a firestorm[10] could develop that would be beyond the abilities of firefighters to control. However, experts suggest in the nature of modern US city design and construction may make a raging firestorm unlikely.

The SD zone is not expected to be conducive to fires because of the enormous wind that ensues and because flammable sources are buried in deep rubble; however, leaking gas lines may still ignite. The MD zone is more likely to sustain fires because many buildings are expected to remain standing, but damage to infrastructure, such as blown out windows and broken gas lines and fuel tanks, is still extensive. Depending on the flammability of various materials and distance from ground zero, blast winds can either extinguish or fan the burning materials. The LD zone with minor infrastructure damage may also have fires, but these should be more easily contained and mitigated.

> A nuclear detonation is accompanied by a thermal pulse. The thermal pulse intensity at any given point will depend on distance from the detonation, the height of burst, and on any shielding from structures. In general, the thermal hazard is greatest in the case of a low-altitude air burst. General thermal effects will be less for ground bursts resulting from less direct line-of-sight contact with the energy radiating from the detonation. Ground bursts result in a large part of the thermal energy being absorbed by the ground and any buildings around ground zero. Partial and sometimes complete shadowing of the thermal pulse and fireball may be provided to people inside or behind buildings and other structures. Terrain irregularities, moisture, and various aerosols in the air near the surface of the earth will tend to reduce the amount of thermal energy that is transported at distance.

Thermal Injuries

Close to the fireball, the thermal energy is so intense that infrastructure and humans are incinerated. Immediate lethality would be 100% in close proximity. The distance of lethality will vary with nuclear yield, position of the burst relative to the earth's surface, line of sight

[10] A firestorm is a conflagration, which attains such intensity that it creates and sustains its own wind system that draws oxygen into the inferno to continue fueling the fires.

with respect to the fireball, type of clothing being worn, weather, environment, and how soon victims can receive medical care.

Thermal radiation emitted by a nuclear detonation causes burns in two ways; direct absorption of thermal energy through exposed surfaces (flash burns - see Figure 1.5) or indirectly from fires ignited by the burst. Thermal energy from the burst is delivered to bare skin or through clothing to the skin so quickly that burn patterns will be evident and the victim will be burned on the side facing the fireball. Tall city buildings between people and the fireball provide substantial shadowing from the burst and reduce the overall flash burn impact. However, people within line of sight of the burst may be subject to burn injuries up to two miles away for a 10 KT explosion. The farther away from ground zero, the less severe the burn injury will be for a person. Early treatment can reduce ***mortality*** rates among the severely burned victims.

The intense flash of light also provides a momentary signal to cover for those a mile or more away, if they are sufficiently aware. The speed of light, perceived as the flash, travels much faster than the blast overpressure allowing a few seconds for some people to take limited protective measures. It is anticipated that some injuries (e.g., eye injuries, blast injuries, particularly from flying debris and glass) can be prevented or reduced in severity if individuals that perceive an intense and unexpected flash of light as described here take immediate protective measures, such as getting away from windows, closing eyes, and lying flat (e.g., ***duck and cover***).

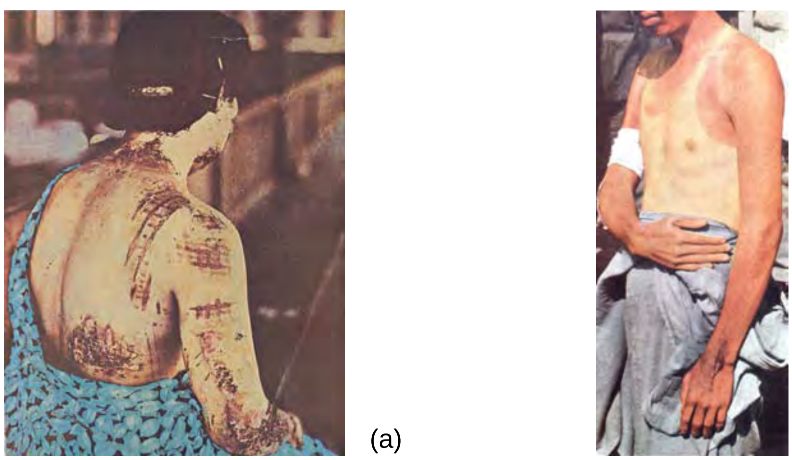
(a) (b)

Figure 1.5: Flash burn victims from (a) Hiroshima showing pattern burns (i.e., the dark colored material pattern on the victims clothing preferentially absorbed the thermal energy and burned the skin), and (b) Nagasaki showing profile burns (i.e., burns around the light colored clothing that reflected the thermal energy).

Secondary fires are expected to be prevalent in the MD zone. Secondary fires will result in burns treatable with basic medical procedures, but the health threat will be compounded by other injury mechanisms associated with a nuclear explosion.

Eye Injuries

Observation of the thermal flash can result in temporary or permanent eye injuries. Temporary flash blindness may occur in people who observed the flash of intense light energy, even via peripheral vision. Flash blindness is a condition that results from a depletion of photopigment from the retinal receptors. The duration of flash blindness can last several seconds when the exposure occurs during daylight. The blindness may then be followed by a darkened after-image that lasts for several minutes. At night, when one's pupils are fully dilated, flash blindness may last for up to 30 minutes and may occur up to 15 miles (24 km) away from the detonation resulting in traffic accidents far removed from the damage zones. Also, regardless of daylight, retinal photochemical reactions can be caused by the ultraviolet part of the light spectrum causing eye complications.

> The intense visible light that occurs is one of the hallmarks of a nuclear explosion; it can be seen from many miles away. Sudden exposures to such high-intensity sources of light can cause eye injury, specifically to the retina and lens. Factors that determine the extent of eye injury include pupil dilation, spectral transmission through the ocular media, spectral absorption by the retina and choroid, length of time of exposure, and the size and quality of the image. Eye injury is a result of not only thermal energy but also photochemical reactions that occur within the retina with light wavelengths in the range of 400 to 500 nanometers.

Direct observation of the highly intense flash of light from a nuclear detonation can also cause macular-retinal burns. Burns of the macula will result in permanent scarring with resultant loss in visual acuity, or blindness. Burns of the peripheral regions of the retina will produce scotomas (blind spots), but overall visual acuity will be less impaired. These burns can occur at distances of several miles under optimal conditions and roughly double in range at night.

> It is anticipated that some injuries (e.g., eye injuries, blast injuries — particularly from flying debris and glass) can be prevented or reduced in severity if individuals that perceive an intense and unexpected flash of light seek immediate cover. The speed of light, perceived as the flash, will travel faster than the blast overpressure allowing a few seconds for some people to take limited protective measures.

Radiation and Fallout

One of the primary outputs from a nuclear explosion is radiation. Radiation from a nuclear explosion is categorized as initial nuclear radiation (prompt radiation and neutron activation), which occurs nearly instantaneously with the flash, and residual radiation, which occurs after the initial explosion and is largely associated with radioactive fallout. Initial radiation can be an important contributor to casualties, particularly in the SD zone. The intensity of initial nuclear radiation, however, decreases with distance from ground zero. This decrease is a result of the radial dispersion of radiation as it travels away from the point of detonation and the absorption, scattering, and capture of radiation by the atmosphere and buildings. Buildings help to block the direct path of initial radiation; however, even if an individual is shielded behind buildings, reflected radiation off the atmosphere can still deliver a ***dose*** at levels that could make people sick or, if the shielding is not thick enough, possibly lead to death some weeks or months after the explosion. In an urban area, it is expected that those close enough to receive a lethal dose from initial radiation are likely to receive fatal injuries from other mechanisms of the blast. Moreover, sub-lethal doses of radiation also can induce acute health effects.

Fallout is a major source of residual radiation hazard. During the fission process, radionuclides, called ***fission products***, are created. Radionuclides emit dangerous gamma and beta radiation. After the explosion, these radionuclides attach to airborne particles of varying sizes to form fallout. If the detonation occurs near the earth's surface, fallout can be especially prevalent as the shock wave crushes and loosens thousands of tons of earth and urban infrastructure (e.g., buildings, roads, concrete) that can become caught in the fireball. Some of this material will be vaporized by the intense heat of the fireball, some will be partially melted, and some will remain essentially unchanged, but all of it becomes fallout.

The majority of the radioactivity in fallout comes from radionuclides produced during detonation (e.g., uranium or plutonium nuclei splitting apart in the fission reaction). These numerous fission radionuclides have widely differing radioactive half-lives ranging from fractions of a second to several months or years.[11] A smaller contributor to residual radiation is induced radioactivity (by activation) of local materials. The absorption of neutrons in materials can make them radioactive and cause them to emit beta and gamma radiation. These radioactive materials decay in the same manner as fission products. Most importantly, neutron activation of materials in the ground and structures in close proximity to ground zero also adds to residual radiation.

As the fallout cloud rises, winds transport radioactive particles from the cloud and carry fallout over significant distances downwind. The fallout pattern will be irregular; rarely does it form easily predictable deposition patterns. Winds of varying speed and direction at different levels of lower and upper atmosphere push the fireball and the descending fallout material in directions that may not be evident from ground-level observation. Therefore, ground-level winds alone should never be used to predict the path of fallout deposition.

As a rule, the most hazardous fallout particles are readily visible as fine sand-sized grains. However, the lack of apparent fallout should not suggest the lack of radiation; therefore, **appropriate radiation monitoring should always be performed to determine the safety of an area**. Fallout that is immediately hazardous to the public and emergency responders will descend to the ground within about 24 hours. The most significant fallout hazard area will extend 10 to 20 miles (16 – 32 km) from ground zero (for a 10 KT explosion), but this will vary with nuclear yield. Within a few miles of ground zero, ***exposure rates*** in excess of 100 ***R/h*** during the first four to six hours post-detonation may be observed.

The area covered by fallout that impacts responder life-saving operations and/or has acute radiation injury potential to the population is known as the dangerous fallout (DF) zone.

[11] The radioactive half-life for a given radionuclide is the time for half the radioactive nuclei in a given sample to undergo radioactive decay. After two half-lives, there will be one-fourth of the original sample, after three half-lives one-eighth of the original sample, and so forth.

Unlike the LD, MD, and SD zones, the DF zone is distinguished not by structural damage, but by radiation levels. A radiation ***exposure rate*** of 10 R/h is used to bound this zone, and the DF zone may span across both the LD and MD zones. While fallout may trigger consideration of PAGs hundreds of miles away, the DF zone pertains to near-in areas (extending 10-20 miles) where activities that limit acute radiation injuries should be focused. Figure 1.6 illustrates the relation of the DF zone to zones LD, MD and SD for three different nuclear yields.

> The most hazardous fallout particles are readily visible as fine sand-sized grains. However, the lack of apparent fallout should not suggest the lack of radiation; therefore, appropriate radiation monitoring should always be performed to determine the safety of an area. Fallout that is immediately hazardous to the public and emergency responders will descend to the ground within about 24 hours.

The DF zone is a hazardous area and any response operations within it must be justified, optimized, and planned. It is important that responders refrain from undertaking missions in areas where radioactivity may be present until radiation levels can be accurately determined and readily monitored. Responder planning recommendations for the DF zone are provided in Chapter 2.

Beyond 20 miles (32 km), sheltering may be warranted to minimize radiation exposure to the population. As a general rule, all should immediately seek adequate shelter to avoid potential exposure to fallout prior to any consideration for evacuation. See Chapter 3 for additional discussion.

Contamination from fallout will hinder response operations in the local fallout areas and may preclude some actions before sufficient radioactive decay has occurred. However, the fallout will be subject to rapid radioactive decay and the DF zone will immediately begin to shrink in size with time. Monitoring ground radiation levels is imperative for the response community. Combining the measured radiation levels with predictive plume models and/or aerial measurement systems can prove invaluable in determining response operations and developing protective action decisions.

As stated earlier, radionuclides in fallout decay rapidly. However, significant decay does not necessarily mean low radioactivity. Because of this rapid decay, the boundary of the DF zone changes rapidly in the first few days. It reaches its maximum extent after the first few hours and then shrinks in size, perhaps going from 10 miles (16 km) or more to a mile or two in just one day.

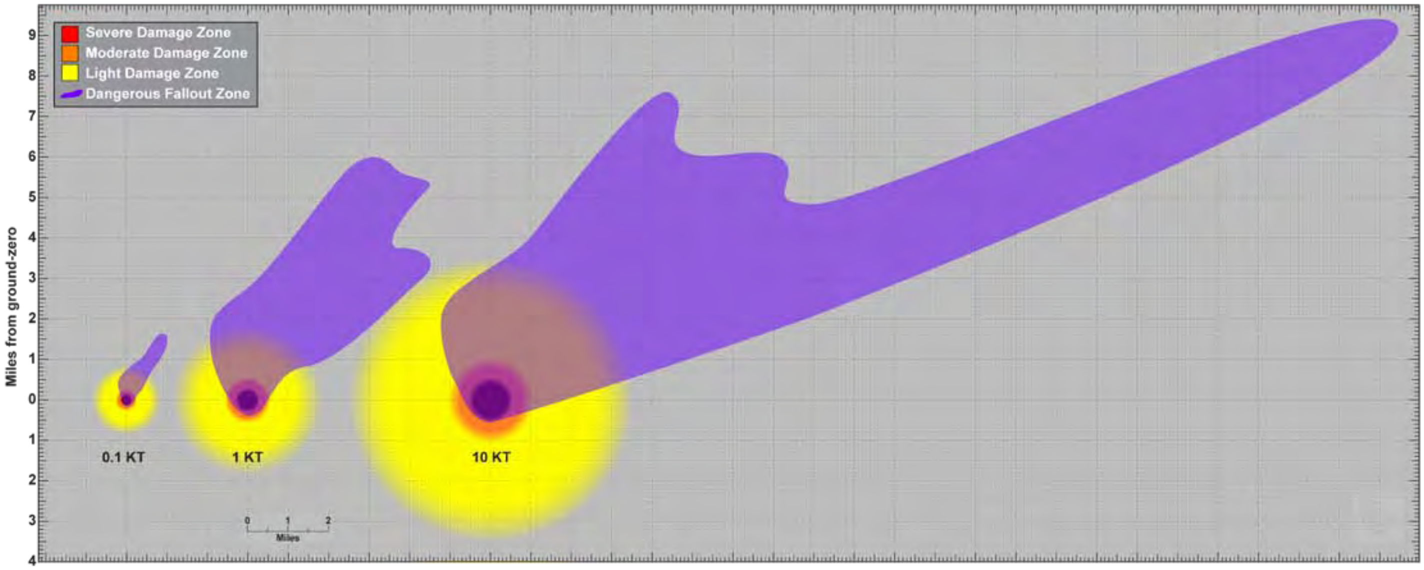

Figure 1.6: Representative dangerous fallout (DF) zones for 0.1KT, 1.0KT and 10 KT in which an early and direct threat from fallout radioactivity exists. A radiation *exposure rate* of 10 R/h is used to bound this zone. The DF zone will begin to shrink immediately and decrease relatively quickly over time.

The decay of nuclear weapons ***fission products*** is approximated by the relationship, $R_t = R_1 t^{-1.2}$, where R_t is the gamma radiation dose rate at time t after the explosion (in hours) and R_1 is the dose rate at unit time (one hour). A standard rule of thumb for the decay, called the 7–10 rule, makes for easy approximations. This rule states that for every sevenfold increase in time after detonation, there is a tenfold decrease in the radiation rate. Table 1.4 summarizes relative dose rates at various times after a nuclear explosion. However, there is a small fraction of fallout that remains radioactive for many years. The following explanation and accompanying Table 1.4 are from *The Effects of Nuclear Weapons*, by Glasstone and Dolan 1977:

> *"For example, if the radiation dose rate at 1 hour after the explosion is taken as a reference point, then at 7 hours after the explosion the dose rate will have decreased to one-tenth; at 7x7 = 49 hours (or roughly 2 days) it will be one-hundredth; and at 7x7x7 = 343 hours (or roughly 2 weeks) the dose rate will be one-thousandth of that at 1 hour after the burst. Another aspect of the rule is that at the end of 1 week (7 days), the radiation dose rate will be about one tenth of the value after 1 day. This rule is accurate to within about 25 percent up to 2 weeks or so and is applicable to within a factor of two up to roughly 6 months after the nuclear detonation."*

Both responders and the public should be aware that while substantial radioactive decay occurs early on, the original radioactivity may be so high that the residual radioactivity may still be elevated to hazardous levels, even after several days.

Table 1.4: Example dose rate decay from early fallout tracked as a function of time after a nuclear explosion; adapted from Glasstone and Dolan[12]

Time (hours)	Dose Rate (R/h)	Time (hours)	Dose Rate (R/h)
1	1,000	36	15
1.5	610	48 (2 days)	10
2	400	72 (3 days)	6.2
3	230	100 (~ 4days)	4.0
5	130	200 (~ 8 days)	1.7
6	100	400 (~ 17 days)	0.69
10	63	600 (~ 25 days)	0.40
15	40	800 (~ 33 days)	0.31
24	23	1,000 (~ 42 days)	0.24

Finally, fallout travels substantial distances beyond the DF zone boundary. Outside of the DF zone radiation levels would not present an acute threat; however, fallout in areas up to hundreds of miles away may warrant protective actions (e.g., sheltering and/or evacuation, food collection prohibitions, and water advisories). Fallout deposition at great distances (e.g., 100 miles) is dictated by the parameters of winds at altitudes of the fallout cloud. Fallout of fine particle size will continue to move on these winds and have a low-level continental impact.

To bound the radiation concerns beyond the DF zone, it is necessary to consider radiation levels characterized in the context of other radiation emergency planning such as for

[12] Glasstone and Dolan 1977

radiological dispersal devices (RDDs) and transportation accidents that involve radiation. A number of authoritative guidance documents have been produced that cite a zone bounded by a radiation dose rate of 0.01 R/h (10 mR/h) and characterize the area as the '*hot zone*.'[13] The area bounded by 0.01 R/h may be depicted as an area where radioactivity is found, and the radiation hazard is lower closest to the 0.01 R/h boundary while and the radiation hazard increases approaching the 10 R/h boundary. In routine radiation emergency response entering the zone bounded by 0.01 R/h entails donning appropriate ***personal protective equipment (PPE)*** and being properly monitored for radiation. For a nuclear detonation, the 0.01 R/h line can reach a maximum extent of several hundred miles within hours of the incident (see Figure 1.7). Like the DF zone, this zone will shrink in size due to decay after it reaches a maximum size (see Figure 1.8). Provided responders take appropriate planning and dose monitoring measures, emergency operations can be safely performed within the area bounded by 0.01 R/h. The area bounded by 0.01 R/h should raise awareness of all responders operating in the zone and result in establishing staging, triage, and reception centers outside of this area whenever possible.

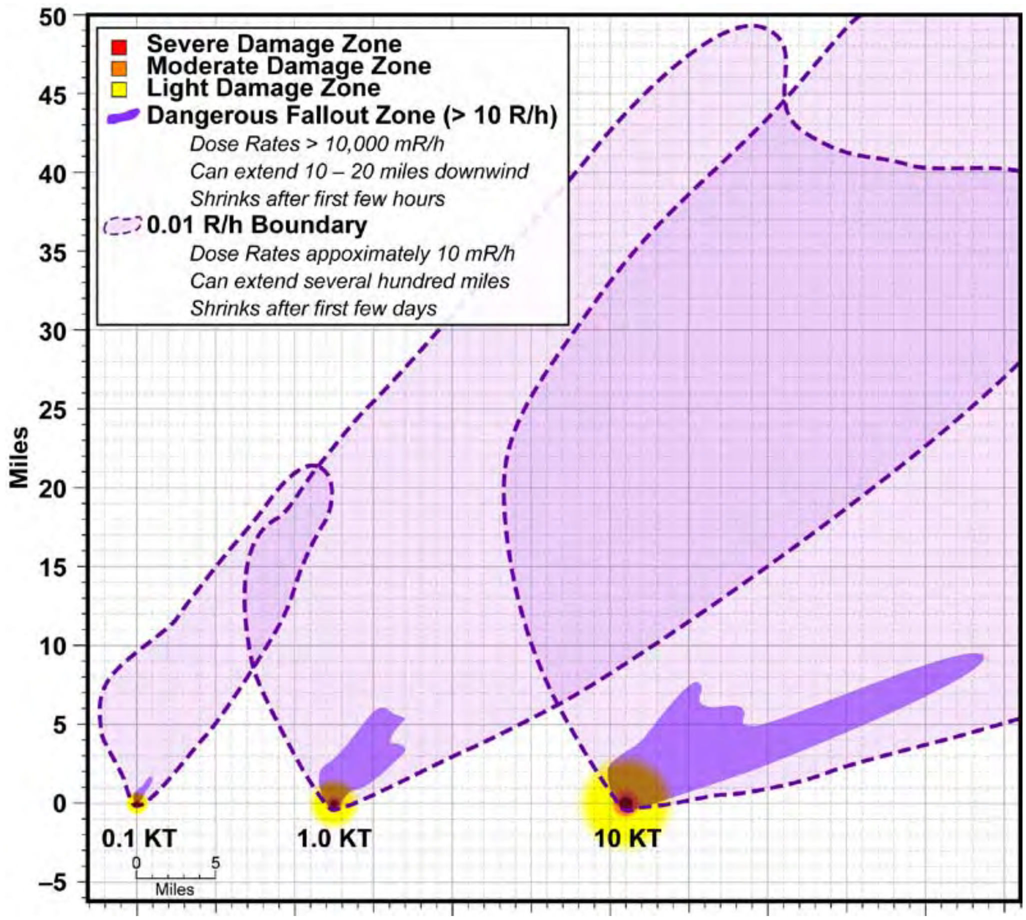

Figure 1.7. Addition of the 10 mR/h boundary to LD, MD, SD, and DF zones (the zone bounded by 0.01 R/h for the 10 KT scenario can extend 100's of miles at its maximum extent)

[13] ASTM E2601-08 (for radiation emergencies including RDDs); IAEA 2006; NCRP Report 165, 2010

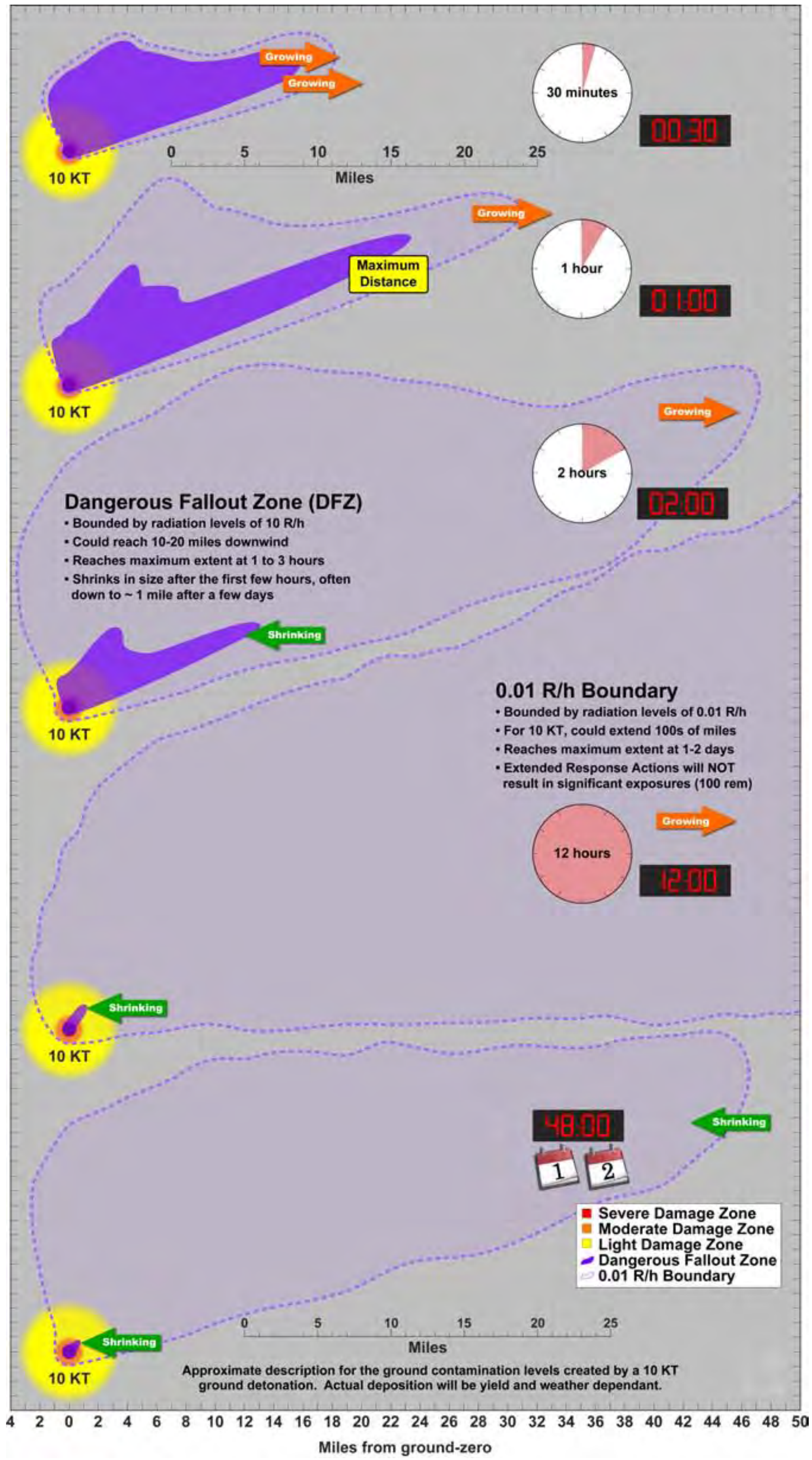

Figure 1.8. Time sequenced size of DF zone and 0.01 R/h boundary for the 10 KT ground burst scenario

Radiation Injuries and Fallout Health Impacts

A nuclear explosion will produce dangerous levels of initial nuclear radiation to those within a ½ mile from ground zero, and radiation from fallout radiation within 10 – 20 miles (16 – 32 km) downwind. In a fallout zone, external exposure to gamma radiation is the dominant health concern, but beta radiation will cause severe tissue damage when fallout material remains in contact with unprotected skin resulting in '***beta burns***.' Excessive radiation dose can cause acute health effects (short-term effects), including death, and long-term health risks, especially cancer. Moderate to large radiation doses are known to increase cancer, and any radiation dose is assumed to contribute to an increased risk of cancer. Generally, radiation doses received over a longer period of time are less harmful than doses received instantaneously.

Fallout effects are potentially avoidable unlike initial effects. Close in to the explosion out to about 10 to 20 miles (16 – 32 km) from ground zero, unsheltered people could receive acute and even lethal radiation doses. The lethal dose (LD_{50})[14] for untreated patients is approximately 400 ***rads*** (4 Gy). Medical care increases one's chances of survival up to a dose of ~600 rads (6 Gy). Even with medical care, many victims that receive radiation doses over ~600 rads (6 Gy) would not be expected to survive. The time to death for these victims ranges from several weeks to a few months. A simplified acute radiation dose chart is shown below (Table 1.5). From this chart, responders will note that if they are subjected to acute doses above ~200 rad (2 Gy), they will likely be unable to perform their jobs adequately and be at risk of becoming a casualty themselves. Below the range of acute effects, the risk of cancer is increased over a person's lifetime.

[14] LD_{50} refers to the radiation absorbed dose that would prove lethal to 50% of an exposed population without the benefit of medical care. LD_{50} is approximately 350 rad (3.5 Gy). Some citations report LD_{50} as 400 rad (4 Gy).

Table 1.5: Death from acute radiation exposure as a function of whole-body absorbed doses (for adults), for use in decision making after short-term[a] radiation exposure adapted from NCRP, AFRRI, Goans, IAEA, ICRP and Mettler.[15]

Short-Term Whole-Body Dose [rad (Gy)]	Death[b] from Acute Radiation Without Medical Treatment (%)	Death from Acute Radiation with Medical Treatment (%)	Acute Symptoms (nausea and vomiting within 4 h) (%)
1 (0.01)	0	0	0
10 (0.1)	0	0	0
50 (0.5)	0	0	0
100 (1)	<5	0	5 – 30
150 (1.5)	<5	<5	40
200 (2)	5	<5	60
300 (3)	30 – 50	15 – 30	75
600 (6)	95 – 100	50	100
1,000 (10)	100	>90	100

[a]Short-term refers to the radiation exposure during the initial response to the incident. The acute effects listed are likely to be reduced by about one-half if radiation exposure occurs over weeks.
[b]Acute deaths are likely to occur from 30 to 180 d after exposure and few if any after that time. Estimates are for healthy adults. Individuals with other injuries, and children, will be at greater risk.

In zones where acute or lethal doses may occur, attention should be directed towards minimizing doses to levels as low as can be achieved to maximize survival under the circumstances. In zones further away and where relatively low radiation ***doses*** are observed (e.g., from low level fallout only), attention should be given to managing radiation exposures with the goal of minimizing cancer risk and other potential long-term effects. Chapters 2 and 3 provide more information on radiation ***dose*** management and protective actions.

Perhaps the most effective life-saving opportunity for response officials in the first hour following a nuclear explosion will be the decision to shelter populations in the expected dangerous fallout areas. When individuals remain in nuclear fallout areas unsheltered, the fallout deposited on the ground and roofs will lead to an immediate external radiation exposure from gamma radiation. The radiation dose from fallout is often referred to as the ground shine dose and it will typically be orders of magnitude greater than internal hazards resulting from inhalation or ingestion of radioactive material in the DF zone. To mitigate internal contamination, respiratory protection for the public, even ad hoc protection (e.g., holding a cloth over one's mouth and nose), is better than no protection at all. Sheltering is often associated with life sustaining and protection actions; however, because of the radiation present immediately following a nuclear explosion, sheltering in place, especially in the immediate hours after the explosion, serves a significant life saving function.

Emergency responder respiratory protection recommendations are provided in Chapter 2, "Response Worker Safety." A number of studies exist for additional guidance.[16]

[15] NCRP 2005; DOD 2003; Goans and Wasalenko 2005; IAEA 1998; ICRP 1991; Mettler and Upton 1995
[16] Studies include: Cooper et al. 1983a, 1983b; Guyton et al. 1959; Sorensen and Vogt 2001.

Fallout exposure can be effectively minimized by taking shelter in a sufficiently protective structure. It is critical that pre-incident public education address this protective action measure directly with the public. Emergency responders should attempt to transmit shelter or evacuation recommendations to the public. In order to follow recommendations and make their own decisions, individuals need to understand the shelter adequacy of the shelter in which they are located. In times of disaster, people will not be able to discern which shelters are more adequate than others. Thus, response planners should implement public messaging prior to the disaster. Sheltering and evacuation is the subject of Chapter 3.

Many people will need at least rudimentary decontamination when they arrive at a location where they choose for shelter. Effective decontamination of people from fallout is straightforward (i.e., remove clothes and shower). If contamination is not brushed or washed off, it can cause ***beta burns*** to the skin. If responders find themselves caught in an area during active fallout from the plume, they should find suitable shelter and then brush each other off. Decontamination needs will place additional constraints on responder resources. Planners need to collaborate with the various agencies regarding who will provide general screening and decontamination for people and their pets before they arrive at shelter locations. Mass decontamination of populations can involve sending people home or to an alternate location to change clothes and shower. This subject is addressed in Chapter 5.

Finally, the population must be warned about the hazards from ingesting fallout in the 24-48 hours when they may be in the DF zone. This includes water that may have collected fallout as well as foodstuffs. Doses from ingestion are potentially high if no consideration is given to avoiding it.

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. Because of the unique nature of radiation dangers associated with a nuclear explosion, the most lives will be saved in the first 60 minutes through sheltering in place.

Combined Injuries

Nuclear explosions produce thermal, blast, and radiation injuries that will often occur in combination. Research has led to the finding that the prognosis of patients suffering from both radiation and traumatic injuries (including burns) will be worse than the prognosis of patients suffering the same magnitude of either trauma or radiation exposure alone. For example, the lethality of a radiation dose of ~400 rad (4 Gy) in an untreated populations with compounding injuries may be reduced to as low as 250 rad (2.5 Gy). Combined-injury patients who have received significant, but less than lethal, radiation doses (100 to 200 rads, or equivalently, 1 to 2 Gy) will also require more support than those who have traumatic injuries alone. See Chapter 4 for greater detail.

Blast, thermal, and radiation injuries in combination will result in worse prognoses for patients than only sustaining one independent injury.

EMP

A phenomenon associated with a nuclear detonation called ***electromagnetic pulse (EMP)*** poses no direct health threat, but can be very damaging to electronic equipment. EMP is an electromagnetic field generated from the detonation that produces a high-voltage surge. This voltage surge can impact electronic components that it reaches. The EMP phenomenon is a major effect for large bursts at very high altitude, but it is not well understood how it radiates outward from a ground level burst, as considered in this guidance, and to what degree it will damage the electronic systems that permeate modern society. Although experts have not achieved consensus on expected impacts, generally they believe that the most severe consequence of the pulse would not travel beyond about 2 miles (3.2 km) to 5 miles (8 km) from a ground level 10 KT explosion. Stalling of vehicles, communications equipment (cell towers, ect.) electronics destroyed or disrupted, computer equipment electrical components destroyed, control systems electrical components destroyed, water and electrical system control components destroyed or disrupted, and other electronic devices damage could result. Another EMP phenomenon called source-region EMP may lead to conductance of electricity through conducting materials (e.g., pipes and wires) and could cause damage much farther away, but this subject requires further research and analysis. Because the extent of the EMP effect is expected to occur relatively close to ground zero, other effects of the explosion (such as blast destruction) are expected to dominate over the EMP effect. Equipment brought in from unaffected areas should function normally if communications towers and repeaters remain functioning.

EMP effects could result in extensive electronics disruptions complicating the function of communications, computers, and other essential electronic equipment. Equipment brought in from unaffected areas should function normally if communications towers and repeaters remain functioning.

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Chapter 2 - A Zoned Approach to Nuclear Detonation

KEY POINTS

1. The goal of a zoned approach to nuclear detonation response is to save lives, while managing risks to emergency response worker life and health.
2. Response to a nuclear detonation will be provided from neighboring response units; therefore, advance planning is required to establish mutual aid agreements and response protocols.
3. Radiation safety and measurement training should be required of any workers that would be deployed to a radiation area. Response teams should not enter affected areas without first confirming the level of radioactivity in the area they are entering.
4. Most of the injuries incurred within the light damage (LD) zone are not expected to be life threatening. Most of the injuries would be associated with flying glass and debris from the blast wave and traffic accidents. The benefits of rescue of ambulatory survivors in the LD zone are low. If injured survivors are able to move on their own, emergency responder actions should focus on directing citizens to medical care or assembly shelters and proceeding towards the moderate damage (MD) zone where victim rescue will be needed most.
5. Responders should focus medical attention in the LD zone only on severe injuries and should encourage and direct individuals to shelter in safe locations to expedite access to severely injured individuals.
6. Response within the MD zone requires planners to prepare for elevated radiation levels, unstable buildings and other structures, downed power lines, ruptured gas lines, hazardous (perhaps airborne) chemicals, sharp metal objects, broken glass, and fires.
7. The MD zone should be the focus of early life-saving operations. Early response activities should focus on medical triage with constant consideration of radiation dose minimization.
8. Response within the severe damage (SD) zone should not be attempted until radiation dose rates have dropped substantially in the days following a nuclear detonation, and the MD zone response is significantly advanced. All response missions must be justified to minimize responder risks based on risk/benefit considerations built into worker safety.
9. In physical locations where the dangerous fallout (DF) zone overlaps the LD or MD zones, response activities should be guided by the potentially lethal radiation hazard of the DF zone.
10. The most important mission in the DF zone is communicating protective action orders to the public. Effective preparedness requires public education, effective communication plans, messages, and means of delivery in the DF zone.
11. Urban search and rescue operations will be most efficiently and effectively engaged in non-radiologically contaminated areas of the MD zones.
12. Decontamination efforts should be limited to those locations that are absolutely necessary to use or occupy to accomplish life saving, including emergency infrastructure and infrastructure that might facilitate life saving (e.g., emergency gas line shutdown).
13. Decontamination of critical infrastructure should be initiated only when basic information becomes available regarding fallout distribution, current and projected radiation dose rates, and structural integrity of the elements to be decontaminated.
14. Standard health physics instruments and alternative radiation detection systems can be used to enhance detection capabilities.
15. All radiation detection systems should be used within their functional limits and design specifications. Also, responders may need additional training to use systems with which they are familiar in new situations.

Overview

As stated in Chapter 1, defining zones can be a useful approach to planning and executing a response, including predicting casualties and medical needs, determining where to locate staging areas, determining incident management requirements, assessing potential worker hazards, determining how to access affected areas, and prioritizing mission objectives especially for medical triage. The zones in this recommended approach are based on visual indicators of physical damage and on radiation levels that will need to be determined in the field. The basic zones were described in Chapter 1 and their use is elaborated here.

While not a focus of this document, establishing communications after a nuclear explosion is expected to be difficult due to local damage to communications infrastructure, and potentially damaging ***electromagnetic pulse (EMP)***. Communications among responders will be critical to effective response operations, and local planners are encouraged to consider emergency communications systems that may be utilized in the wake of a catastrophic incident. The ability to communicate directly to the public is also essential, and may be critical to saving lives after a nuclear explosion.

While presented generically here, response planning must be done on a city-specific basis using city-specific impact assessments. The priority of saving lives is emphasized together with protecting emergency response workers. In each case, the guiding principle when performing a response is to ensure that the overall benefits (primarily lives saved) outweigh the risks (primarily risks to response worker life and health). The guiding principle for planning a response action is to optimize the response by maximizing the total benefits expected and minimizing the total risk (radiation and non-radiation risks) to the responder. Thus, the risk-benefit balance must address not just a single mission under consideration, but the need for responders to continue response missions for days to come as the response progresses.

> The goal of a zoned approach to nuclear detonation response is to save lives while also managing risks to emergency response worker life and health.

Zoned Approach to Response

The physical and radiological (***fallout***) impacts of nuclear explosion may be extensive making local response to the incident particularly difficult. Responder units within one or two miles from ground zero at the time of a nuclear explosion may be compromised or completely nonfunctional. However, response capabilities more than five miles away from ground zero are likely to be only nominally affected by blast and EMP and should be able to mobilize and respond, provided they are not within the path of dangerous fallout levels. Therefore, response capabilities and resources may be mostly provided by neighboring boroughs, suburbs, cities, counties, and States through mutual aid agreements or other planning mechanisms. Some neighboring response capabilities, however, will be directly affected by fallout and advised to ***shelter*** until ***dose*** rates have fallen.[1] Response personnel should not enter lethal dose zones for any reason. Regional response planning in advance of a nuclear explosion is imperative to maximize response efficacy.

[1] In the scenario being considered here, a ground level nuclear explosion will generate a large amount of dangerous fallout.

Response to a nuclear detonation will largely be provided from neighboring response units; therefore, advance planning is required to establish mutual aid agreements and response protocols.

The hazard from high radioactivity is an ever-present threat for responders and survivors in the early post-detonation time period. Radioactivity cannot be seen or felt; it must be detected and measured with specialized equipment capable of measuring high levels of radioactivity consistent with a nuclear detonation. All radiation detection systems should be used within their functional limits. Radiation safety and measurement training should be required of any workers deployed to radiation areas. Response teams should not enter affected areas without first confirming the level of radioactivity in the area they are entering. The selection of radiation detection equipment is addressed in the last section of Chapter 2.

Radiation safety and measurement training should be required of any workers that could potentially be deployed to a radiation area. Response teams should not enter affected areas without first confirming the level of radioactivity in the area they are entering.

Planners and responders should remember that dose rates will be decreasing significantly in the first 48 hours. The level of radioactivity will need to be monitored periodically to properly characterize the changing hazard. Federal assets to support radiation monitoring will become available in the early days following a nuclear explosion, but local responders will be operating without substantial Federal support on the ground for approximately 24 to 72 hours. Beginning 15 minutes to 1 hour after a nuclear detonation, the Department of Homeland Security (DHS) led Interagency Modeling and Atmospheric Assessment Center (IMAAC) will begin to provide plume and fallout projections to Federal, State, and local authorities. Under the National Response Framework, the IMAAC "*provides a single point for the coordination and dissemination of Federal dispersion modeling and hazard prediction products that represent the Federal position*" during actual or potential incidents.[2] The Department of Energy (DOE) National Atmospheric Release Advisory Center serves as the operations hub for the IMAAC. IMAAC fallout maps provide guidance on potentially contaminated areas and impacted populations and are useful for planning radiation monitoring. As the response continues, IMAAC uses field data to refine model predictions, reducing the degree of uncertainty in the estimated impacts. Other DOE assets will begin arriving in 24 – 72 hours including Radiological Assistance Program (RAP) teams and Federal Radiological Monitoring and Assessment Center (FRMAC) resources that can aid with actual measurements of radiation. IMAAC cooperates closely with the FRMAC to provide updated maps of estimated dose and dose rates.

Response Functions and Priorities

Response teams that may use a zoned response approach to nuclear explosion response include radiation assessment support teams, police and fire fighters, emergency medical personnel, search and rescue teams, Hazmat teams, engineering response teams,[3] medical triage units, and response support functions. The main objective of early response is the preservation of life. While the life-saving objective is aimed at the general public, the safety and health of response

[2] http://imaacweb.llnl.gov
[3] The term engineering response teams is used here to include teams of workers tasked with clearing rubble and debris from transportation routes, repairing critical transportation infrastructure, stabilizing damaged utilities (e.g., gas, electric, and water), assessing structural damages to buildings, bridges, and other structures, and other critical engineering-related tasks.

workers is also essential. Response plans must be optimized to maximize the benefits while minimizing the total risks to the responders, including protecting responders and maximizing responder resources available for the duration of the response. Security of medical facilities and supplies should also be considered in planning. During the first hours and days after a nuclear attack, as many as one hundred thousand[4] individuals may live or die depending on their ability to choose appropriate protective actions and on the ability of responders to treat injuries, fight fires, and protect people from lethal exposures to radiation.

A number of nuclear explosion effects, as described in Chapter 1, severely hinder life-saving missions.[5] Successful execution of life-saving and other critical response missions, such as search and rescue and fire fighting, is determined in part by the incident area conditions. Area access for such missions is likely to be severely hindered by debris and rubble, fire, smoke and dust, stalled and crashed automobiles, and downed power lines. Fire fighting may be hampered or prevented by low or no water pressure. Worker safety concerns will affect response planning and mission execution. Planning for response in impacted areas according to zones (by type and magnitude of physical impact and level of radiation) will help planners optimize response asset allocation and deployment of resources to most effectively support the life-saving activities. For example, rapid deployment of street clearing equipment may be needed to allow access to areas where medical triage is a priority, or to open critical access routes for other key missions. Likewise, engineering teams and utility crews may be needed to stabilize structures and shut off utilities, such as water, gas, and power lines before fire, search and rescue, or medical teams can enter. Also, the development of a response plan that depends on contracted services will need to clarify what contractors can and cannot do. A clear understanding of the contractors' capabilities will allow for a better understanding of what a true response time will be following a disaster.

Preparing for these incidents is always difficult, but prearranged agreements and arrangements may help to ease the initial hours of confusion. Some examples include the use of Memorandum of Understandings (MOUs) that allows for a neighboring jurisdiction to assume control of the damaged locality's operational duties. One example may include roadway network monitoring through access to transportation management centers. Another example would be the availability of pre-staged resources, including equipment needed to remove rubble, shore up infrastructure, and stabilize utilities.

The nature and magnitude of impacts provide indicators for prioritizing search and rescue and medical triage missions. For example, close to ground zero the likelihood of ***survivable victims*** is very low and the total risk (radiation and physical hazards) to responders is very high. Other zones will have varying proportions of injured people, and varying degrees of injury, thus providing rough indicators where limited resources may be best deployed. Planning response activities by zones based on the magnitude and type of impact, expected casualties and the risks to responders will help planners set priorities to realize the greatest number of lives saved for the lowest total risk to the response force.

Finally, high radiation from fallout may overlay zones with heavy physical impacts as well as outlying areas with no physical impact at all. Therefore, planning in these zones must account for heavy, moderate, or light damage and no damage at all, depending on the distance from

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[4] In some computer simulated high-density urban scenarios, several hundred thousand people may be at risk of death following a 10 KT nuclear explosion where effective planning and response actions could save many of them.

[5] A life-saving mission is geared toward rescuing a survivable victim, or executing functions that lead to the preservation of life, such as fighting fires that threaten populations.

ground zero along the path of fallout deposition. Before work is performed in any fallout impacted area the radiation levels must be carefully assessed. In Chapter 1, four zones were described based on the magnitude of physical damage and radiation levels associated with fallout. Emergency response operations should be planned using these four zones.

It is important to note that the National Incident Management System and National Response Framework will remain the overarching strategies for emergency management, and State and local officials should plan consistent with these frameworks. However, State and local frameworks will provide the structure for the response organization.

LD Zone Response

In the Light Damage Zone (LD zone), damage is caused by shocks, similar to a those felt from a thunderclap or sonic boom, but with much more force. Although some windows may be broken over 10 miles (16 km) away, the injury associated with flying glass will generally start to occur at overpressures above 0.5 psi, which can be out to about 3 miles (4.8 km) from ground zero for a 10 KT ground detonation. This distance is a reasonable estimate of the outer boundary of the LD zone. The damage in this area will be highly variable as shock waves reflect and diffract off of buildings, the terrain, and even the atmosphere.

Responders will begin to consistently see broken windows more than 3 miles (4.8 km) from ground zero. The LD zone will require some street clearing of small rubble and debris (e.g., shutters, gutters, mail boxes, power lines, glass, and rubbish) and stalled or crashed vehicles. Passage deeper into this zone will become increasingly difficult and require heavy equipment and debris removal capabilities. Much of the LD zone may be essentially non-radioactive. However, responders should be prepared to encounter elevated radiation. The most hazardous radiation levels would be associated predominantly with the major path where fallout deposition overlays the LD zone.

The severity of injuries responders will encounter in the LD zone should be relatively light and, consist of mostly superficial wounds with occasional flash burns. Elevated radiation doses from initial nuclear radiation and burns from the detonation itself, as described in see Chapter 1, are not expected in the LD zone (except where it is overlain by fallout) because of the distance from ground zero and the shielding provided by buildings. Injuries are anticipated to result primarily from flying glass and debris, falls, and traffic accidents. Glass and other projectile penetrations are expected to be superficial (i.e., about ¼ inch depth) in the torso, limbs, and face. Eyes are particularly vulnerable. As responders proceed inward they will begin to observe an increasing frequency and severity of injuries from flying glass and debris, and crush, translation, and tumbling injuries.[6] Glass alone, depending on where it has entered the body, may present a direct threat to life. Hazards to responders are present in this zone, including from glass falling from damaged buildings, sharp debris, fire, and structural instability. Response teams should not enter without first confirming the level of radioactivity in the area they are entering.

[6] Translation and tumbling injuries are those incurred when people are thrown about and into solid objects by the blast wave.

Most of the injuries incurred within the LD zone are not expected to be life threatening. Most of the injuries would be associated with flying glass and debris from the blast wave and traffic accidents. The benefits of rescue of ambulatory survivors in the LD zone are low. If injured survivors are able to move on their own, emergency responder actions should focus on directing citizens to medical care or assembly shelters and proceeding towards the MD zone where victim rescue will be needed most.

Responders should expect LD zone survivors to be panicked and confused and to request medical assistance. A small percentage of injured in the LD zone may require emergency care, for example, for severe blood loss or injury from a traffic accident. But, the population as a whole in the LD zone is estimated to have a good chance for survival without immediate medical attention. Responders should resist spending time and resources on minor injuries in order to maximize the use of medical resources on more critical needs closer in to ground zero. Response actions in this zone should be focused on encouraging individuals to stay safely sheltered so that responders can expedite access to MD zone casualties. To accomplish this, responders could enlist neighborhood emergency response teams, spontaneous volunteers, and public information officers to accompany or help direct injured survivors to medical or assembly points.

It is important to note that the large number of ***ambulatory*** casualties coupled with debris on usual access roads may result in many responder assets being ‘stalled’ in the LD zone. It will take a concerted effort to get follow-on responder resources to keep pushing forward and may require street clearing in advance. Stalling should be avoided at all costs.

Responders should focus medical attention in the LD zone only on severe injuries and should encourage and direct individuals to shelter in safe locations to expedite access to severely injured individuals.

In summary, the most common non-fallout radiation injuries incurred within the LD zone are not expected to be life threatening, which means the overall benefit of rescue actions in this zone is relatively low because the number of victims requiring rescue to survive is low. However, a key role for responders will be directing people to medical care or, in areas where evacuations may be ordered after initial shelter in place, to assembly centers (ACs). Moreover, responders moving into the MD zone should encourage ***ambulatory*** survivors in the LD zone to assist one another. Injuries resulting from traffic accidents are likely to be the most serious injuries in the LD zone. As responders penetrate further in towards the MD zone, the number and severity of physical injuries will increase, as will the hazards responders will face.

Advancing through the LD zone, the occurrence of shattered windows continues to increase until all windows in buildings are blown in, and damage to roofs, doors, trim, and building facades is observed. Some lighter buildings will have collapsed. Injury from flying glass and debris will be more severe and serious trauma associated with building structural damage will increase. At this point, responders are entering the MD zone.

MD Zone Response

While no clear boundary exists, responders may recognize the transition to the MD zone by the prevalence of significant building structural damage. The determination is made by ground-level observation and/or overhead imagery. Characteristics of the MD zone include significant structural damage, overturned vehicles, and fires. In the MD zone, sturdier buildings (e.g., reinforced concrete) will remain standing, lighter commercial and multi-unit residential buildings may be structurally unstable or collapsed, and many wood framed and brick residential structures will have collapsed. Some telephone poles and street light poles may be blown over. Substantial rubble in streets from damaged buildings and crashed and overturned vehicles should be expected and will make evacuation and passage of rescue vehicles very difficult or impossible without street clearing by heavy equipment and debris removal capabilities. Within the MD zone, broken water and utility lines (e.g., gas, electricity, and communications) and numerous fires should be expected.

Fire is expected to be a major threat to survivors. Fire was a major cause of death in the nuclear attack on Hiroshima in which a raging firestorm occurred; however, experts suggest that differences in modern US city design and construction make a similar firestorm unlikely. Yet, fires in tall office buildings can still lead to high concentrations of fatalities. Water pressure for firefighting will be a major concern if utility systems are damaged, and trained engineering teams would be required to stabilize them. This challenge may take many hours as rubble in the streets will make access difficult or impossible without concerted street clearing and debris hauling efforts.

The MD zone is expected to have the highest proportion of '***survivable victims'*** who require medical treatment.[7] The greatest opportunity to effect life-saving in the MD zone is in areas not affected by fallout (i.e., where the DF zone is not overlapping the MD zone - see Figure 1.6). Early response activities in non-, or low-radioactivity areas should prioritize and facilitate prompt access, fire suppression, and delivery of search and rescue and medical care in the MD zone. Responders should avoid the dangerous fallout (DF) zone in the first 12 hours except to implement shelter or evacuation orders as appropriate. This approach will help maximize life-saving while reducing the risks to the responder workforce.

The need for search and rescue will far exceed the resources that will likely be obtainable. Search and rescue missions should be practicable in the MD zone, and may target locations with high likelihood of multiple survivors, or with special populations (e.g., schools or hospitals), or in discrete locations such as tunnels and subways. As a result of the extent of impacts and hazards, an effective MD zone response will require well-planned, expeditious actions to maximize saving lives while minimizing the total risk to the responders. Therefore, early response planning should focus on facilitating MD zone medical triage; this includes such operations as road clearing, search and rescue, extraction, and establishing staging and triage sites.

The MD zone presents significant hazards to response workers, including elevated radiation levels, unstable buildings and other structures, downed power lines, ruptured gas lines, hazardous chemicals, asbestos and other particulates released from damaged buildings, and sharp metal objects and broken glass, for which consideration and planning is needed. Fires fed by broken gas lines, ruptured fuel tanks, and other sources will be prevalent and may pose a significant danger to both survivors and responders. Visibility in much of the MD zone may be low for an hour or more after the explosion resulting from dust raised by the shock wave and from collapsed

[7] Survivable victims are those individuals who will survive the incident if a successful rescue operation is executed, and will not survive the incident if the rescue operation does not occur.

buildings. Low visibility may be exacerbated and extended in duration because of smoke from fires.

Radiation levels in the MD zone may be very high, especially in the first hours after the incident, even up wind of the apparent direction of the fallout plume. High latent radiation may be a result of local deposition of fallout. Where the primary path of fallout deposition (the DF zone) crosses the MD zone, radiation levels are expected to be very high and pose an immediate danger for 12 hours or more. Responders advancing into a zone should always have at least one person with them who has radiation instruments, personal dosimeters, and the additional responsibility of ensuring that his team has adequate monitoring and advice. A mission into a radioactive zone should always have a benefit that justifies the anticipated total risks (radiation, fire, rubble, collapse, explosions, etc.) to response workers.

> Response within the MD zone requires planners to prepare for elevated radiation levels, unstable buildings and other structures, downed power lines, ruptured gas lines, hazardous (perhaps airborne) chemicals, sharp metal objects, broken glass, and fires.

The MD zone should be the focus of nuclear explosion emergency response efforts, with the goal of managing the impacted scene through aggressive rubble removal and site access, fire suppression, and structural and utility stabilization, in order to facilitate expeditious search and rescue and medical triage. On a city-specific basis, response planners should develop plans for MD zone response that includes:

- Establishing nuclear emergency response procedures that maximize rescue operations focused on ***survivable victims***
- Minimizing the total risk to responders
- Organizing neighboring response units (and sharing such plans with the State emergency management officials so they will be aware which jurisdictions would be stepping in)
- Pre-deploying appropriate supplies to locations likely to contain large populations, including fallout shelters or subways
- Deploying radiation assessment teams, engineering response teams (e.g., road clearing, debris hauling, and stabilization capabilities), Hazmat, search and rescue teams, medical response teams, and law enforcement (to secure the scene)

> The MD zone should be the focus of early life-saving operations. Early response activities should focus on medical triage with constant consideration of radiation dose minimization.

SD Zone Response

Once the responder recognizes severe damage to infrastructure, such as complete building destruction and high rubble piles completely preventing access, the chance of encountering survivors is minimal, and the risk to response workers should be considered prohibitive. However, as the overall response progresses, the Incident Commander may consider strategic search and rescue operations within the SD zone. Response within the SD zone should not be attempted until radiation dose rates have dropped substantially in the days following the incident, and the MD zone response is significantly advanced. At that point, search and rescue efforts may focus on massive above ground, or underground structures, that may have maintained structural integrity.

Response within the SD zone should not be attempted until radiation dose rates have dropped substantially in the days following a nuclear detonation, and the MD zone response is significantly advanced. All response missions must be justified to minimize responder risks based on risk/benefit considerations built into worker safety plans.

DF Zone Response

Fallout will likely be extensive longitudinally along the path of upper level winds. Locally, fallout may exhibit significant spread as a result of lower level wind patterns. High levels of radiation from fallout pose a direct threat to survivors and response workers.[8] With the rapid settling of the larger particles, the footprint of the DF zone, including the area with a sufficiently high dose rates to produce acute radiation syndrome (ARS), will be defined within 1-2 hours.

In the DF zone, fallout particles may be visible as fine sandy material, either actively falling out as the plume passes, or visible on clean surfaces (such as the top of an automobile). Visible fallout provides strong evidence of dangerous levels of radioactivity. However, fallout may not be noticeable on rough or dirty surfaces, and there is no method to reliably estimate radiation dose rates based on the quantity of visible fallout. Therefore, visible fallout may be used as an indicator of an immediate radiation hazard, but the lack of apparent fallout does not indicate a safe area, and should not replace appropriate radiation measurements.

The National Council on Radiation Protection and Measurements (NCRP) has recommended 10 ***R/h*** as a nuclear-explosion fallout zone delimiter, stating responders should, *"Establish an inner perimeter at 10 R h^{-1}* ***exposure rate*** *(~0.1 Gy h^{-1} air-kerma rate). Exposure and radioactivity levels within the inner perimeter have the potential to produce acute radiation injury and thus actions taken within this area should be restricted to time-sensitive, mission-critical activities such as life-saving*".[9] Thus, the perimeter of the DF zone is defined by an ***exposure rate*** of 10 R/h. The 10 R/h point would normally indicate that workers should return to a safe area unless they are undertaking a sufficiently justified mission; that is a mission with a benefit that justifies the anticipated radiation dose (other potential responder hazards would be additive). This ***exposure rate*** also indicates that much higher rates may be nearby and is useful for making shelter/evacuation decisions. See Chapter 3 for additional discussion.

Dangerous levels of fallout are expected in the MD and LD zones as well as areas beyond that are otherwise unaffected, for example 10 to 20 miles (16 – 32 km) from ground zero (see Figure 1.6). Lower level fallout will continue for a hundred miles or more (see Chapter 3 for downwind shelter and evacuation planning recommendations). As stated in Chapter 1, the highest hazard from fallout occurs within the first four hours to six and continues to drop as the ***fission products*** decay. As radioactivity levels drop, the DF zone will steadily shrink in size. The 7–10 rule, described in Chapter 1, is a useful rule-of-thumb for estimating radiation dose rates after a nuclear explosion. Officials and responders should not rely on the 7–10 rule in lieu of actual measurements when sending responders into radioactive areas, but it is a useful indicator of the relative radioactive decay in a given area.

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[8] The other source of residual radioactivity after a nuclear explosion is induced radioactivity in materials (e.g., construction materials, rock, and soil) resulting from neutron absorption. Generally, in the scenario being considered here, significant neutron activation will not occur beyond the SD zone. Activation radioactivity decays rapidly similar to the decay rate for fallout.

[9] NCRP 2005

The most important mission in the DF zone is communicating protective action orders (e.g., sheltering or evacuation) to the public. Generally, the recommendation action is that the public should seek and remain in a robust shelter until advised otherwise to avoid exposure to fallout. This is a critical temporary action that is necessary until the affected population can be evacuated in a safe and orderly fashion. Preparedness planning and effective communication plans, messages, and means of delivery will be the key to survival for many in the DF zone.

> In physical locations where the DF zone overlaps the LD or MD zones, response activities should be guided by the potentially lethal radiation hazard of the DF zone.

> The most important mission in the DF zone is communicating protective action orders to the public. Effective preparedness requires public education, effective communication plans, messages, and means of delivery in the DF zone.

Radiation ***exposure rates*** in high-fallout areas can reach hundreds if not thousands of R/h, delivering doses that are fatal. Therefore, Incident Commanders should use great discretion in sending workers into highly radioactive areas, and planning and training are critical to successful post-nuclear response. Allowing time for radioactive decay of fallout significantly improves the ability to respond safely. When planning response in highly radioactive zones, the time for decay must be weighed against the urgency of saving lives or related missions. In the most critical time period for casualties, the first hours after the explosion, radiation is also highest. Responders must also consider the added radiation dose evacuees would incur in an attempt to vacate the area; in some cases, the evacuation could push evacuee's total dose into the acute range.

Response Worker Safety

An emergency response worker safety management program will need to be integrated with the Safety Officer and into the overall operations. Essential to minimizing the fatalities, trauma, and social impact of a nuclear explosion is the effective and safe deployment of response forces. Therefore, emergency response worker safety and health is a key consideration in all response planning. Emergency response workers will be an indispensible, primary resource for the response. For a nuclear detonation, emergency response workers will not only include urban search and rescue, fire and police, but will also include emergency medical technicians, utility workers, and other skilled support personnel (such as truck drivers, equipment operators and debris contractors) that provide immediate support services during response operations. Besides the radiation hazards, these responders may face widespread fires, collapsing structures, chemical exposures, smoke/dust inhalation, and numerous other physical hazards. In general, very few emergency response workers have experience working in major disasters that include highly radioactive areas. Effective emergency response actions within the damage zones can only be accomplished with appropriate planning, responder training, provision and use of appropriate ***personal protective equipment (PPE)***, and other mission critical capabilities, including radiation dosimetry.[10]

[10] The goal of response worker protection is to minimize the total, not just radiation, risk to the response worker. It must be recognized that in some circumstances, the benefits of using PPE are outweighed by the risks.

Beginning about 15 minutes to 1 hour after a nuclear detonation, the IMAAC will be able to provide plume and fallout projections to State and local authorities through DHS. The initial plume models will be based on meteorological inputs from the local NOAA National Weather Forecast Office; and will include inputs such as temperature, humidity, wind speed and direction. The initial plume models will be based primarily on predictions; the only incident-specific information likely to be available will be wind speed and direction. Therefore, while initial plume models may be helpful in determining the general direction of the fallout plume and assist officials in making initial protective action decisions, they will not be adequate for making worker protection decisions. Worker protection decisions should be based on measurements taken by initial responders and assessed in real time by radiation health physicists. It is critically important that any responders entering contaminated areas be supported by personnel equipped with and trained in the use of radiation measuring equipment.

Response Worker Safety Strategy

Most emergency response organizations have a safety and health management program; however, no single organization will be able to effectively execute a response and sustain resources for the extended nuclear response operations given the vast array of major hazards that would be encountered. An emergency response worker safety management program for this scenario will need to be integrated into overall operational planning and review the tasks and occupations involved in the operations, analyze the overall impact and hazards posed to the workers, and establish the necessary protection for the workers. Worker safety programs should adhere to the following principles:

- **Justification**: Justification is the principle that an action should only be taken if the benefits of the action outweigh the total (radiation and non-radiation) risks, or 'do more good than harm.' For the initial response to a nuclear explosion, the primary mission is rescuing ***survivable victims***. This means that the benefit of the operation is the number of ***survivable victims*** rescued, and the risk of the operation is the total risk to the responders conducting rescue operations.

- **Optimization:** Optimization is a principle that ensures that the magnitude of the individual impact (radiation dose, or chemical or physical injury), the number of people impacted, and the likelihood of incurring such impacts where these are not certain to be received, are kept as low as reasonably achievable.[11] Every effort should be taken to maximize the total benefit to the affected populations while minimizing the total (radiation and non-radiation) risks to response workers. As already discussed, maximizing the number of survivors is accomplished through effective deployment of response forces to the region (principally the MD Zone) where most survivable victims are expected.

- **Limitation:** Limitation is the principle that radiation doses should be capped. Limits are always established for normal operations, but the Department of Homeland Security has published guidance stating that *no limits should be required for lifesaving operations following major acts of radiological or nuclear terrorism*.[12] Once operations no longer involve emergency lifesaving, limits should follow OSHA regulations for radiation

[11] Modified from ICRP-60. Annals of the ICRP, Publication 60, 1990, p. 29
[12] DHS 2008

exposure. Emergency responders should be trained to understand ARS and the limits to prevent onset of ARS.

Safety Management Program

An emergency responder safety management program capable of accommodating the hazards and demands of a nuclear response should be established. The safety management program should include SME on behavioral health, and worker health should explicitly include psychological health. During an incident, local responders would need to establish a base-level program early on that would expand as more response organizations arrive. The safety management program will also need subject matter experts on the safety precautions necessary for the vast array of radiological, chemical, fire, and physical hazards. The challenges of the safety management program will be to assess hazards accurately and to track and analyze radiation dosimetry for those responders who have entered the impacted area and provide this information back in a timely manner for making future operational decisions.

Since radiation cannot be seen, felt, or smelled, an area may appear safer than it really is and the urgency of the situation may tempt some to recklessly enter highly radioactive areas. The Incident Commander must ensure this does not occur. Neither can the radiation exposures of workers be determined by atmospheric modeling products of the IMAAC or the environmental monitoring performed by the FRMAC. Worker health and safety monitoring will need to address the specific hazards to which each responder is subject. Each individual responder will ideally be equipped with radiation dosimeters, but at a minimum, one member of a team should carry a dosimeter for the team. Chemical exposure monitoring may also be necessary.

Components of the emergency responder safety management program may include the following:

- Hazard risk assessments for each operation to minimize total risk (radiation exposure and other risks) during the response
- Worker safety and health monitoring capability
- ***Personal Protective Equipment (PPE)***
- Dosimetry, including alarming dosimeters, that can read very high doses
- Data management to track responders and their accumulated radiation doses and other health data
- Training for high hazard environments similar to a nuclear explosion
- A long-term medical and behavioral health surveillance program

The DHS Guidance[13] provides radiation emergency worker guidelines, referencing the EPA 1992 Manual of Protective Action Guides and Protective Actions for Nuclear Incidents.[14] The DHS Guidance states:

> *"EPA's 1992 PAG Manual states that "Situations may also rarely occur in which a dose in excess of 25* ***rem*** *for emergency exposure would be unavoidable in order to carry out a lifesaving operation or avoid extensive exposure of large populations." Similarly, the NCRP and ICRP raise the possibility that emergency responders might receive an equivalent dose that approaches or exceeds 50* ***rem***

[13] DHS 2008
[14] EPA 1992

> *(0.5 Sv) to a large portion of the body in a short time (NCRP 1993; ICRP 1996). If lifesaving emergency responder doses approach or exceed 50* ***rem*** *(0.5 Sv), emergency responders must be made aware of both the acute and the chronic (cancer) risks of such exposure."*

The DHS Guidance was developed for a wide range of possible terrorism scenarios, from a small radiological dispersal device (RDD) that may impact a single building to an improvised nuclear device (IND) that could potentially impact a large geographic region. The Guidance 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.

The decision to execute a rescue mission must consider multiple factors. Two of the most important are the ratio of health benefit to health risk of the operation and the second is the ability of the responders who performed in the mission to continue response operations for the duration of the incident response. Initially, these decisions must be made with limited field data and information, under duress and time pressure, and by nature involve considerable judgment on the part of the Incident Commander. The first criterion (benefit/risk) is the most important because it is the primary determinant of whether the mission can proceed.

Response Health-Benefit – Life-Saving Missions

To make on-scene responder deployment decisions, the Incident Commander will need to assess radiological, chemical, fire, and physical hazards to best extent possible. However, situational awareness will initially be poor, and though there may be a degree of overall coordination, a lot of the strategic and tactical decisions will be up to the on-scene personnel. Advance preparations will help; for example, plans for mobilizing and deploying radiation measurement teams and knowing how to access plume model projections and overhead imagery rapidly to pass that information to the incident scene will assist in response decisions. It may be much more difficult to determine whether a particular mission warrants the risk it poses to response workers. The mission is the benefit to be achieved; for example, US&R search and rescue operations to save trapped people or extinguishing a fire that threatens lives. The challenge is determining whether the 'benefit' merits the 'risk.'

Both responders and survivors are at risk; both may face hazards that pose immediate risk of acute injury or death and long-term chronic risks, primarily from increased risk of cancer from radiation or chemical exposure (radiation is exemplary here). The disparity in the consequences between acute injuries or death and long-term cancer makes a direct comparison of health risks difficult. Ideally, total mortality would be used as the index of health risk, meaning one would directly consider the estimated acute risk of death and the estimated delayed risk of cancer death for both responders and victims.

The following methodology is a simple approach to crisis decision-making when data are scarce and does not account for all risk/benefit factors. It is recognized, for example, that mortality is only one of many indices of health that could be considered. It is also acknowledged that immediate fatality is vastly different from delayed mortality (for example, from cancer 30 years later). The endpoint of interest here is the benefit-to-risk ratio for crisis decision-making, and not a definitive estimate of health detriment.

This methodology uses group risks versus individual risks to estimate risk and benefit. The primary objective is to ensure that the total detriment resulting from the response action (radiation and the other health risks in the operation) does not exceed the total benefit (lives saved).

For lifesaving operations, there are two populations of interest – ***survivable victims*** and response workers. [15] The total mortality risk for response workers or victims can be expressed as the sum of the non-radiation operational mortality risks (such as fire, falling debris, vehicle accidents, etc.) and the mortality risks from acute radiation dose. A third mortality risk, the fatal cancer risk from radiation exposure, may also be considered if time allows, but long-term cancer fatality risk may be difficult to factor in under the duress of a nuclear response.

For this simplistic methodology, the health benefit of a rescue operation is the number of victims saved by the rescue effort. The health risk is rescue worker mortality (immediate and delayed). The benefit to risk ratio is the ratio of victim lives saved to the responder lives lost for a particular response course of action. However, the Incident Commander should also minimize the total radiation dose to the response workers in order to make the maximum use of scarce worker resources in a prolonged high demand incident. Therefore, the decision is not always determined by a simple benefit/risk ratio.

Example questions the Incident Commander should ask in making high risk response operational decisions include:

1. Are there victims to be rescued; what level of confidence do you have that there are survivable victims?
2. How many survivable victims are there?
3. What is the likelihood of a successful rescue mission (victims are saved)?
4. How many response workers are needed to execute the mission?
5. What are the hazards response workers will encounter?
6. How many response workers would be placed at potentially lethal risk?
7. Does the benefit (potential lives saved) merit the risk (of death) to response workers?
8. What are the physical resource implications of the mission; are the appropriate resources available, and is the quantity adequate to sustain further response efforts?
9. Are there more critical missions evident that would take precedence? Or other rescue missions where there is a greater likelihood of survivable victims and less risk to workers?
10. Would the impact of the mission on responders (injury, high radiation dose, or death) compromise the extended incident response?

State and local emergency response officials should use these guidelines to develop specific operational plans and response protocols for protection of emergency response workers. It is essential to ensure that emergency workers are trained to perform high risk missions, and have full knowledge of the associated risks prior to initiating any emergency action. Having adequate training is also necessary for emergency response workers to give informed consent. Indeed, above 5 **rem** (0.05 Sv), the normal occupational annual dose limit, worker participation should proceed only on a voluntary basis, and in full comprehension of the risks they are taking. In

[15] A survivable victim is an individual that will survive the incident if a successful rescue operation is executed and will not survive the incident if the rescue operation does not occur.

particular, careful consideration must be given to conducting search and rescue operations in regions of very high radiation were the likelihood of survivors eventually succumbing to ARS is high. Such efforts may not represent the best use of limited search and rescue resources. Finally, it is also essential that emergency responders have adequate PPE and other equipment for responding to the incident and are provided follow-up medical evaluation, treatment, and health monitoring.

During all on-scene operations, Incident Commanders should make every effort to employ the 'as low as reasonably achievable' (***ALARA***) optimization principle when responding to an incident. Protocols for maintaining ***ALARA*** doses should utilize the following health physics and industrial hygiene practices:

- Maintain distance from sources of radiation
- Shield people from the radiation source
- Minimize the time spent in the contaminated area
- Use personal dosimeters (radiation badges) and alarming dosimeters to determine and keep track of radiation dose
- Use appropriate decontamination procedures for both responders and survivors
- Properly select and use respirators and other ***personal protective equipment (PPE)***, to minimize internally deposited radioactive materials

The National Institute of Occupational Safety and Health (NIOSH) prepared guidance on selecting appropriate PPE for response to terrorism incidents involving chemical, biological, and radiological incidents.[16] OSHA's web site is a resource for emergency response planning and action as it provides guidance on the proper use of respiratory protection equipment (http://www.osha.gov/). Effective advance planning will help to ensure that the emergency worker guidelines are correctly applied and that emergency workers are not exposed to radiation levels that are higher than necessary in the specific emergency action.

[16] DHHS 2008

NCRP's Commentary 19[1] provides additional responder guidelines that are applicable for consideration in planning for nuclear detonation response. These guidelines only address short-term (acute or deterministic) effects. Exposure at these levels can also result in long-term (lifetime cancer or stochastic) health effects. The NCRP guidelines are summarized in Table 2.1.

Table 2.1: NCRP Emergency Responder Guidelines (Adapted from NCRP Commentary 19[1])

CONCEPT	VALUE	EXPLANATION
Inner Perimeter	10 R/h	Responders should establish an inner perimeter (e.g., an operational boundary) at an ***exposure rate*** of 10 R/h. Exposure and radioactivity levels within the inner perimeter have the potential to produce acute radiation injury and thus actions taken within this area should be restricted to time-sensitive, mission-critical activities such as life-saving.
Decision Dose	50 rad (0.5 Gy)	The cumulative absorbed dose that triggers a decision on whether to withdraw an emergency responder from within or near (but outside) the inner perimeter is 50 rad (0.5 Gy).
Responder Acute Radiation Sickness	>100 rad (1 Gy)	Nausea and vomiting are among the earliest clinical signs of acute radiation sickness. Nausea and vomiting are symptoms that occur as whole-body absorbed doses become high [i.e., >100 rad (>1 Gy)]. If these symptoms occur during the conduct of activities within a radiation area, the affected individual(s) should be removed from the area, and provided appropriate medical care.
ALARA for Terrorism Incidents	No value assigned	In a nuclear terrorism emergency, it may be neither practical nor appropriate for radiation protection considerations to automatically be governed by guidelines applied in more routine scenarios. While the fundamental concept of keeping all radiation exposures as low as reasonably achievable (***ALARA***) should still apply, it may not be realistic to apply other traditional radiation protection guidelines for limitation of radiation dose. The traditional guidelines are based on an assumption of low-level exposure over long periods, and govern activities and situations that are more controllable and are not as critical as those associated with responding to a nuclear terrorism incident.
Radiation Control for Terrorism Incidents	No value assigned	The approach to worker radiation protection in a terrorism incident is based on two considerations: (1) the identification of radiation control zones, and (2) the control of the absorbed dose to individual emergency responders. The radiation control zones segment the site into areas of differing levels of radiation risk by using observed ***exposure rates***. The absorbed dose to an individual emergency responder governs decisions regarding duration (stay time) for various emergency response activities.

[1]NCRP 2005

US Military Planning

The US Military has established a system for mission-specific risk-based dose limits that includes life-saving activities. In current doctrine, US military personnel become restricted from ever again engaging in operational radiological/nuclear missions once they have exceeded 125 rad (1.25 Gy) dose accumulation. Whereas military commanders set their Operational Exposure Guidance (OEG) (i.e., dose limits to US troops) at any level in nuclear war, the risk analysis for extremely high-priority missions, to include life-saving, yields a maximum OEG of 125 rad (1.25 Gy). For operations other than war and also based on mission priorities and risk analysis, military commanders limit OEG levels to 75 rad (0.75 Gy) and below.[2]

[2] DOD 2008; DOD 2001

Search and Rescue Operations

Search and rescue (SAR) operations, specifically urban search and rescue (US&R) operations, are anticipated to be critical to lifesaving operations following a nuclear detonation. Initially, US&R operations will be most efficiently and effectively engaged in non-radiologically contaminated areas of the MD and LD Zones by utilizing visual cues and detected radiation. During the early phases of the response, US&R teams should utilize visual cues and detected radiation levels to prioritize operations in the MD Zone. It is not recommended that US&R be conducted in the SD Zone until radiation levels have dropped and the MD zone response is sufficiently advanced. It is recommended that US&R operations not be performed in the DF zone, including where it overlaps the MD and LD Zones, until dose rates have dropped substantially after normally six hours or more.

US&R operations within a contaminated area must be conducted by responders trained in radiation protection in accordance with hazardous materials standard operating procedures. US&R operations require a multi-disciplinary and multi-agency response due to the contaminated environment and should always include a radiation assessment capability. US&R operations will be complicated by the presence of other non-radiological hazards due to the disruption of utilities and local industrial installations located within the affected areas. Fire and deep rubble will hamper US&R efforts.

The benefit/risk analysis performed for deployment of US&R forces should as account for high radiation levels, wide spread fires, deep rubble, structural instability, other hazards that threaten responders, and will impact responders' ability to sustain operations throughout the response.

Local jurisdictions should initiate contact with and maintain an awareness of local US&R teams, task forces, and hazardous materials teams in their region. Mission-capable resources within the State can usually be requested through local mutual aid agreements. Other resources outside the State can be requested through the ***Emergency Management Assistance Compact (EMAC)*** via the respective State emergency management agency. Additionally, FEMA, DOD, and the National Guard Bureau maintain resources that could be employed to augment and support the US&R mission in a post-nuclear explosion environment. Request for these resources should be made through the respective State emergency management agency.

Urban search and rescue operations will be most efficiently and effectively engaged in non-radiologically contaminated areas of the MD zones.

Decontamination of Critical Infrastructure

In the early phase of response, decontamination of affected areas or infrastructure should be limited to those locations that are absolutely necessary to access, utilize, or occupy in order to accomplish the life saving mission. Examples of infrastructure that may need to be decontaminated include public health and healthcare facilities, emergency services facilities, and transportation and other critical infrastructure (e.g., power plants, water treatment plants, airports, bridges, and transportation routes into and out of response areas). Affected infrastructure should be prioritized and radiation ***exposure rates*** should be estimated to determine whether postponing decontamination is preferable. Several factors should be considered when assessing the need to decontaminate:

- The DF zone can involve lethal and non-uniform fallout disposition ('hot spots') early in the response. Anyone working in areas with significant fallout contamination will require real-time radiation measurements and a robust, actively managed personal dose-monitoring system.
- Fallout decays rapidly and it may be preferable to delay decontamination efforts. For every sevenfold increase in time after detonation, there is a tenfold decrease in the radiation rate.
- Where possible, facilities or locations outside the fallout footprint (which will extend beyond the DF zone) should be used to minimize worker does monitoring and the need for secondary decontamination. These facilities and locations could be available immediately and can be expected to be free of contamination. FEMA Continuity of Operations Program (COOP) guidance and planning resources (http://www.fema.gov/government/coop/index.shtm) can be used as a template for local emergency preparedness planners and can help them choose appropriate COOP locations that will not be affected by fallout or require decontamination.
- If decontamination is required in the early hours after a nuclear explosion, local responders, who may have had little or no training in radiological decontamination methods, may be needed to perform these duties.
- Gross decontamination methods that are effective, fast, and easy to implement should be considered, such as vacuum and water washing technologies.
- Early in the response, there are few situations where significant gains in avoided dose can be achieved through decontamination as opposed to allowing fallout to decay.

Decontamination efforts should be limited to those locations that are absolutely necessary to use or occupy to accomplish life saving, including emergency infrastructure and infrastructure that might facilitate life saving (e.g., emergency gas line shutdown).

Operational Guidelines

Operational Guidelines are pre-derived levels of radiation (presented as stay times and radionuclide concentrations) that can be compared to field radiation measurements to quickly determine if Protective Action Guides are exceeded and actions for protection of workers and the public need to be implemented. They can be employed to inform decisions on the need for protective actions associated with the selection of decontamination approaches to facilitate life and property saving measures and continued use of critical infrastructure during the early and intermediate phases of response. (See http://www.ogcms.energy.gov for resource information.)

Decontamination of critical infrastructure should be initiated only when basic information becomes available regarding fallout distribution, current and projected radiation dose rates, and structural integrity of the elements to be decontaminated. In this early phase, rather than trying to plan the work in detail, it may be desirable to choose the best decontamination methods based on historical research findings (see References) and available resources and start using them in where necessary. It is important first to estimate how much decontamination is required to use or occupy the areas and for how long these areas need to be used. The Incident Commander, in coordination with State and local officials, must determine what requires decontamination and what level of decontamination is necessary. Consideration should be given to the amount of work and operator exposure the decontamination work will entail to achieve that goal. Natural decay of radioactive contaminants should be maximized and accounted for in the dose estimates. This will help avoid unrealistic expectations of the decontamination effort. If the area requiring decontamination is very large and significantly contaminated, and/or if the goal is a very low dose rate or level of contamination, it may take an unreasonable amount of effort to decontaminate that area by the chosen method.

Decontamination of critical infrastructure should be initiated only when basic information becomes available regarding fallout distribution, current and projected radiation dose rates, and structural integrity of the elements to be decontaminated.

Early decontamination of infrastructure may be termed ‘gross decontamination’ because the purpose should be to remove a substantial portion of contaminant to lower radioactivity in order to facilitate use or occupancy of an asset. Gross decontamination may be best accomplished with the simplest technologies. Effective decontamination methods that are easiest to implement will use equipment and operator skills that are immediately available in an urban setting. These methods include:

- Vacuuming / vacuum sweeping
- Fire hosing / rinsing
- Washing with detergents or surfactants
- Steam cleaning
- Surface removal using abrasive media (e.g., sandblasting)
- Vegetation and soil removal
- Road resurfacing

In general, more effective methods take longer and require more highly skilled operators. The above methods have been demonstrated to remove 20-95% of existing contamination in various conditions, but many factors must be considered to select the most effective method. Often, combinations of methods will produce better results than any single method. Paraphrasing guidance from an International Atomic Energy Agency (IAEA) technical report, *Clean Up of Large Areas Contaminated as a Result of a Nuclear Accident*, the following is offered as an initial recommendation for selecting decontamination methods:[17]

> *“In general, it is recommended that vacuum sweeping and/or vacuuming be considered an initial decontamination process, especially if the contamination is in the form of dry loose particulate material. Even if only marginal decontamination is achieved, the amount of waste produced is minimal and the process does not fix the contamination to the surface or cause it to penetrate porous surfaces. Use of this equipment in areas of medium to high activity would not be possible unless shielded or remotely operated equipment is available. The use of vacuum cleaning for the inside of urban buildings and smooth building surfaces should be beneficial. Fire hosing is also recommended under controlled conditions, especially on smooth surfaces such as roads and parking lots which need to be cleaned up quickly. However, it should only be used if suitable drainage routes are available and contamination of drinking water does not occur. Fire hosing should also be useful for decontaminating certain types of roofs, buildings and equipment having smooth impermeable surfaces.”*

[17] IAEA 1989

If vacuuming followed by fire hosing is not successful in cleaning up heavily contaminated areas, more aggressive methods such as abrasive cleaning, road planning or paint removal would be required. Moreover, no decontamination method is entirely effective; there will always be some level of remaining contamination. Locations that need more than a 90% reduction in dose rate to be safely occupied are poor candidates for early decontamination. Although it may not be practical to contain all the runoff and collect all waste generated from these early phase decontamination operations, local authorities, including emergency responders, should do their best to reduce the impact on the environment.

Related to decontamination is protective clothing for responders. Responders should be instructed in the care of any protective clothing in their possession and when replacement is needed. Supplies will be extremely limited and in many cases, resupply from local stocks will be impossible. At the minimum, monitoring, cleaning, and re-use should be considered.

Waste Management Operations

A nuclear explosion in an urban area will generate large quantities of waste and debris. Moreover, decontamination and cleanup efforts will also generate waste. All wastes will require proper characterization, segregation, transportation, and disposal. The waste streams are likely to be highly variable ranging from building debris and contents (concrete rubble, soil, structural metal, asbestos-containing materials, carpets, wallboard, electronics, etc.) to contaminated fluids, sludge, animal carcasses, vegetative debris, and human remains. An important aspect of managing waste from a nuclear explosion incident is that decontamination decisions can profoundly affect potential waste disposal options and quantities of wastes generated, and, conversely, waste disposal costs and barriers may impact the decontamination strategies. State and local waste management personnel should be incorporated into the planning process to lend their expertise to those that will be responding, to obtain an understanding of debris that might be encountered, and to help identify the appropriate equipment necessary to remove obstacles and obstructions for expedient access to victims and access to medical facilities. Moreover, State and local waste management personnel should pre-select candidate site(s) within their boundaries for short-term storage and the need to address the public that is affected by waste storage or transportation. An important consideration of waste management is that some of the debris and waste piles may contain human remains, which will require special handling procedures.

Traditionally, waste management operations would begin after life saving operations, stabilization, and evidence collection. During a large-scale incident like a nuclear explosion, however, waste management operations will by necessity overlap with the search and rescue, criminal investigation, and human remains recovery immediately following the incident. State and local waste management personnel will need to work with emergency management officials to determine the priority needs for opening access and egress routes and identify the appropriate equipment necessary for debris clearance.

During initial roadway debris clearance, the priority will likely be to push debris to the sides of the road to provide access, if possible, rather than remove the debris to a staging and holding areas. Given limited resources in the first 72 hours, there is a greater priority to ensure clear access routes to expedite the movement of emergency vehicles and facilitate critical operations than to begin debris removal operations. Waste management personnel may also remove debris to temporary staging points where the debris can be examined for the presence of human remains and debris can be segregated, but this segregation and search for human remains is not anticipated to be a priority in the first 72 hours.

Debris found downwind of the blast area will likely be contaminated with radiation; however, other debris found upwind of the blast area will likely have little contamination. Considering the amount of contamination present on debris will be important in determining the best methods for managing it. The radioactivity of the debris should be measured, the potential for contaminating debris removal equipment considered, and the co-mingling of contaminated and uncontaminated debris avoided.

Another waste management activity that may be necessary during the initial hours is hot spot removal. Hot spots are areas with higher concentrations of radiation contamination posing a greater threat to response workers and the public. Hot spot removal will reduce the radiation dose received by the emergency responders allowing them to execute their mission for a longer period of time. Serious consideration should be given to the location of a staging area(s) for this material because it has the potential to cause risk to human health due to the higher levels of radiation.

State and local authorities should include waste management planning priorities in comprehensive nuclear detonation response plans. While on-site waste management activities will be limited in the early days after a nuclear explosion incident, State and local waste management personnel should immediately be involved in planning activities. They should begin identifying and specifying holding/storage areas. Officials should begin to assess inventories of necessary equipment and locate heavy equipment and other specialized waste management assets to support immediate recovery efforts. Considerations for the waste staging and holding locations should extend beyond debris segregation and storage to include sufficient space for operations to screen the debris for human remains, ensuring site security, environmental and human health impacts, and any applicable waste management requirements.

To summarize, planners should consider the following in the first 72 hours:

- Waste management officials will need to work with Incident Commander to identify waste management priorities.
- Waste management must prioritize the safety and health of workers and training issues must be coordinated in advance of an incident.
- Clearing debris from roads and other infrastructure during the emergency phase to facilitate lifesaving and other emergency response activities will be a response priority. The scope of this action is expected to be limited to moving the debris to create safe ingress and egress corridors for emergency personnel and/or the public.
- Promptly removing highly contaminated materials, or hot spots, may be necessary to reduce potential exposure or continued impact to the responders.
- Locations and mechanisms for the screening of debris that may contain human remains will need to be identified, and for the staging and holding of waste and for short term storage, categorization, segregation, transportation, and preparation for disposal.

Selection of Radiation Detection Systems

The need for radiation detection systems will be overwhelming and few Federal resources will be available during the first 24 hours. The magnitude of a nuclear explosion requires detection resources that exceed quantities and capabilities of standard health physics detectors, which are the preferred and readily available tools for standard incidents involving radiation. The large and growing number of radiation detection systems deployed in support of preventive radiological nuclear detection missions offers a non-standard solution to augment resources at the disposal of responders. Standard health physics instruments and alternative radiation detection systems can be used to enhance detection capabilities. Several reports provide details of detection system capabilities and usage.[18] This section is designed to help responders maximize their radiation surveillance capabilities within the constraints of readily available equipment and personnel. This guidance assumes that systems be properly used based on situation and detection system-specific training and plans.

Standard health physics instruments and alternative radiation detection systems can be used to enhance detection capabilities.

The categories of radiation detection systems can be organized according to the critical response mission areas in this guidance: shelter/evacuation recommendations, early medical care, population monitoring and decontamination, and worker safety. Alternatively, responders may prefer to categorize their detection systems according to functional tasks: detection, survey, radionuclide identification, and dosimetry. All radiation detection systems should be used within their functional limits and design specifications. It is highly recommended that local authorities within a particular response unit (e.g., firehouse) have at least one instrument that is capable of reading dose rates up to 1,000 R/h during the first 12 hours following a nuclear detonation to ensure that they are not entering an area that exceeds 100 R/h. If instruments with this functionality are not a practical purchase, then the authorities should ensure that instruments clearly indicate when radiation intensities exceed the upper measurement limit as opposed to saturating and providing no indication of high radiation. Responders may need additional training to use systems with which they are familiar in new situations (i.e., contaminated environments and high radiation areas).

All radiation detection systems should be used within their functional limits and design specifications. Also, responders may need additional training to use systems with which they are familiar in new situations.

The list of radiation detection systems and uses is not exhaustive and is subject to change as technologies improve, but it covers common systems and missions/functions. Federal, State, local, and tribal response planners should document these proposed uses as well as resource constraints as they develop their response plans and standard operating procedures. To optimize use of limited resources, the first response community within a jurisdiction or region should consider coordinating their purchases of radiation detection systems.

Table 2.2 is organized based on key mission areas and activities according to a zoned approach consistent with this guidance. It lists the main categories of radiation detection systems that can be used during the response and whether each is useful, marginal, or not useful to support each mission area.

[18] NCRP 2005; CRCPD 2006; NCRP 2010

Table 2.2. Mission-oriented detector selection

Mission	Alarming Dosimeter	Personal Radiation Detector	Survey Meter[1]	Radioisotope Identification Device	Backpack	Mobile System	Aerial System	Portal Monitor	Sensor Networks	Medical Instrumentation[2]
Confirmation of Nuclear Yield	●	○	●	○	○	○	●	○	○	—
Activities inside the area bounded by the 0.01 R/h line										
Location of Ground Zero	—	—	—	—	—	—	●	—	○	—
Worker Safety	●	○	●	○	—	—	—	—	—	—
Area Survey	●	—	●	—	—	—	●	—	○	—
Radiation Monitoring at Shelters	●	○	●	—	—	—	—	—	—	—
Establish Evacuation Routes	●	●	●	○	○	○	●	—	○	—
Activities outside the area bounded by the 0.01 R/h line										
Worker Safety	●	○	●	○	—	—	—	—	—	—
Area Survey	●	○	●	○	○	●	●	—	○	—
Cumulative Dose Determination[3]	●	—	—	—	—	—	—	—	—	○
Population Monitoring at Medical Facilities	●	○	●	○	—	—	—	—	—	○
Radiation Monitoring at Shelters	○	●	●	○	○	○	—	○	—	—
Internal Personnel Contamination Detection	○	○	●	●	—	—	—	—	—	●
External Decontamination Monitoring[4]	●	○	●	●	○	○	○	○	—	—

LEGEND[5]: ● Useful ○ Marginal — Not Useful

Notes:
[1] Model dependent. Not all models have this capability.
[2] Includes nuclear medicine diagnostics, gamma imaging cameras, etc.
[3] Assumes dose is received after instrumentation is in place. Retrospective dosimetry not feasible with current systems.
[4] Includes facilities as well as personnel, vehicles, and material.
[5] Definitions of the Legend categories:
Useful - This is a device that can effectively perform the designated mission or task without modification of the device or of its normal mode of employment. In a sense, the device was designed or intended for that mission or task.
Marginal - The device can provide useful and relevant data in support of the designated mission or task but with modification to the normal mode of employment. In addition, its use may create a potentially unsafe condition to the user of the device. This implies a need for care in the interpretation of the data produced by such a device under the circumstances.
Not Useful - While the device is capable of detecting nuclear radiation, its technical performance characteristics or conditions of use are such that it is unlikely to be able to provide useful information in support of the designated mission or task. In addition, its use may create a grossly unsafe condition to the user of the device.

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Chapter 3 - Shelter / Evacuation Recommendations

KEY POINTS

1. There are two principal actions that may be taken to protect the public from ***fallout***: taking ***shelter*** and evacuation.
2. **The best initial action immediately following a nuclear explosion is to take shelter in the nearest and most protective building or structure and listen for instructions from authorities.**
3. Shelters such as houses with basements, large multi-story structures, and parking garages or tunnels can generally reduce ***doses*** from fallout by a factor of 10 or more. These structures would generally provide shelter defined as 'adequate.'
4. Single-story wood frame houses without basements and vehicles provide only minimal shelter and should not be considered ***adequate shelter*** in the DF zone.
5. No evacuation should be attempted until basic information is available regarding fallout distribution and radiation dose rates.
6. When evacuations are executed, travel should be at right angles to the fallout path (to the extent possible) and away from the plume centerline, sometimes referred to as 'lateral evacuation.'
7. Evacuations should be prioritized based on the fallout pattern and radiation intensity, adequacy of shelter, impending hazards (e.g., fire and structural collapse), medical and special population needs, sustenance resources (e.g., food and water), and operational and logistical considerations.
8. Decontamination of persons is generally not a lifesaving issue. Simply brushing off outer garments will be sufficient to protect oneself and others until more thorough decontamination can be accomplished.

Overview

One of the greatest threats to the life and health of people in the vicinity of a nuclear explosion is exposure to radioactive fallout. People may be exposed to dangerous levels of fallout where the dangerous fallout (DF) zone intersects the moderate damage (MD) and light damage (LD) zones, and further out to 10 or 20 miles (16 – 32 km) to the full extent of the DF zone. There are two principal actions that may be taken to protect the public from fallout: taking shelter and evacuation. These protective actions may be self-executed by informed members of the public, or they may be communicated and orchestrated by response officials during the incident. Timely decisions about shelter and evacuation are critical to saving lives and reducing radiation injuries. The effective implementation of protective actions during an incident is largely dependent on preparedness and timely guidance to the public. This section provides an overview of sheltering and evacuation and describes the protective actions and planning considerations for the decision-maker.

Given the large uncertainties involved, recommendations presented here are necessarily general in nature and should be used to inform city-specific response planning and preparedness. In addition, both responders and the public will need to consider their own specific circumstances (e.g., physical condition, ease of egress, access to evacuation routes, and access to ***adequate shelter***) in deciding the best course of action.

There are two principal actions that may be taken to protect the public from fallout: taking shelter and evacuation.

The standard ways to reduce radiation exposure are as follows: reduce time in the zone, increase distance from the source of radiation (the fallout), and/or use of dense materials (e.g., concrete, brick, or earth) as shielding against the radiation. In the case of widespread fallout, the primary protective actions are to take shelter and to evacuate. Sheltering protects people by (a) providing shielding and (b) increasing distance from fallout, especially in the center of a large building.

To take 'shelter' as used in this document means going in or staying in any enclosed structure to escape direct exposure to fallout. Shelter may include the use of pre-designated facilities or locations.

It also includes locations readily available at the time of need, including staying inside where you are or going immediately indoors in the best available structure. 'Adequate' shelter is shelter that protects against acute ***radiation effects*** and significantly reduces radiation dose to occupants during an extended period. Moreover, a properly executed evacuation reduces time spent exposed to radiation; the goal, of course, is to minimize total exposure.

The objectives of guidance in this chapter are as follows:

- Protect the public from the acute effects of high radiation exposure associated with fallout in the initial 72 hours after a nuclear explosion. Generally, symptoms will occur with radiation doses approaching 100 ***rad*** (1 Gy). The potential for acute ***radiation effects*** increases with higher radiation doses, and above 200 rad (2 Gy), medical treatment will likely be needed.
- Reduce long-term risks from radiation exposure associated with fallout from a nuclear explosion.
- Ensure that actions taken are technically informed and result in more benefit than harm to both individuals and the public.

The highest priority in managing sheltering and evacuation responses following a nuclear detonation is to reduce the number of people exposed to life-threatening acute radiation. Treating life-threatening injuries and not interfering with critical life saving operations must also be high priority planning factors.

Protective Actions

Protective Action Recommendations

The Environmental Protection Agency (EPA) publishes protective actions guides (PAGs) for nuclear incidents. The Department of Homeland Security (DHS) *"Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents*" affirms the applicability of existing EPA guidance for radiological dispersal device (RDD) and improvised nuclear device (IND) incidents in areas beyond those subject to the elevated radiation dose rates and other impacts associated with a nuclear explosion.[1] The radiation protection principles, however, are the same regardless of the potential dose or circumstances. In the case of a nuclear explosion, priority must be given to preventing acute-level radiation exposures. Existing PAGs could be applied in areas outside the DF zone, which could be below the radiation level of acute health effects. They should also be applied during the intermediate phase of the incident, when relocation would be considered as a protective action. For the first hours to days after a nuclear detonation, the primary protective actions are sheltering and staged/informed evacuation if application of PAG levels is impractical to implement over the very large area where PAGs are exceeded.

As stated earlier, the primary means of protecting the public from radiation associated with fallout following a nuclear explosion is to shelter and/or to evacuate. Secondary protective actions include removal of fallout particles from one's clothing and body (decontamination) and avoiding inhalation and ingestion of fallout particles. Planners should consider what actions are to be recommended to the public, where those actions would apply, how they would be communicated, how they would be supported and implemented by responders, and what resources are needed for successful implementation. One special consideration to acknowledge in planning is recommendations to the public for their animals. This is addressed in Chapter 5.

Nuclear explosion impacts are complex and extensive. See Chapter 1 for a detailed discussion. No single protective action will be adequate for all locations and times; therefore, planners should consider the following three tiers of protective action recommendations:

1. Generic recommendations issued in advance of an incident that are coupled with public education and outreach – Pre-designated public shelters may be part of this strategy for communities that do not have abundant, ***adequate shelter*** options.
2. Initial recommendations issued as soon as possible after an incident, which are based on little or no incident data – Generally, the recommendation would be for the public to take shelter immediately in the most protective, readily available shelter.
3. Follow-up recommendations issued once additional data and information become available – These recommendations may include continued shelter for a set period of time followed by evacuation, and specific evacuation instructions for selected areas or populations, such as heavily impacted areas or for vulnerable populations. The most important information influencing these recommendations will be the local

[1] DHS 2008

distribution and extent of the fallout, the intensity of fallout radiation, and the available shelter and evacuation options.

Shelter Recommendations

Sheltering in the most accessible and sufficiently protective building or structure is the best initial action immediately following a nuclear explosion. This includes ***'Shelter-in-place,'* which means staying inside or going immediately indoors inside the nearest yet most protective structure**. People should expect to remain sheltered for at least 12-24 hours. During that time, the intensity of the fallout radiation will decrease significantly, allowing for less hazardous egress from dangerous fallout areas. Sheltered individuals should not self-evacuate prior to 24 hours following the detonation unless instructed by authorities. Earlier evacuation may be beneficial in some cases (for example after 12 hours), such as to attend to medical needs. Even in areas where fallout is not apparent, sheltering is advised until the fallout areas are clearly known. Otherwise, evacuees could be caught outside when the fallout arrives or flee unaffected areas and unknowingly enter into a fallout area.

The best initial action immediately following a nuclear explosion is to take shelter in the nearest and most protective building or structure and listen for instructions from authorities.

'*Adequate shelter*' is defined as shelter that protects against acute *radiation effects*, and significantly reduces radiation dose to occupants during an extended period. The adequacy of shelter is a function of initial radiation dose rates when fallout arrives and the dose rate reduction afforded by the structure. A shelter far from the DF zone may be adequate even if it provides little shielding, whereas the same shelter close into the DF zone may not be adequate. The primary risk from nuclear fallout is penetrating radiation that needs to be reduced as much as possible by shielding using dense building material and increased distance from deposited fallout, including on roofs that may be afforded by large buildings. Cars and other vehicles are not ***adequate shelters*** because they lack good shielding material. Good shielding materials include concrete, brick, stone and earth, while wood, drywall, and thin sheet metal provide minimal shielding. Basements and large concrete structures are good examples of ***adequate shelter***. Large buildings can have thick walls of concrete or brick, but also provide the benefit of increased distance from deposited fallout materials when people gather away from exterior walls. This distance from exterior walls and roofs can substantially reduce radiation dose to those sheltering.

Shelters such as houses with basements, large multi-story structures, and parking garages, or tunnels, can generally reduce doses from fallout by a factor of 10 or more. These structures would generally provide ***adequate shelter***, and individuals with ready access to these structures would protect themselves effectively even where initial unshielded fallout dose rates would result in lethal radiation dose levels. Where ***adequate shelter*** is available, sheltering for periods even longer than 24 hours may be desirable if the appropriate resources (e.g., food, water, medications) are available.

Shelters such as houses with basements, large multi-story structures, and parking garages or tunnels can generally reduce doses from fallout by a factor of 10 or more. These structures would generally provide shelter defined as ‘adequate.’

Some structures offer limited fallout protection, particularly vehicles and single-story wood frame structures without basements and should not be considered *adequate shelter* in the most hazardous regions of the DF zone. Emergency response officials may have to issue supplemental orders to those sheltering in wood frame structures (e.g., stay in the center of the structure at ground level) in order to minimize dose while sheltering. If acceptable early evacuation options are available, authorities may advise evacuation for some occupants of inadequate shelters. However, early evacuation without adequate knowledge of the highest fallout hazard areas, even from poor shelters, can be extremely hazardous.

Single-story wood frame houses without basements and vehicles provide only minimal shelter and should not be considered ***adequate shelter*** in the DF zone.

Figure 3.1 provides a summary of the radiation exposure reduction factors as a function of building type and location within the building. Table 3.1 presents a tabular summary of radiation reduction factors for buildings.

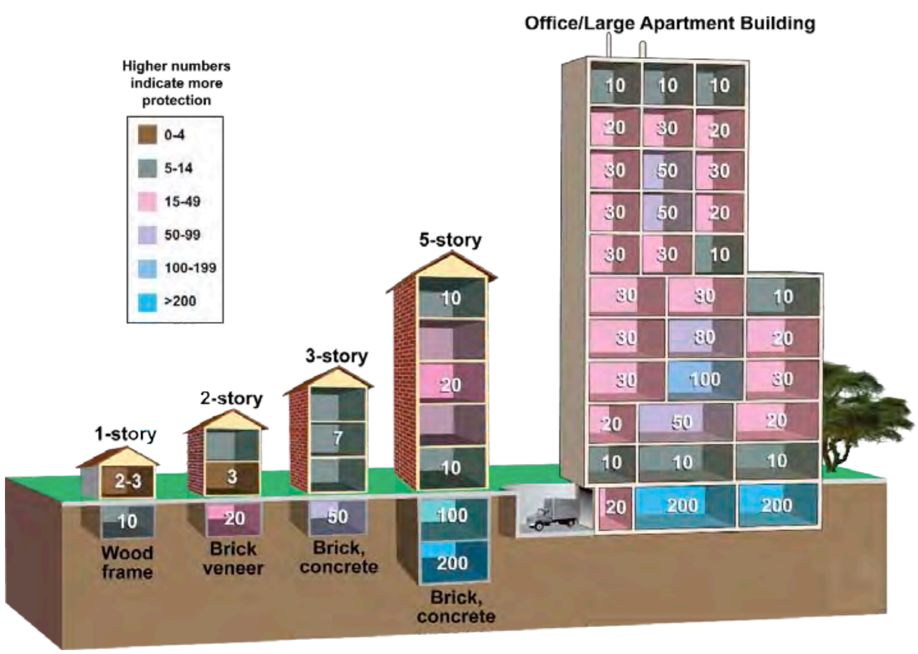

Figure 3.1: Building as shielding – Numbers represent a dose reduction factor. A dose reduction factor of 10 indicates that a person in that area would receive 1/10th of the dose of a person in the open. A dose reduction factor of 200 indicates that a person in that area would receive 1/200th of the dose of a person out in the open.

While sheltering is a priority for protecting public health, it goes against natural instincts to run from danger and reunify with family members. The need for reunification is especially true for parents who are separated from their children at the time of the event. Communications aimed at families and those who want to evacuate will be critical to successfully keeping people inside. After a nuclear detonation, people will need to understand why they and their families are safest staying sheltered. Before an event occurs, planners can work with schools to make sure that parents know the school's policy for major disasters, including lockdown and pickup policies. Specifically, schools should develop preparedness plans for shelter-in-place in their settings. These should be shared with parents to ensure existing safely procedures for children when there is a need for shelter-in-place. It is also important for locals (e.g., public health departments) to quickly, effectively, and broadly communicate the status of children's' safety in school settings in order to keep parents sheltered in place.

Sheltering is implicitly short term; everyone sheltering may need to be evacuated at some point until the safety of the area can be confirmed by officials. The duration of time spent in shelter may range from short, on the order of hours, to several days, depending on the fallout dose rates, adequacy of shelter, local factors and operational factors, and individual circumstances. Recommended shelter departure times for individuals will depend on several factors, including dose rate at the shelter and along the evacuation path, adequacy of the shelter, impediments during evacuation, interference with other response operations, and individual circumstances. Sheltering for the first 12 hours following detonation is particularly critical due to the high fallout dose rates and uncertainty in the fallout hazard areas initially following the detonation.

Authorities (e.g., local/city public health departments) must develop communication methods to continuously update the community about reasons for recommending and the importance of abiding by shelter-in-place, the status of shelter-in-place recommendations, and the estimated time evacuations might occur, among other messages. It is important to continuously communicate and update community members about sheltering; otherwise, individuals may break from shelters due to lack of available information or because of assumptions about safety over time.

Evacuation Prioritization

Sheltering should be followed by staged, facilitated evacuation for those in fallout-impacted areas. Evacuations should be prioritized based on the fallout pattern and radiation intensity, adequacy of shelter, impending hazards (e.g., fire and structural collapse), medical and special population needs, sustenance resources (e.g., food and water), and operational and logistical considerations. Evacuations should be planned so as not to obstruct access to transportation routes that are critical for ongoing life-saving missions.

For areas closer in (including the DF zone), where fallout arrives quickly, evacuations should take place after a period of sheltering and after an appropriate evacuation path can be determined by officials.

Early evacuation (i.e., less than 24 hours following the detonation) may be needed to protect some people shortly following sheltering. The staging of evacuations should be driven by the hazard to members of the public and logistical considerations. Early evacuation should be considered for individuals (1) who are in the highest dose rate regions of the DF area and do not have ***adequate shelter*** or (2) who face special circumstances or vulnerabilities, such as children or the elderly.

No evacuation should be attempted until basic information is available regarding fallout distribution and radiation dose rates.

Prioritization of early evacuation of at-risk populations should be balanced against responder risk, modes of transport, ease of access and egress, control of fires in the area, the ability to communicate with them, etc. Uninjured individuals with ***adequate shelter*** conditions should not be the highest priority for early evacuation. Similarly, priority evacuation should not be executed outside of the DF zone as long as people have access to minimally protective shelter, including single-story frame houses without basements, unless other threats to survival exist.

When evacuations are executed, travel should be at right angles to the fallout path (to the extent possible) and away from the plume centerline, sometimes referred to as "lateral evacuation."

Evacuations should be prioritized based on the fallout pattern and radiation intensity, adequacy of shelter, impending hazards (e.g., fire and structural collapse), medical and special population needs, sustenance resources (e.g. food and water), and operational and logistical considerations.

Evacuation Planning

In undamaged areas beyond the LD zone, evacuation should be advised only for critical areas and populations within the DF zone. Those within the area bounded by the 0.01 ***R/h*** line should shelter until it is safe to evacuate. For some people in the LD, MD, and DF zones that are not adequately sheltered, are critically injured, or threatened by building collapse or fire, early evacuation may be required for their survival.

The rapid identification of populations and areas that could benefit from priority evacuation should be a goal of responders. Movement of individuals who occupy inadequate shelter within the highest radiation portions of the DF zone could reduce the incidence of acute radiation syndrome in this population. However, identifying such populations and facilitating timely, safe transport is a challenging task. The following are critical steps in planning and implementing an early evacuation effort.

1. <u>Situational Awareness</u>: The first step in establishing evacuation priorities is to develop an accurate understanding of fallout distribution and radiation dose rates. A variety of data inputs may become available. Plume models (either local and/or Federal) can project the hazardous area based on the best available information on attack parameters and local

weather conditions. The Interagency Modeling and Atmospheric Assessment Center (IMAAC) will provide Federal plume modeling calculations that represent the Federal position during the response under DHS and Department of Energy (DOE) auspices. Reports of high radiation levels from local Hazmat teams may become available. Visual observations of the fallout cloud and its downwind drift might provide some indication of the direction of the fallout hazard area. Additionally, fallout particulates near the detonation may be visible as fine sandy material either actively falling out as the plume passes or visible on clean surfaces. While visible fallout particulates may indicate high radiation environments, this signature may not be noticeable on rough or dirty surfaces, and can never be used to estimate radiation dose rates. Each source of information will provide only a partial and uncertain characterization of the fallout area. Only radiation measurements can provide the level of information needed to plan early evacuations. Without such measurements, response teams may inadvertently direct individuals along evacuation routes that are more hazardous than remaining in even poor quality shelter. This is particularly the case in the early hours following the detonation when fallout radiation levels can be very high. Operational planning for use of available radiation detection assets is an essential aspect of regional nuclear explosion response planning.

2. Evacuation Priorities: Priority for early evacuation should be given to individuals in poor quality shelters within the most intense radiation regions of the DF zone. These are the areas in which the radiation dose rates exceed ~ 100 rad/hr. In these regions, highest priority should be given to those in the poorest shelters (e.g., those with protection factor of ~ 2 or below, see Figures 3.1a and 3.1b). Individuals in somewhat better shelter (e.g., > 10) should remain inside until radiation dose rates have abated. For example, priority should also be given to children in a wood framed school. To minimize the risks of evacuation during the first hours following a detonation, the Incident Commander should seek to communicate the best available information regarding the most dangerous fallout areas as soon as possible.
3. Shelter Transition: Individuals in the poorest shelters (e.g., those with protection factor ~ 2) in the DF zone can reduce their dose by early transit to an ***adequate shelter*** (e.g., one with protection factor >10). These individuals should be outside no more than 30 minutes, and move in directions generally away from ground zero. This recommendation is very sensitive to the quality of the initial shelter. For individuals in a slightly better shelter with PF~4, the reduction in risk is significantly smaller and the transit times needed to achieve these reductions are shorter. This sensitivity underscores the importance of a regional survey of shelter effectiveness as one of the foundations of urban shelter-evacuation planning for nuclear detonation incidents.
4. Evacuation Hazards: Early evacuation from the high dose rate regions of the DF zone can be extremely hazardous, especially in the first hours following the detonation when complete information may not be available to identify the safest evacuation routes. When knowledge of severe radiation hazards is not available, evacuees may move into even more dangerous areas than they occupied initially. Other factors may also reduce the benefit of early evacuation. Debris, rubble, and other obstructions may make use of vehicles impossible. Responders may be able to provide only indirect support to self-evacuees due to the high radiation hazards. Communication breakdowns may make it impossible to inform residents in the high dose rate regions regarding their best strategy for survival.

5. Other DF Zone Evacuation Considerations: Outside of the most hazardous areas of the DF zone, early evacuation (t < 24 hours) should be discouraged by response officials. However, guidance can be provided to those who choose to evacuate in spite of these warnings. Information concerning route conditions (e.g., rubble and debris in streets, collapsed bridges, and other obstacles to mobility) will assist those who decide to evacuate, and perhaps dissuade those who might choose a risky departure from shelter. When planned evacuations are initiated, these should be staged. Attempting to evacuate an excessively large area could divert resources from the higher dose rate regions closer to the detonation that deserve the greatest attention. A poorly planned evacuation could result in excessive radiation dose and even unnecessary fatalities due to radiation or other unforeseen hazards.

Self-Evacuation

It is likely that responders will not have direct control over much of the evacuation process following a detonation. Responder access may be limited over much of the fallout area. Many may choose to self evacuate either using guidance from response officials or based upon uninformed, spontaneous decisions. Self evacuation is strongly discouraged because self evacuees clog transportation arteries and increase demands on responders. Nevertheless, planners should anticipate such self evacuations and be prepared to assist all individuals to the degree possible. Assistance could include providing information to self-evacuees, including instructions about how best to leave the area, what direction to travel, and when to go. Support may also be provided to evacuees as they leave (e.g., public reception centers, medical treatment, transportation, self-decontamination instructions, etc.). Self-evacuation may also present a significant obstacle to emergency responder life-saving operations. Unnecessary evacuations can complicate those that are necessary. Public messaging and communication should clearly instruct self-evacuees what to do for their safety and protection, and to avoid hindering critical operations.

Contamination Concerns

In those areas subject to fallout, internal exposure (inhalation or ingestion) will be a secondary radiation protection concern. For evacuees, use of respiratory protection should not interfere with the primary objective of avoiding excessive external radiation exposure. Using even crude respiratory protection (e.g., breathing through a cloth mask) while in fallout areas can further reduce this concern. Responders, however, should maintain respiratory protection at all times during operations in contaminated areas. Responders should consider other potential critical needs of evacuees, such as critical medical care, and how those needs can be met in a timely manner. Decontamination of persons, however, is generally not a lifesaving issue. Simply brushing off outer garments in the course of evacuation will be useful until more thorough decontamination can be accomplished.

Decontamination of persons is generally not a lifesaving issue. Simply brushing off outer garments will be sufficient to protect oneself and others until more thorough decontamination can be accomplished.

Safe Areas
For people who were initially sheltered but who are in areas where there is no fallout (or negligible fallout), evacuation based on radiation hazard will not be necessary.[2] It is possible, however, that non-radiological hazards may warrant protective actions. Once an area has been determined to be without significant fallout or other hazards from the incident, protective actions are no longer necessary. It is pertinent to remember that self evacuation is strongly discouraged because self evacuees clog transportation arteries and increase demands on responders.

Decontaminating Vehicles
The public may attempt to self-evacuate in personal vehicles that may be contaminated. Although this may result in some spread of contamination, concern over spread of minor contamination should not hinder timely evacuations. The public should simply be directed to rinse or wash down vehicles as soon as practical once they are out of danger. More detailed instructions should be provided at a later time. When possible, official vehicles that are used to evacuate individuals from contaminated areas should be surveyed and controlled (e.g., simple washing or rinsing in a common area) to minimize the potential for spreading contamination; however, as in the case of personal vehicles, these actions should be implemented in a manner that does not restrict or inhibit timely evacuations. If there is potential that these simple protective actions will slow down evacuations, they should be avoided.

Planning Considerations

Planning considerations are key factors to consider in preparing for and ultimately implementing public shelter and evacuations. The planning considerations provided below are not in priority order and the list is not exhaustive. Additional factors unique to each community should be considered during the planning process.

Situation Assessment
The path of fallout transport and deposition and the delineation of the DF zone and the larger contaminated area beyond the DF zone are key pieces of information for early shelter and evacuation decision-making. Planners should anticipate the need for this information and consider what resources and means they will use to obtain initial fallout projections. Weather information, computer models, visual observations, and access to early Federal developed data and fallout projections will all be useful. Standard emergency response tools, including radiation detection instrumentation used in other high-hazard emergency situations, will also be necessary. Planners should continuously assess information and be looking to fold in new resources as time passes and new information becomes available. It is recommended that State and local response officials immediately request Federal produced fallout projections and recommendations on protective actions.

Response officials will also need to quickly assess the status of infrastructure and the general impacted environment. Within a few hours, responders will need a basic assessment of the status of transportation systems (i.e. vehicles, roads, bridges, rails, subways/tunnels, airports,

[2] EPA 1992

and harbors); communications infrastructure; the electric power grid; water, sewer, and gas infrastructure; the number, location, and severity of fires; identification of any major chemical or oil spills; and building structural damages. These factors have a major influence on shelter and evacuation decisions. Prior to an incident, models and simulations can help estimate planning needs and constraints.

Adequacy of Shelter

Because the radiation protection properties of potential shelter structures are of significant importance, planners should evaluate the types of shelter commonly available in their planning area (e.g., basements and other below-ground structures, concrete structures, and multi-story structures) that can generally provide ***adequate shelter***. Planners should specifically evaluate the occurrence and general locations of single-story, wood frame structures without basements. These structures provide limited protection against fallout radiation and may not be adequate for shelter. Planners should consider areas where ***adequate shelter*** is not readily available and develop options for protection of the public, including information and awareness messaging, evacuation plans, and self-protection measures the public may take. Planners in communities that generally lack ***adequate shelters*** should consider implementing a public shelter program that would meet the needs of the community. For example, cities in regions of the country where residential basements are uncommon should consider pre-designating large buildings as public shelters in which people nearby can quickly find ***adequate shelter***.

People occupying inadequate shelter may need to be selectively evacuated early to avoid acute exposures and minimize overall dose. Other factors that would warrant early selective evacuation include stability of the structure, critical medical needs, lack of basic resources such as water (especially after 24 hours), occurrence of fire, and other hazards that may threaten people's lives.

Time

For all protective actions, but especially for the immediate actions after a nuclear explosion has occurred, the speed with which protective action recommendations are developed, communicated, and implemented is of primary importance. Delays in issuing and implementing recommendations (or orders) could result in a large number of unnecessary fatalities. Planners can expedite these early messages by preparing messages in advance and by planning how they will be communicated in an emergency.

The following guidelines are designed to help planners, although it is recognized that conditions may limit the ability of responders to meet these guidelines. They are provided for planning purposes only and as a basis for identifying planning and resource needs.

- Initial projections of fallout deposition should be communicated to responders as rapidly as possible; at most within the first hour and updated every hour.
- Initial self-protection recommendations should be communicated to the public as rapidly as possible, at most within the first hour.

- Staged or phased evacuations (or relocations following sheltering-in-place) should begin, where appropriate, within 24 hours depending on estimated radiation exposure of the subject population and logistical and other factors.

Communications

The effectiveness of protective action recommendations depends on the ability to communicate with responders and the public. Planners should specifically consider communications problems that will be caused by a nuclear detonation (e.g., EMP and infrastructure damage) and recognize in their planning that normal means of communication may not be available. Mass communication methods and public guidance on stocking of battery powered radios may be appropriate.

Transportation Planning

A nuclear explosion will create particularly challenging circumstances for carrying out an evacuation. If no advance warning is given, incomplete, inaccurate, and, at times, contradictory information about the incident is likely at the same time decisions need to be made. Decision makers have little or no time to wait for additional or better information in a no-notice scenario because any delay will likely have a significant effect on the safety of their citizens; they must make decisions with the information available at the time.

Because of the central role of evacuation in a response, transportation planners should be an integral element of the planning effort. Transportation and other planners should consider the full range of planning elements associated with a nuclear explosion. These may include the following:

- Priority areas for evacuation and how to identify them
- Access to the impacted zones
- Transportation resources (e.g., vehicles, public transit, air, rail and water routes of egress)
- Massive infrastructure damage (e.g., roads, bridges, tunnels, electricity), and
- Evacuation routes, impediments to evacuation, and evacuation time estimates

Further information may be found in the Evacuation Bibliography and References listed at the end of this chapter.

Long-Term Planning

It should be anticipated that many people will be relocated for months to years at great distances downwind, to avoid unnecessary exposure to fallout radiation. The EPA PAG for relocation in the intermediate phase (2 rad in the first year) may be applied. This should be taken into consideration when planning how far to extend recommendations for shelter during the first 72 hours.

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Chapter 4 – Early Medical Care

KEY POINTS

1. There will be a spectrum of injury types and severity, including those from blast, radiation, and heat (or fire). These may occur alone or in combinations.
2. Initially, when resources are scarce, assets will be committed to maximizing lives saved and relieving suffering. Scarcity will vary dramatically by distance from ground zero and time after the incident.
3. Life-saving tasks take precedence over external radiation decontamination from ***fallout*** or visible debris.
4. There is guidance available, but currently no Federal or internationally agreed upon medical triage systems specifically for radiation mass casualty incidents. Existing mass casualty emergency triage algorithms will be used with modification for the impact of radiation.
5. Initial mass casualty triage (victim sorting) should not be confused with subsequent clinical triage for more definitive medical management.
6. During scarce resource conditions, emergency responders and first receivers will likely have to modify conventional clinical standards of care and adopt contingency and crisis standards of care to maximize the number of lives saved. This change is best initiated using predetermined criteria, Scarce Resources Allocation and Triage Teams, and protocols.
7. Initial triage and management of victims with acute radiation syndrome (ARS) will be based on (a) clinical signs, symptoms, and physical examination, and (b) estimates of whole body ***dose*** using clinical biodosimetry (blood count analysis), dose reconstruction which links victim location to radiation maps generated by computer models, and real-time environmental radiation measurements.
8. Initially, many victims who would be provided definitive care under circumstances with sufficient resources, may be triaged into the ‘expectant’ (expected to die) category. Compassionate palliation (treatment of symptoms) for expectant victims should be offered whenever possible.
9. The social, psychological, and behavioral impacts of a nuclear detonation will be widespread and profound, affecting how the incident unfolds and the severity of its consequences. Among key issues are the mental health impacts on the general public, potential effects on emergency responders and other caregivers, and broader impacts on communities and society.
10. Initially, saving lives will take precedence over managing the deceased. Nonetheless, fatality management will be one of the most demanding aspects of the nuclear detonation response and should be planned for as early as possible.

Overview

A nuclear detonation in a modern urban area would impact the medical system more than any disaster previously experienced by the nation. Large numbers of casualties with traumatic, thermal, and radiation injuries, in all possible combinations, will be seen including automobile accidents (from flash blindness), glass injuries, and burns from secondary fires that occur outside the blast and radiation zones. There will be a spectrum of injury types and severity including those from blast, radiation, and heat (or fire). The death toll will be high, but there are opportunities to save tens to hundreds of thousands of lives. Providing appropriate and timely public messages to those who need to ***shelter-in-place*** and providing appropriate and timely care for those with trauma, burns, and/or radiation will save lives. Improving survival will require deploying medical, surgical, burn, and other treatment assets toward the location of the incident as well as transporting many victims to intact regional and national facilities capable of providing specialized care. Currently, the majority of clinicians, including expert emergency medicine physicians and nurses, are unfamiliar with triage or treatment of victims with radiation injury.

Initially, mass casualty management will require a valid triage (sorting) system to provide care that saves the greatest number of victims of trauma, burns, and acute radiation syndrome (ARS) while providing comfort care to the extent possible. The Department of Health and Human Services (DHHS) Assistant Secretary for Preparedness and Response (ASPR) Scarce Resources project is developing publications relevant to triage during a nuclear detonation.[1] ARS triage and management will be based on the following:

(a) Victim clinical signs, symptoms, and physical examination
(b) Estimates of a victim's whole body radiation dose using:

- Clinical biodosimetry: (blood count analysis, cytogenetics and possibly newer methods in development)
- Physical (geographic) dosimetry: retrospective reconstruction of an individual's dose by linking his/her location during the incident to maps generated by computer models and real-time environmental radiation measurements

Combined injury (trauma, burn, and radiation in all combinations) will adversely affect prognosis and ***mortality*** and will need to be considered in triage and treatment decisions. Initially, when resources are scarce, assets will be committed to maximizing lives saved and relieving suffering. Many victims who would ordinarily be provided the full level of complex, resource-intensive care may need to be initially triaged into the 'expectant' category. This will be considered because there may not be resources available or these victims would consume the most resources but have little chance of survival. The limited resources available initially will be devoted to maximizing lives saved and providing compassionate palliation.[2] As the availability of close-in response resources increases over time, more victims will be able to receive resource-intensive life-saving care.

Scarcity of treatment resources will vary dramatically by distance from ground zero and time after the incident. Immediately after an incident, when resources are scarce at locations

[1] DHHS ASPR 2010
[2] Coleman 2010; DHHS ASPR 2010

closest to ground zero, emergency responders and first receivers will likely have to modify conventional standards of care and initiate contingency or crisis standards until shortages of medical staffing, logistics, and infrastructure assets improve.[3]

Planners can use hospital surge models (e.g. http://www.hospitalsurgemodel.org/) to estimate casualty arrival patterns, number of expected hospitalizations, number of deceased, and the resources that would be consumed to care for the patients.[4]

In a nuclear detonation mass casualty situation, due to the overwhelming number of people seeking medical care, it is expected that the vast majority of ***ambulatory*** people will reach medical care facilities before encountering an emergency responder. For responders that find themselves in a field of significant radiation, the highest priority is to save the greatest number of lives while respecting their own personal safety. In some circumstances, it may be appropriate to consider modifying time-consuming rescue methods (e.g. those that require physical stabilization such as backboards and neck braces) to facilitate faster rescue and treatment of a larger number of casualties. Judgment is required to assess who might be evacuated with less rigorous stabilization. Local and regional preplanning and training is required if these modified procedures are to be used.

There will be a spectrum of injury types and severity, including those from blast, radiation, and heat (or fire). These may occur alone or in combinations.

Initially, when resources are scarce, assets will be committed to maximizing lives saved,and relieving suffering. Scarcity will vary dramatically by distance from the ground zero and time after the incident.

Acute Radiation Syndrome (ARS)

The essential features distinguishing a nuclear detonation from other types of mass casualty incidents are the presence of radiation and the large number of victims. Radiation produces characteristic signs and symptoms (i.e., Acute Radiation Syndrome or Acute Radiation Sickness, ARS). Radiation injury increases with increasing dose and is compounded when accompanied by physical trauma and/or thermal burns (***combined injury***).[5]

Effects of ARS can be detected clinically at whole body radiation doses above approximately 50-100 ***rad*** (0.5-1Gy),

Radiation Exposure Risks Years after the Nuclear Detonation
(adapted from FEMA 2008)

The precise relationship between radiation dose and cancer risk is the subject of debate. There is a relative long latency between exposure to radiation and development of a radiation-induced cancer, often 5-10 years for leukemia and decades for "solid tumors." As a general estimate, 5 rad (0.05 Gy), the annual limit for a radiation worker but not necessarily the limit to be used for an incident such as this, would increase the lifetime risk of cancer by <0.5%. The average lifetime risk is around 25% so this dose would add <0.5% to that risk. For 25 rad (0.25 Gy) the increased risk is approximately 2%, and for 100 rad (1 Gy), approximately 6-8%.

[3] IOM 2009; IOM 2010
[4] DHHS 2008a
[5] Fliedner 2009

although acute toxicity at this level is mild. Higher doses produce more intense signs and symptoms of ARS and develop sooner. ARS evolves over time often in predictable phases. The first, or ‘prodromal’ phase (e.g., nausea, vomiting, fatigue), indicates that more serious manifestations may follow and provides important clues for triage. A ‘latent’ phase develops next when clinical problems are usually much less evident. The third, or ‘manifest illness’ phase, occurs when clinical problems are most evident and require intensive management. This may be days or weeks after exposure. This is followed by clinical recovery or death. More information on ARS is provided in the grey box below.

Acute Radiation Syndrome - General Considerations

(For details see Radiation Emergency Medical Management (REMM) at www.remm.nlm.gov and the Armed Forces Radiobiology Research Institute (AFRRI) at www.afrri.usuhs.mil)

Phases: Radiation victims may have some initial symptoms, such as nausea or vomiting in the *prodromal* phase that may then clear for a few days or weeks (*the latent phase*) followed by the eventual onset of ARS possibly 1-4 weeks later depending on the dose (*the manifest illness phase*). At higher doses there will be a shorter or no latent phase at all.

Four Classical Subsyndromes: *Hematopoietic* (blood and immune system), *Gastrointestinal* (digestive tract), *Cutaneous* (skin), and *Neurovascular* (nervous and circulatory systems). Severity and speed of onset of all these are dose related. The hematopoietic system is in general the most vulnerable and mitigation and treatment is considered at a whole body dose of ~ 200 rad (2 Gy) and higher.

Good Prognosis:
- Vomiting starts > 4 hours after exposure
- No significant change in serial lymphocyte counts within 48 hours after exposure
- Erythema (reddened skin) absent in first 24 hours
- No other significant injuries

Poor Prognosis:
- Neurovascular syndrome (e.g., coma, seizures)
- Severe erythema (reddened skin) within 2-3 h of exposure indicates dose of >1,000 rad (10 Gy)
- Vomiting less than 1 hour after exposure although vomiting can be a misleading clue to dose. [1]
- Serial lymphocyte counts drop more than 50% within 48 hours
- Gastrointestinal syndrome (e.g., bloody vomitus or stool) (> 600 rad [6 Gy])
- Burns and/or other physical trauma plus ARS (“combined injury”)

$LD_{50/60}$: Lethal dose $_{50/60}$
- The whole body radiation dose at which 50% of the victims will die by 60 days.
- Is thought to be approximately 350-400 rad (3.5 – 4 Gy) (Anno 2003).
- Vigorous medical management, if available, can increase the LD_{50} possibly to 600 – 700 rad (6 – 7 Gy), but the capacity to provide this level of care to a very large number of victims will be limited, at least initially in a nuclear detonation.

[1]Demidenko 2009

DHHS Concept of Operations (CONOPS)

DHHS has developed the following CONOPS model to plan and execute responses to a nuclear detonation. It provides standardized terminology and a detailed perspective on how a nuclear detonation alters all-hazard response plans. It will also help state and local responders request and receive Federal medical assets. The DHHS CONOPS was developed in collaboration with experts in emergency medicine physicians, with the goal of helping emergency community responders.[6]

The DHHS CONOPS uses the physical damage concepts from this Planning Guidance. It describes concentric damage zones around ground zero where various types of damage and levels of radiation are likely to occur. See Chapters 1 and 2 of this document for a detailed discussion. Understanding where to expect damage will assist in the selection of response staging areas and venues where Federal aid can be optimally located.

The following text describes a model for the Emergency Support Function #8 of the National Response Framework, Public Health and Medical Services.

Federal CONOPS for Nuclear Detonation Response – the RTR System

RTR (**R**adiation **TR**iage, **TR**ansport, and **Tr**eatment, see Figure 4.1) is a conceptual system for the settings at which various levels of medical care are likely to be delivered after a nuclear detonation. Multiple RTR sites will form following the incident. RTR is not a formal medical triage system like START or SALT.[7] Following a nuclear detonation, there are likely to be three types of sites that **form spontaneously**:

- **RTR1 –** Sites would have victims with major trauma and relatively high levels of radiation. This limits responder time and would be associated with relatively severe victim injuries; many victims may be expectant. The location will be near the severe damage (SD) zone external border and/or in the moderate damage (MD) zone. Rubble may prevent entry into this zone.
- **RTR2 –** Sites will be for triaging victims with radiation exposure only or possibly with minor trauma. The location will be along the outer edges of the Dangerous Fallout (DF) zone and the Light Damage (LD) zone and will have some elevated levels of radiation. Most victims are expected to be ambulatory.
- **RTR3 –** Sites are collection points where radiation is **not** present and will allow occupation for many hours or more. Victims are anticipated to have limited trauma, such as glass injury, and most victims will be ambulatory, including people displaced by the explosion who have no injury or exposure. Extensive self-evacuation is likely to be observed at these sites. These may occur in the LD zone and beyond. RTR3 sites are likely to form in various locations spontaneously or by direction of the Incident Commander as opposed to preplanned Assembly Center (AC) sites. Changes in the fallout pattern due to wind shifts may require some RTR3 sites to change roles (to RTR2) or possibly be abandoned.

The locations of the RTR sites will reflect infrastructure damage and available access, as outlined in Chapters 1 and 2 and are summarized in Figure 4.1.

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[6] Hrdina 2009
[7] Hrdina 2009

From the RTR sites, victims will be directed and/or transported to appropriate secondary facilities in *predetermined locations*:

- **Medical care (MC) sites:** includes hospitals, healthcare facilities and alternative care sites for those who need immediate medical care
- **Assembly centers (AC)**: collection points for displaced persons or those who do not need immediate medical attention.
- **Evacuation centers (EC)**: for organized transportation

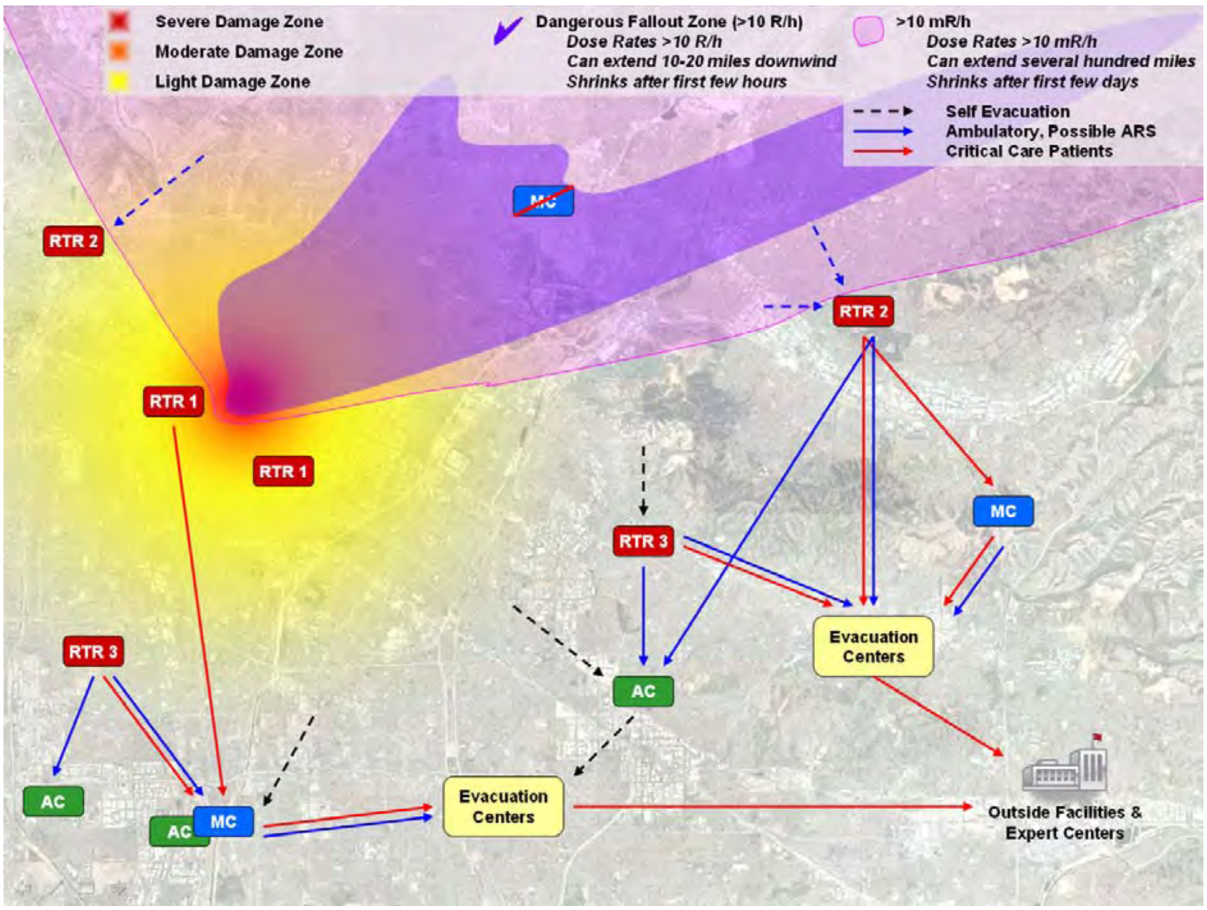

Figure 4.1: The RTR system for a nuclear detonation response; theoretical zones in a 10 KT nuclear explosion at ground level

Optimal locations for operational MCs and ACs will likely be identified jointly by the local incident commander, regional incident managers, and emergency operations center at DHHS. It is expected that this Federal-local collaboration will use the DHHS MedMap software and mapping system. This is a geographic information system (GIS) with layers and kinds of data showing the location, assets, and capabilities of potential MCs and ACs throughout the United States. Information such as roads, weather, radiation levels, and response-related facilities can be displayed in layers as well.[8]

[8] Shankman 2010

Transportation and logistics hubs will also be displayed on MedMap. This capability for real-time situational awareness will optimize transport of victims requiring medical care from close-in MCs with damage to the following:

- Intact medical treatment centers and hospitals locally and regionally
- National facilities, including networks such as the Radiation Injury Treatment Network, and National Disaster Medical System hospitals[9]
- Temporary housing and ***shelters***

Major transportation hubs are likely to include airports, seaports, railroad stations, and multi-modal terminals. Recognizing that in the early post-detonation hours, many people near the incident will be instructed to ***shelter-in-place***, victim flow is likely to be away from the incident. If transport of contaminated victims is excessively constrained or prohibited by transport providers and if medical facilities will not accept potentially contaminated victims, victims survival will be significantly diminished. These issues are best addressed in advance.

At all RTR, MC, and AC sites, efforts will be made to register and track victims and evacuees as they are transported to MC or AC sites regionally and nationally. See Chapter 5 for additional population monitoring information. Consideration should be given to placing the most sophisticated medical personnel in higher-level treatment facilities and avoiding their use for first aid. Non-professional volunteers, support personnel, and possibly minimally injured ***ambulatory*** victims can be asked and/or directed to help with a range of administrative tasks, basic first aid, and comfort for those awaiting care.

Life-saving tasks take precedence over external radiation decontamination from fallout or visible debris. Nevertheless, the presence of high levels of radiation in some zones in the field will make it unsafe for first responders to go to areas near the SD Zone and some RTR1 or 2 locations. Radiation levels in the environment will be measured and analyzed repeatedly over time by sophisticated equipment in order to map the location of the radiation, track the rate of radioactive decay, support responder safety, and assist with dose reconstruction for victims. Responders in any area where radiation is suspected should always use appropriate ***personal protective equipment*** and wear personal dosimeters. Radiation dose limitations and protection of response personnel are discussed in detail in Chapter 2.[10]

Life saving tasks takes precedence over external radiation decontamination from fallout or visible debris.

Initial Mass Casualty Triage (Sorting)

There are several established triage systems for mass casualty trauma incidents (e,g. START, SAVE, JumpSTART and others[11]). There is guidance available, but currently no Federal or internationally agreed upon medical triage systems specifically for radiation mass casualty

[9] RITN 2009; NDMS 2010
[10] DHHS 2008
[11] Lerner 2008

incidents.[12] Existing mass casualty emergency triage algorithms will be used with modification for the impact of radiation.

The Department of Defense (DOD) has done extensive trauma triage planning. Some of these documents are accessible to civilians. The Department of Defense uses the mass casualty 'DIME' medical triage categories (Delayed, Immediate, Minimal and Expectant).[13] These triage categories are similar to the civilian systems as is the approach of serial reassessment and life-saving interventions. The expertise and experience from DOD has been valuable in formulating the civilian response. However, the specifics of the DOD and civilian triage guidance will vary, as the civilian population includes many individuals with extremes of age, co-morbidities and special needs, and the mission of the military may impact their triage decisions. These DOD efforts were used by Waselenko and coauthors to assess how radiation might affect the triage of civilian trauma victims.[14]

This Planning Guidance does not endorse any specific initial triage algorithm. Local emergency responders will choose their own system. Initial mass casualty triage algorithms (victim sorting) should not be confused with subsequent clinical management algorithms for more specific medical management.

There is guidance available but currently no Federal or internationally agreed upon medical triage systems specifically for radiation mass casualty incidents. Existing mass casualty emergency triage algorithms will be used with modification for the impact of radiation.

Initial mass casualty triage (victim sorting) should not be confused with subsequent clinical triage for more definitive medical management.

Triage System - Concepts from SALT

Recently, a major consensus meeting on mass casualty triage in the United States resulted in the publication "*Mass casualty triage: an evaluation of the data and a proposed national guideline.*"[15] Based on extensive review of the various triage systems, the expert panel proposed a new five-category mass casualty trauma triage system called SALT (Sort, Assess, Life-Saving Intervention, Treatment and/or Transport). The utility of SALT compared to other systems remains under debate. DHHS medical response planning endorses the conceptual part of SALT that addresses victim reassessments iteratively over time and the need to change a victim's triage category as the availability of resources evolves.

First responders will use the triage algorithms for trauma and burns with which they are familiar. However, these standard triage algorithms are likely to require significant modification, at least initially after a nuclear detonation. In standard triage, the most severely injured are given first priority. After a nuclear detonation, priorities are likely to change. It may be necessary for those with less severe injuries (e.g., those who are ambulatory,

[12] See DHHS ASPR 2010
[13] DOD 2001
[14] Waselenko 2004
[15] Lerner 2008

responsive and only moderately injured) to receive priority in order to provide the greatest good to the greatest number of victims.

Scarce Resources Situations

In a landmark series of papers about optimizing responses to pandemic influenza, experts from multiple specialties addressed how to manage severe resource scarcity while saving the greatest number of lives.[16] DHHS used this series of papers as a template to consider scarce resource issues after a nuclear detonation.

During scarce resources conditions, emergency responders and first receivers will likely have to modify conventional clinical standards of care and adopt contingency and then crisis standards of care to maximize the number of lives saved.[17] This change is best initiated using predetermined criteria, Scarce Resources Allocation and Triage Teams, and protocols at medical facilities.[18]

To address the issues for a nuclear detonation, DHHS initiated the Scarce Resources Project, a multi-specialty expert panel from government and the private sector to build upon scarce resources and hospital surge concepts already developed.[19] Triage and treatment of potentially hundreds of thousands of patients is addressed in a series of manuscripts (submitted for publication in mid-2010).[20]

During the scarce resources circumstances following a nuclear detonation, each of the following categories of victims will need to be addressed:

- Radiation injuries alone with various levels of severity, mostly from fallout
- Trauma and/or thermal burn injuries without significant radiation exposure – these may occur in the MD and LD zones or even beyond from accidents due to flash blindness or secondary fires
- ***Combined injury*** (e.g., trauma and/or thermal burn injuries plus radiation)
- Co-morbid conditions (i.e., impact of pre-existing illnesses and those with special needs such as the very young and very old)

Triage and management decisions will employ fair and ethical processes to achieve the goals of saving the greatest number of lives and providing compassionate palliative care to as many expectant victims as possible. The key issues to consider in developing response algorithms are:

- The existence of scarce resources (e.g., personnel, equipment/medication, and facilities often referred to as ‘staff, stuff, and structure’)[21]
- The diverse and constantly-changing status of resource assets that will vary markedly by distance from the SD zone and time after the incident

[16] Devereaux 2007 among others
[17] IOM 2009
[18] US Dept. of Veterans Affairs 2009
[19] US DHHS, AHRQ 2007 and 2008a
[20] DHHS ASPR 2010
[21] Kaji 2006

- The change in priorities for sorting victims as the resource conditions change from conventional to contingency to crisis care as defined in the IOM report[22]

Figure 4.2 presents an example of how triage categories will vary by resource scarcity. Details are provided in the Scarce Resources manuscripts.[23]

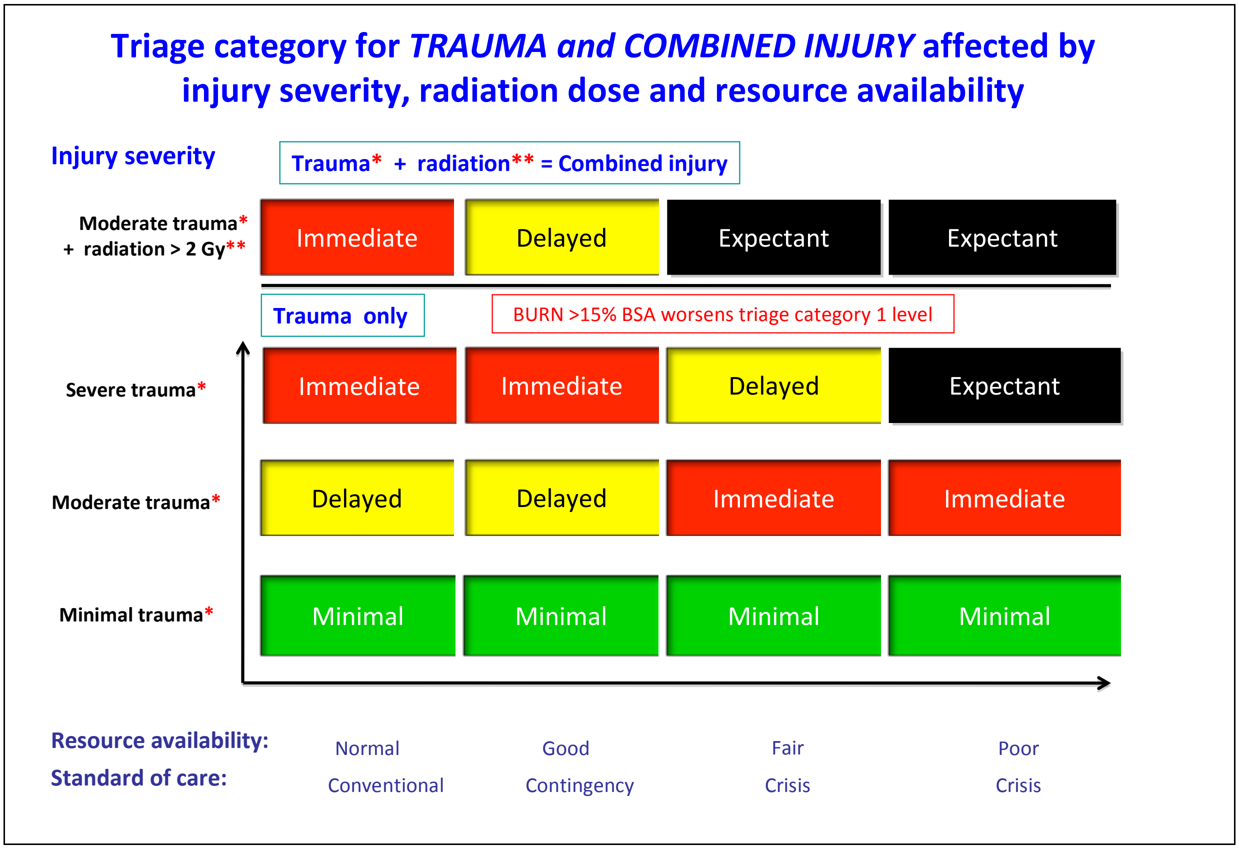

Figure 4.2. Illustration of possible changes in prioritizing victim with trauma alone and *combined injury* for care after a nuclear detonation (see publication for details) (Trauma* has 3 categories: Minimal, Moderate and Severe [y-axis, left]; *Combined injury*: moderate trauma plus radiation dose > 200 rad (2Gy) [top row]; Resource availability [x-axis]: worsens from normal to good, fair, and poor [row second from bottom]; Standard of care changes from Conventional to Contingency to Crisis[24] [bottom row])**

To maximize fairness and lives saved over time after a nuclear detonation, it will be important to plan for Scarce Resources Allocation and Triage Teams with experienced leaders as described in a recent Veteran's Affairs (VA) document for pandemic influenza.[25] This will require agreed upon triggers and well understood procedures which will be

[22] IOM 2009
[23] DHHS ASPR 2010
[24] IOM 2009
[25] VA document 2009

activated when normal standards of care must be replaced by crisis standards of care.[26] Ideally, each medical facility or regional group of facilities should create a formal system proactively so that senior, experienced teams of practitioners can assess the current operating limitations and provide guidance for individual physicians who then do not have to make *ad hoc* decisions for each patient under his/her care without knowledge of the larger picture.[27] Decisions can change later based on the availability of intact regional and national resources and the ability to transport victims.

During scarce resources conditions, emergency responders and first receivers will likely have to modify conventional clinical standards of care and adopt contingency and then crisis standards of care to maximize the number of lives saved. This change is best initiated using predetermined criteria, Scarce Resources Allocation and Triage Teams, and protocols.

Combined injury and Radiation Protection, Mitigation, and Treatment

Experimental animal data indicate that excellent supportive care, including bone marrow growth factors, improves survival following whole body injury from radiation alone.[28] Limited data demonstrate a decreased prognosis for ***combined injury***.[29] Although there are limited data for ***combined injury*** in humans, it is currently assumed that whole body doses above 200 rad (2 Gy) will decrease survival when combined with significant burn or blast injuries. Furthermore, because of extensive damage and scarce resources, normal rescue capabilities will be severely degraded, at least initially, significantly hampering the ability to provide care to those with severe combined injuries. In small incidents with only a few patients, patients with ***combined injury*** who might be triaged to the ‘immediate’ category might need to be triaged into the ‘delayed’ or ‘expectant’ categories in a nuclear detonation response.[30]

Because a nuclear detonation would presumably occur without notice or warning, radiation protectors (e.g., medical prophylaxis prior to radiation injury) are not currently a component of the medical response for victims or responders. In the future, should novel agents be developed that can reduce long-term risks for responders, those would be considered assuming they do not compromise responder safety and performance.

Current medical management for radiation toxicity includes therapies for the following:

- Injury mitigation before the development of manifest illness effects, with possible improvement in survival and reduction in resources needed for care
- Injury treatment after the development of manifest illness

At present, ARS therapies are mostly for the hematological subsyndrome of ARS, as included on the Radiation Emergency Medical Management or REMM website

[26] IOM 2009
[27] VA document 2010
[28] MacVittie 2005
[29] Ran 2004; Pellmar 2005; Stromberg 1968; Ledney 2010
[30] Waselenko 2004; DHHS ASPR 2010

(http://remm.nlm.gov). Therapies are being developed for the gastrointestinal and cutaneous systems including both drugs and cell-based therapies.[31]

Emergency Care for ARS

Robust laboratory support is necessary to assist with clinical management. Complete blood counts (CBCs) and absolute lymphocyte count will be the major assessment used initially. The various biodosimetry tools have recently been reviewed including cytogenetic biodosimetry.[32] Initial resource constraints and time to complete the assay will limit use of dicentric cytogenetic assays in large mass casualty emergencies although they will be useful for secondary and tertiary triage. There is ongoing research to develop technologies for high throughput screening in the field.[33]

The REMM website provides clinicians with an interactive software tool that allows input of clinical and laboratory information to quickly estimate radiation dose from whole body gamma exposure. The tool, called the Biodosimetry Assessment Tool algorithm, was developed by The Armed Forces Radiobiology Research Institute (AFRRI) investigators.[34]

Supportive medical care (e.g., appropriate use of fluids, nutritional support, antibiotics, drugs, and overall medical/surgical management) is the most important component of managing ARS. Supportive care alone should be initiated even if cytokine therapy is not available, as it can increase survivability to as much as 50% for patients with severe ARS. A generic template for adult hospital orders is on the REMM website.

Current recommendations suggest that for patients receiving doses above 100 – 200 rad (1- 2 Gy), open wounds should be decontaminated, debrided (dead tissue removed), and closed quickly. Emergency surgery should be completed within 36-48 hours, before the expected drop in blood counts. If this is not possible, surgery may need to be delayed until hematopoietic recovery is evident.[35] Use of cytokines that boost the white cell count may extend the window for surgery, but this is not known for certain.

Currently, white cell cytokine drug treatment is recommended within 24 hours of injury only for victims with doses > 200 rad (2 Gy). Additional research is needed to define the time period over which effective mitigation is possible. Cytokines will not benefit victims receiving doses < 200 rad (2 Gy) because low radiation doses are unlikely to cause prolonged neutropenia that is severe enough to confer a susceptibility to life-threatening infections. Therefore, scarce resources like cytokines should **be reserved** for those who will benefit. Medical countermeasures and other supplies will be available in-part from the Strategic National Stockpile (SNS).

Although a whole body radiation dose from 500 – 800 rad (5-8 Gy) is usually considered fatal within 2 - 6 weeks without treatment, nearly all of these patients will exhibit a 'latent'

[31] US DHHS NIAID and BARDA
[32] Swartz 2010
[33] Grace 2010
[34] AFRRI Biodosimetry Tools
[35] NATO-AMedP-6(b)

(asymptomatic) period of days to weeks immediately following their initial symptoms. For those with doses of 200 – 500 rad (2 – 5 Gy), the latency period may be 3 – 4 weeks. To improve the likelihood of saving these patients, it will be critical to use the latent period to find facilities that will accept them and have the expertise to care for them using the vigorous supportive care methods that will be required. Typically, this expertise is found in the hematology/oncology and infectious disease medical communities, including the Radiation Injury Treatment Network (RITN).

Initially, many victims who would be provided definitive care under circumstances with sufficient resources may be triaged into the 'expectant' category. Compassionate palliation (treatment of symptoms) for expectant victims should be offered whenever possible. Treating significant radiation exposure is a high priority during the first few days after a nuclear detonation, but treating internal contamination is not.[36] Administration of radiation blocking or decorporating agents such as potassium iodide (KI), Prussian blue, or DTPA is not useful in the early medical response.

Initial triage and management of victims with ARS will be based on (a) clinical signs, symptoms, and physical examination and (b) estimates of whole body dose using clinical biodosimetry (blood count analysis), dose reconstruction which links victim location to radiation maps generated by computer models, and real-time environmental radiation measurements.

Initially, many victims who would be provided definitive care under circumstances with sufficient resources, may be triaged into the 'expectant' (expected to die) category. Compassionate palliation (treatment of symptoms) for expectant victims should be offered whenever possible.

Referral to Expert Centers

Following the initial sorting and the subsequent identification of those with or at risk for ARS, medical management will require highly specialized expertise. The medical specialties most familiar with diseases with manifestations similar to ARS are hematologists and oncologists. The RITN (http://www.nmdp.org/RITN/) currently works with DHHS and international partners to implement medical management protocols and receive patients in mass casualty radiation emergencies.[37] Expertise is also available through the NDMS and other specialized facilities.

Radiation response experts in the US will rely on clinical and laboratory estimates of a victim's dose. While specific organ systems are affected in ARS (e.g., hematological, gastrointestinal, cutaneous, and neurovascular systems), victims will likely have some degree of multi-organ dysfunction and possibly radiation injury to other organs (e.g. kidney, lung, liver).[38]

[36] Levanon 1988; Peterson 1992
[37] Weinstock 2008; Fliedner 2009
[38] Brit J Radiol 2005; Fliedner 2009

The European approach for managing radiation casualties, called METREPOL, is based on medical signs and symptoms and laboratory data, not on dose per se. It uses ‘Response Categories’ (labeled 1-4 based on severity) for each of the four subsyndromes (H for hematological, G for gastrointestinal, N for neurovascular, and C for cutaneous).[39] The overall Response Category (RC), the most severe category assigned to any subsyndrome, is used to recommend treatment and determine what kinds of medical facility a patient should be transported to. This system was originally developed for limited size incidents such as industrial accidents, and its complexity limits its use for field triage after a nuclear detonation. However, in small incidents and also once victims are under the care of medical experts in larger incidents, the METREPOL system could be employed to estimate prognosis and create appropriate treatment plans.

Behavioral Healthcare

The social, psychological, and behavioral impacts of a nuclear detonation would be wide spread and profound, affecting how the incident unfolds and the severity of its consequences. Among the key issues are the mental health impacts on the general public, potential effects on emergency responders and other caregivers, and broader impacts on communities and society.[40]

Given the existing knowledge, there are some reasonable assumptions that can be made about public reactions. First, it can be assumed that the dominant behavioral response will likely be for people to engage in the kinds of pro-social, altruistic behaviors that occur in most disaster situations, unless fear of radiation and contamination or lack of needed information complicates response and recovery efforts. Second, emergency responders in large numbers will do their best to carry out their missions provided they have the training and information they require. To the degree that these are lacking, stress will increase, responder confidence will diminish, and there will be increased risk for an ineffective response.

During the first 72 hours, the overarching goals are to support lifesaving activities for those with immediate injuries and to prevent additional casualties from fallout. In this initial phase of confusion and limited resources, behavioral healthcare providers (BHCPs) can:

- Promote appropriate protective behaviors (e.g., adhering with guidance to ***shelter-in-place***) and address psychological barriers to taking them (e.g., paralyzing anxiety)
- Discourage dangerous behaviors (e.g., entering contaminated areas to search for loved ones)
- Help manage survivor/patient flow in support of crisis standards of care
- Support first responders and first receivers’ ability to function
- Assist with triage
- Aid in caring for expectant patients

Communication will be important to reduce surge on hospitals and medical care sites. In the aftermath of a disaster, people converge on hospitals for a number of reasons (e.g., to look

[39] Fliedner 2001, 2006, 2009
[40] adapted from US DHHS, ASPR 2010

for missing loved ones, to receive treatment for minor injuries, and to seek a safe haven). Consequently, a major task will be to divert those without immediately life threatening injuries to RTR-3 sites and ACs in order to help conserve and better target scarce medical resources. Behavioral health care providers may be useful in providing information, calming people, and redirecting them to established assembly and evacuation sites.

As conditions permit, BHCPs, especially those with consultation, liaison, or emergency department experience, can assist in triage to distinguish organic from psychological disorders and to intervene when psychiatric symptoms are the predominant reason for seeking care. They can also help care for expectant patients and support other staff with this responsibility.

As more information is gathered about the nature of the attack and as one gets farther from the affected area, radiation concerns may become more prominent for both medical personnel and the public. Ideally, BHCPs will have participated in planning for reception centers and the screening process for radiation. Reminding planners that **procedures that separate children from parents will be unsuccessful** is the kind of behavioral advice that can make systems run more smoothly.

The opportunity to support emergency responders and healthcare practitioners in the affected area will be extremely limited until additional resources are brought in. Therefore, consultation to medical leadership will likely be the most effective way to provide immediate assistance to healthcare providers. This consultation may take several forms. It may include some limited opportunities to support staff in making the difficult transition from conventional practice to crisis standards of care. It may also include helping responders focus on actions that relieve suffering when they are unable to save lives and thus diminish feelings of helplessness. Other behavioral support to providers would include preventing unnecessary exposure to the dead and dying as a way to diminish traumatic stressors. Studies suggest that pairing experienced staff with those in training or new to the field may be useful in minimizing stress in the latter group.

A common challenge for response personnel, especially leaders, is transitioning from a sprint-like pace to one that can be sustained over time. As soon as sufficient resources become available to manage the response, initial responders need rest and recovery such as counseling and coping assistance. There is often a tendency for responders, especially leaders, to keep working despite the arrival of relief personnel. Mechanisms should be developed to identify and curtail such 'over-dedication.' Guidance published by HHS incorporates psychological factors into occupational safety for disasters.[41]

Just-in-time training or refresher courses that educate healthcare professionals at receiving facilities on how to safely care for patients with internal and/or external radioactive contamination will be important. The rapid identification of those who have received significant radiation exposure and who could benefit from medical intervention will be a high medical and behavioral priority. This rapid screening of potentially exposed people will be enormously important from a psychological as well as medical standpoint.

[41] HHS 2005, supplement 11

Rapid screening, enrollment in registries, and the provision of appropriate treatments can foster trust and confidence in survivors and should be initiated, but will be the focus of efforts that extend beyond 72 hours. Understandably, people will want to learn as much as possible about their health status, including potential long-term implications of exposure. Uncertainty and waiting are very discomfiting aspects of the human condition; in general, the more quickly people learn about their exposure status, the better they will fare psychologically even if the news is bad. Fairness in the allocation of scarce resources is a very strong value held by the public. It will be essential to keep people informed about the process for evaluating radiation exposure and to be transparent about why certain groups may be prioritized higher than others. Because concentration and the ability to retain information decrease under high stress, those screened should be given a record of their results, however primitive that record may be. Ideally, these results would also be entered into a registry.

In the days and weeks that follow patients learning they have severe ARS, psychological support may help them and their families cope better with treatment. BHCPs familiar with working with cancer patients and other life-threatening conditions may be especially useful in planning for these patients' and their families' needs. Past radiation incidents suggest that active outreach be made to women with small children and those who become pregnant due to high levels of concern about the potential adverse health effects of radiation on children and developing embryos.

Psychiatric disorders associated with terrorist attacks can be expected to develop over time. The usual path of mental response is one of resilience, in which initial signs and symptoms of distress resolve between a few days and several weeks from discrete traumatic incidents. However, due to the potential differences between a nuclear detonation from other incidents (i.e., primarily radiation spread, terrorist nature, etc), the event may be viewed as an ongoing traumatic process for even the first month or more, with resulting delay of symptom improvement or resolution. In contrast to prevention and mitigation activities, there are evidence-based interventions to guide treatment of these psychiatric conditions. Risk factors for the development of psychiatric disorders after disasters are:[42]

- Severity of traumatic exposure (most robust predictor)
    - ✓ Number of stressors
    - ✓ Death of loved one
    - ✓ Injury to self or family member
    - ✓ Panic during the disaster
    - ✓ Threat to life
    - ✓ Financial loss
    - ✓ Relocation
    - ✓ Property Damage
- Female gender
- Lower socioeconomic status
- Avoidance as coping mechanism

[42] Watson 2008

- Assignment of blame
- Parenthood
- Parental distress (predicts child's distress)
- Ethnic minority
- Pre-disaster psychological symptoms

Beyond understanding public reaction to the immediate incident, behavioral health experts have knowledge of human behavior that can inform many aspects of the response. This expertise includes several factors that affect health outcomes, such as information, communication, and population behavior. Bringing this expertise to the table when planning for and responding to a nuclear detonation could reduce negative impacts on health over the near and long term, for both the local community and society at-large.

The social, psychological, and behavioral impacts of a nuclear detonation will be widespread and profound, affecting how the incident unfolds and the severity of its consequences. Among the key issues are the mental health impacts on the general public, potential effects on emergency responders and other caregivers, and broader impacts on communities and society.

Fatality Management

After a nuclear detonation, fatality management will be one of the most demanding aspects of the response. The large number of fatalities will overwhelm the normal Medical Examiners/Coroners (ME/C) system. A respectful, culturally sensitive plan for fatality management, despite diminished capacity of the infrastructure, will have a direct impact on the citizens' perception of the government's ability to manage the emergency and the resilience and recovery of the community and the nation.

While fatality management is an important concern, life-saving operations will take precedence over fatality management during the first 72 hours of the response, which is the time frame covered by this guidance. Nonetheless, it is crucial to establish, as soon as possible, a robust capacity to handle the overwhelming number of calls expected from distraught families, loved ones, and interested persons. Caller information will be important in creating a missing persons list that can be used to formulate a decedent manifest.

Authorities may be confronted with a decision regarding whether or not to attempt identifications or individual examinations in all cases given the scale of such operations and the potential radiation exposure to personnel.

Fatality management will usually involve multiple steps: collection of remains from the field, transfer to interim sites, transfer to temporary morgues, coordination with families, collection of ante-mortem data, including information and reference DNA specimens, at family assistance centers, examination and processing of the remains in the temporary morgue, identification of the remains, creation of death certificates, notification to the next-of-kin, and disposition of the remains. The ME/C operations will need to increase their morgue storage capacity significantly, in coordination with incident managers. Contaminated decedents will require special kinds of caskets and special transport procedures. They should not be cremated to avoid contamination of the environment.

Fatalities near the blast site as well as those in less damaged zones may be contaminated. Radioactive contamination may be external or internal or both, and the level of contamination will vary considerably. Radiation safety personnel can help determine which victims are contaminated. In incidents much smaller than a nuclear detonation, gross external decontamination is indicated. After a nuclear detonation, complete external decontamination will not likely be possible for all decedents, and internal decontamination is not indicated or possible.

ME/C, radiation safety personnel (who can survey decedents for radiation), and local Incident Commanders should consider the following issues:

1. Designation of a proper medicolegal death investigatory authority to lead the fatality management operations
2. Identification of required capabilities (e.g., personnel, equipment, supplies)
3. Creation of a comprehensive incident-specific plan for managing contaminated decedents including identification material to gather, recover, transport, store, and dispose of remains in the context of the available resources
4. Characterization of the disaster site and decedents with the assistance of health physicists to determine radioactivity of the environment as well as each decedent
5. Development of a comprehensive health and safety plan to protect those handling decedents, including the use of personal monitoring devices
6. Creation of family assistance centers or alternative means to gather antemortem data, collect family reference DNA specimens, conduct notification, and disposition meetings with the next-of-kin, and to keep next-of-kin apprised of identification activities; moreover, it will also be important to understand and respect specific cultural issues to the extent feasible and safe
7. Planning for recovering and processing decedents that avoids cross contaminating radioactive material to clean areas and personnel
8. Planning for a public communications strategy that outlines all plans for fatality management, especially where survivors will not be able to recover family members who are deceased and contaminated, or unidentifiable
9. Planning for requesting mortuary assistance from outside the impacted area

Several key references are available to assist in planning for fatality management after a radiological incident. Military guidance may not be fully applicable to the civilian community, but their available assets (e.g., Mortuary Affairs Teams, remains identification through DNA testing, etc.) may be used for assistance. DHHS has Disaster Mortuary Operational Response Teams (DMORTs, http://www.dmort.org/) within the NDMS (NDMS, http://www.hhs.gov/aspr/opeo/ndms/index.html), but their numbers are limited. Other references include US DOD Mass Fatality Management 2005, US DOD Mortuary Affairs 2006, PAHO 2006, Morgan 2005, US DHHS CDC 2008, Medical Examiner/Coroner Guide 2006 and DOE Transportation, National Assoc Med Examiners 2010, and NCRP Report No.

161 (2009) Management of Persons Contaminated with Radionuclides, Chapter 14: Contaminated decedents (hospital and mortuary).

Initially, saving lives will take precedence over managing the deceased. Nonetheless, fatality management will be one of the most demanding aspects of the nuclear detonation response and should be planned for as early as possible.

Additional Resources

The DHHS-sponsored REMM web portal provides a comprehensive set of medical diagnostic and management guidelines for training for and responding to radiation emergencies. It is available at http://www.remm.nlm.gov. First responders and first receivers can also download REMM to their computers for use offline during training and responses. Key files are also available for download to selected mobile devices. Joining the REMM ListServ is advised for notification about key content updates. The REMM system was created in collaboration between the National Library of Medicine and DHHS, with input from US and international subject matter experts.

AFRRI, located at the DOD medical school Uniformed Services University of the Health Sciences (USUHS), has published several very useful tools:

- Medical Management of Radiological Casualties Handbook[43]
- AFRRI Emergency Radiation Medicine Pocket Guide[44]
- AFRRI Biodosimetry Assessment Tool (BAT)

The Centers for Disease Control and Prevention (CDC) Radiations Studies Branch (http://emergency.cdc.gov/radiation/) provides references for professionals and the public

The DOE Radiation Emergency Assistance Center/Training Site (REAC/TS) (http://orise.orau.gov/reacts) also provide very useful clinical information and training opportunities.

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[43] DOD AFRRI 2009
[44] DOD AFRRI 2008

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Chapter 5 – Population Monitoring and Decontamination

KEY POINTS

1. Population monitoring activities and decontamination services should remain flexible and scalable to reflect the prioritized needs of individuals and availability of resources at any given time and location.
2. The immediate priority of any population monitoring activity is identification of individuals whose health is in immediate danger and requires urgent care.
3. The primary purpose of population monitoring following a nuclear detonation is detection and removal of external contamination. In most cases, external decontamination can be self performed if straightforward instructions are provided.
4. Prevention of acute radiation health effects should be the primary concern when monitoring for radioactive contamination.
5. Radioactive contamination is not immediately life threatening.
6. Self-evacuating individuals will require decontamination instructions to be communicated to them in advance of the event (e.g., public education campaign) or through post-event public outreach mechanisms.
7. Planning must provide for the consideration of concerned populations because it is anticipated that a significant number of individuals, who should remain safely sheltered, will begin to request population monitoring to confirm that they have not been exposed to radiation or contaminated with radioactive materials.
8. Use of contaminated vehicles (e.g., personal or mass transit) for evacuation should not be discouraged in the initial days following a nuclear detonation; however, simple instructions for rinsing or washing vehicles should be provided.
9. There is no universally accepted threshold of radioactivity (external or internal) above which a person is considered contaminated and below which a person is considered uncontaminated.
10. State and local agencies should plan to accommodate the needs of pets and service animals. Contaminated pets can present a health risk to pet owners especially children who pet them.
11. State and local agencies should establish survivor registry and locator databases as early as possible. Initially, the most basic and critical information to collect from each person is his or her name, address, telephone number, and contact information.
12. Planners should identify radiation protection professionals in their community and encourage them to volunteer and register in any one of the Citizen Corps or similar programs in their community.

Overview

Population monitoring is the process of identifying, screening, and monitoring people for exposure to radiation or contamination with radioactive materials. Decontamination is the process of washing or removing radioactive materials on the outside of the body or clothing and, if necessary, facilitating removal of contamination from inside the body.

The population monitoring process begins soon after a nuclear emergency and continues until all potentially affected people have been monitored and evaluated as appropriate for the following:

- Needed medical treatment
- Presence of radioactive contamination on the body or clothing
- Intake of radioactive materials into the body
- Removal of external or internal contamination (decontamination)
- Radiation ***dose*** received and the resulting health risk from the exposure
- Long-term health effects

Assessment of the first five elements listed above should be accomplished as soon as practical. However, long-term health effects are usually determined through a population registry and an epidemiologic investigation that will likely span several decades and are beyond the scope of this guidance.

It is important to recognize that early decisions by emergency responders and response authorities related to monitoring for radioactivity and decontamination should be made in the context of the overall response operations. For example, as stated in Chapter 4, survival rates will decrease if evacuation is constrained by policies for nontransportation or acceptance of potentially contaminated patients imposed by ambulance providers and medical facilities. Furthermore, the needs of a displaced population and concerned citizens hundreds of miles away are different from those of the immediate victims near the site of detonation. Therefore, radiation survey methods, screening criteria used for radiation screenings, and decontamination guidance or services offered or recommended should be adjusted to reflect the prioritized needs of individuals and availability of resources at any given location.

Population monitoring activities and decontamination services offered should remain flexible and scalable to reflect the prioritized needs of individuals and availability of resources at any given time and location.

The recommendations in this chapter are derived from the Department of Health and Human Services (DHHS) Centers for Disease Control and Prevention (CDC) publication *"Population Monitoring in Radiation Emergencies: A Guide for State and Local Public Health Planners"* (http://emergency.cdc.gov/radiation/pdf/population-monitoring-guide.pdf).[1] The relevant portions of the CDC guidance are summarized here; however, readers are referred to that document in its entirety for more information.

[1] DHHS 2007

Primary Considerations

There are several priority considerations that should be applied in any radiation emergency, especially in a nuclear emergency where life-threatening conditions exist for a potentially large number of individuals.

Identification of individuals whose health is in immediate danger and require urgent care is the immediate priority of any population monitoring activity. Near the incident scene, this monitoring need is accomplished as part of the medical triage already described in Chapter 4. Management of serious injury takes precedence over radiological decontamination.

1. **The primary purpose of population monitoring, following a nuclear detonation, is detection and removal of external contamination. In most cases external decontamination can be self performed, if straightforward instructions are provided.** There are two types of decontamination. External decontamination removes ***fallout*** particles and other radioactive debris from clothes and external surface of the body. Internal decontamination, if needed, requires medical treatment to reduce the amount of radioactivity in the body.

2. **Prevention of acute radiation health effects should be the primary concern when monitoring for radioactive contamination.** Population monitoring personnel should offer or recommend gross external decontamination such as brushing away dust or removal of outer clothing. Cross-contamination issues (e.g., from transport vehicles) are of secondary concern, especially in a nuclear emergency where the contaminated area and the potentially impacted population are large.

3. **Population monitoring and decontamination activities should remain flexible and scalable to reflect the available resources and competing priorities.** For example, if water is a scarce commodity or is needed to fight fires, dry methods can be used for decontamination. Moist wipes can be used to wipe the face and hands in addition to a change of outer clothing. Instead of pouring water as in a shower, small amounts of water can be used to wet paper towels and clean the skin.

4. **Radioactive contamination is not *immediately* life threatening.** Individuals who are self evacuating may be advised to self decontaminate. Suggestions for monitoring and decontamination in this chapter assume radioactivity is the only contaminant and that there are no chemical or contagious biological agents present.

The immediate priority of any population monitoring activity is identification of individuals whose health is in immediate danger and requires urgent care.

The primary purpose of population monitoring following a nuclear detonation is detection and removal of external contamination. In most cases, external decontamination can be self performed if straightforward instructions are provided.

Prevention of acute radiation health effects should be the primary concern when monitoring for radioactive contamination.

Radioactive contamination is not immediately life threatening.

Impacted Population

Victims who may be suffering from severe burn and trauma injuries are addressed in Chapter 4. Evacuating those critical patients away from the scene should not be hindered by lengthy or restrictive decontamination and transport policies. People who are not critically injured may fall into four broad categories that can be linked with general decontamination considerations as follows:

1. **Individuals who self evacuate from the affected and surrounding areas and who are not under the direction of emergency response officials —** These are individuals who self evacuate before emergency responders arrive. Even after responders arrive, there may not be sufficient responders to direct all of the individuals who may continue to self evacuate. For this group of individuals, responders will not have an opportunity to provide on-the-scene decontamination assistance before they leave the area. Decontamination instructions will need to be communicated to these individuals in advance of a nuclear detonation (e.g., public education campaign) or through post-incident public outreach mechanisms. Some of these individuals may go directly to hospitals or seek care in public ***shelters***.

2. **Individuals who leave the affected areas under the direction of emergency response officials —** These are people leaving the immediate impact zone (e.g., moderate damage (MD) or light damage (LD) zones) of the incident may require assistance from responders to evacuate (e.g., search and rescue, emergency medical service). Some people may be able to leave unassisted but will be part of an organized immediate evacuation. Responders will need to make decontamination decisions regarding these individuals. As stated earlier, these decisions must be made in the context of the overall response effort and reflect the prioritized needs of the evacuating individuals and available resources.

3. **Individuals who initially sheltered, both in the immediate impact area as well as in the fallout zone, then evacuate as part of an organized evacuation —** As in the previous category, these individuals will be dependent on responders to make and communicate decontamination decisions.

4. **Individuals who are in the surrounding area of the detonation, have not received an evacuation notice, but who are concerned about possible contamination and seek screening from public officials to confirm that they have not been exposed** — These individuals may report to hospitals or public shelters. This group could represent a significant number of individuals, and planners will need to ensure they

adequately address this group's concerns. Community reception centers, as described in CDC's publication "*Population Monitoring in Radiation Emergencies: A Guide for State and Local Public Health Planners*," present an infrastructure to address the needs of this population as well as those of the displaced population reporting to reception centers.[2]

Self-evacuating individuals will require decontamination instructions to be communicated to them in advance of the event (e.g., public education campaign) or through post-event public outreach mechanisms.

Planning must provide for the consideration of concerned populations because it is anticipated that a significant number of individuals, who should remain safely sheltered, will begin to request population monitoring to confirm that they have not been exposed to radiation or contaminated with radioactive materials.

The public may self evacuate using personal vehicles that may be contaminated. Although this evacuation may result in the spread of some contamination, such actions should not be discouraged during the initial days following a nuclear detonation. Simple rinsing or washing of vehicles in a common location before or after use should be considered; however, these actions should be implemented so that they do not restrict or inhibit necessary evacuations. The public should be directed to rinse or wash down vehicles as soon as practical once they are out of danger.

In communities where people do not speak English as their primary language, these instructions should be provided in languages appropriate for the affected community. At later times following the detonation, more detailed instructions should be provided along with protective action guidance basing mitigation measures on potential for contamination, dose, and residual risk.

If public mass transportation (e.g., rail, bus) is used to evacuate individuals from contaminated areas, the vehicles should be surveyed and controlled, to the extent practical, to minimize the potential for contaminating land and people. During the early phase, simple rinsing or washing of mass transit equipment in a common location before or after use should be considered; however, these actions should be implemented in a manner so they do not restrict or inhibit necessary evacuations. If there is a potential that these simple protective actions will inhibit needed evacuations then they should be delayed. Decisions should be made regarding the benefit of expedient evacuation verses the risk of spreading contamination by using vehicles that have been exposed. Once a contaminated vehicle has been used, it cannot be returned to service until appropriate decontamination has been accomplished.

[2] DHHS 2007

Use of contaminated vehicles (e.g., personal or mass transit) for evacuation should not be discouraged in the initial days following a nuclear detonation; however, simple instructions for rinsing or washing vehicles should be provided.

External Contamination Considerations

The first step in external monitoring is to check people for radioactive contamination on their bodies and clothing. Note that detailed radiological surveys are not necessary and initial screenings for external contamination can be done in a matter of several seconds by trained professionals using proper radiation detection instruments. Depending on the situation and if adequate staff and decontamination resources are available, more restrictive radiological screening criteria may be used.

There is no universally accepted level of radioactivity (external or internal) above which a person is contaminated and below which a person is uncontaminated at a 'safe' level. A discussion of key considerations in selecting a contamination screening criterion and a number of benchmark screening criteria are described and referenced in Appendix C of the CDC population monitoring guide.[3] Screening values may also be found in other agency documents such as Federal Emergency Management Agency (FEMA)-REP-21 (1995) and FEMA-REP-22 (2002), National Council on Radiation Protection (NCRP) Commentary 19 (2005), International Atomic Energy Agency (IAEA) (2006), Conference of Radiation Control Program Directors (CRCPD) (2006), and the DHHS Radiation Emergency Medical Management (REMM) web site (2010) as well as military manuals.[4]

Keeping in mind that screening levels may need to be adjusted when large populations need to be screened in a short time and with limited resources, State and local planners, together with their state radiation control authority, should consider a range of possible circumstances and establish operational levels beforehand which can be communicated clearly to their emergency responders.[5]

There is no universally accepted threshold of radioactivity (external or internal) above which a person is considered contaminated and below which a person is considered uncontaminated.

As uncontaminated people are referred to discharge stations and contaminated people to washing (decontamination) stations, care must be taken not to co-mingle contaminated and uncontaminated people while making sure families are not separated. Wrist bands or similar tools can be used to distinguish people who have been cleared through decontamination.

It would be prudent to assume that most people will be able to self decontaminate at community reception centers, but provisions for those who cannot, such as people using wheelchairs or people with other disabilities, must also be made. A best practice during the

[3] DHHS 2007
[4] DHS 1995; DHS 2002; NCRP 2005; IAEA 2006; CRCPD 2006; DHHS 2010
[5] DHHS 2007; NCRP 2008; DHHS 2010

decontamination process would be to determine if parents can assist their children with washing. For people who do not have wounds, direct them to perform the following actions:

- Remove contaminated clothes and place them in a bag
- Wash with warm water
- Use the mechanical action of flushing or friction of cloth, sponge, or soft brush
- Begin with the least aggressive techniques and mildest agents (e.g., soap and water)
- When showering, begin with the head, bending it forward to direct washwater away from body
- Keep materials out of eyes, nose, mouth, and wounds; use waterproof draping to limit the spread of contamination
- Avoid causing mechanical, chemical, or thermal damage to skin

Use of pumper fire truck systems for mass decontamination, although effective in decontaminating large numbers of people at a hazardous materials scene, is not necessary and may not be even advisable when other decontamination methods are considered.[6] If water resources are scarce or not available, a change of outer clothing or carefully brushing off the fallout dust can significantly reduce exposure. When cold temperatures or poor weather conditions exist, the use of water-based decontamination techniques may not be advisable. Furthermore, firefighting resources may be more urgently needed to fight fires or to conduct search and rescue operations.

To the extent possible, responders should take reasonable measures to contain the spread of contamination from runoff or solid waste generated by decontamination activities. However, these containment measures should not slow down or delay the processing of contaminated individuals or contaminated vehicles leaving the impacted area to address imminent threats to human life or health. Addressing people's needs and facilitating their decontamination or evacuation to protect human life or health takes priority.[7]

People in need of medical care must be directed to a medical treatment facility or to a designated medical triage station, if established. Supporting response organizations should be prepared to provide for the security of the designated monitoring, decontamination, and staging areas as well as items of personal value.

Self Decontamination

Steps to remove or reduce external contamination for most people in the initial hours, perhaps days, after a nuclear detonation will have to be self performed. Family members, companions, or caregivers can assist individuals with special needs. It is therefore important for emergency management officials to quickly provide easy-to-understand and straight forward instructions in languages that are appropriate for the affected community. As discussed in Chapter 6, communication after a nuclear detonation will be difficult because of loss of infrastructure. Every possible communication outlet should be used to provide life-

[6] Capitol Region Metropolitan Medical Response System 2003
[7] EPA 2000

saving messages including instructions for self decontamination. In some areas, flyer drops and loud speakers may be the only available means of communication.

A thorough wash or complete removal of external contamination will not likely be practical in the early hours or days for most people, but any action to reduce the external exposure and potential for internal contamination should be encouraged. It is important to emphasize the importance of 'dusting off' as often as possible until such time when people can change clothes or wash. In providing instructions for self decontamination, the use of phrases such as 'washing' and 'change of clothes' are preferred to 'decontamination' because they provide the same meaning more clearly and sound less threatening.

Another challenge in providing blanket instructions for self decontamination is that in those critical hours and days post detonation, people's circumstances and the supplies and facilities they may have access to vary greatly. For example, some may not have access to water, clean replacement clothing, or bags to store away contaminated clothing. A sample Q&A is provided in Chapter 6. Examples of instructions that officials can provide include:

- If you must be outdoors and unprotected when fallout is still accumulating, do not remove your clothing. Gently dust off any visible fallout dust while being careful not to breathe or swallow the dust.
- Once you have some overhead cover or no visible fallout is accumulating, remove the outer layer of clothing (coat or jacket), place it inside a bag if available, and store it away from people. Instructions for appropriate disposition of contaminated clothing should be provided by authorities as applicable.
- If you are not wearing any coat or jacket and have only a single layer of clothing (shirt), keep dusting it off until you have access to clean clothing.
- If the weather is severely cold and you need to keep your jacket, keep dusting it off until you have access to clean replacement clothing or you are no longer exposed to cold temperatures.
- When you arrive at home or another destination, act as if you are covered with mud and try to minimize tracking the material inside. Remove shoes and, if possible, the rest of your clothing, and place them in a bag. Place the bag as far away as possible from people and animals until you receive further instructions from officials.
- At the earliest possible time, shower from the top down with warm water and soap. Use shampoo if available, but do not use hair conditioner. If no shower is available, use a sink and wash as best you can, paying particular attention to your hair and areas around your mouth, nostrils and eyes. If no water is available, use moist wipes to clean the hands and face.

These actions can be performed at any location of opportunity or at ad hoc facilities set up by emergency response organizations to facilitate washing. An ample supply of clean replacement clothing, plastic bags, and moist wipes should be available and would be a valuable resource at these ad hoc facilities. The first responders can use these same actions to reduce their exposure unless other specific protocols, provided by their safety officer, apply.

Pet Decontamination

Experience from past disasters has shown that when people have to evacuate their homes, they most likely take their pets or service animals with them. In fact, the Federal government advises pet owners against leaving pets behind if they ever have to evacuate their homes.[8] In the United States, the number of pet dogs and cats alone exceeds 150 million.[9] In a nuclear emergency, the pets accompanying their owners will present a challenge to response and relief organizations as pet evacuation, decontamination, and sheltering have to be considered along with people evacuation, decontamination, and sheltering. The Pet Evacuation and Transportation (PETS) Act of 2006 requires that State and local emergency plans address the needs of people with household pets or service animals.[10] Therefore, as resources permit, animal issues should be managed as an element of protecting public health and safety.

A thorough cleaning of animals can present a challenge because there is no layer of clothing to take off and animals with long hair are more difficult to clean. As with people, any action to dust off and partially remove contamination is helpful. When brushing animals, care should be taken to avoid inhaling any particulates. Using a dust mask and brushing the animals outside and upwind from the animal may be appropriate. When possible, bathing and grooming thoroughly will be useful in removing additional contamination.

At community reception centers, areas can be designated and facilities provided so that pet owners can clean their own animals as this will reduce anxiety for the animals and will speed up the process. However, to the extent possible, assistance should be provided to those who are unable to clean the animals by themselves. For those who are not able to report to a reception center, instructions for cleaning their pets should be provided along with instructions for self decontamination as already discussed.

An important health and safety consideration is the possibility for the animals to re-contaminate themselves and bring that contamination inside the home or shelter. At community reception centers or public shelters, animals are usually restricted in movement and spaces they can roam around. For people sheltering at home, communication messages should address the need for placing pets in cages or on a leash as appropriate if there is any risk of animals becoming contaminated again after washing. Animals cross contaminating the owners, especially children who pet them, will present a health risk. Communications should also target veterinary professionals to ensure that they provide appropriate advice and services to clients whose animals may have been contaminated or may have received harmful levels of radiation exposure.

> State and local agencies should plan to accommodate the needs of pets and service animals. Contaminated pets can present a health risk to pet owners especially children who pet them.

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[8] Federal Emergency Management Agency, *Information for Pet Owners.* Available from www.fema.gov/plan/prepare/animals.shtm
[9] American Veterinary Medical Association. *U.S. Pet Ownership and Demographics Sourcebook*. 2007. www.avma.org/reference/marketstats/sourcebook.asp
[10] Public Law 109-138, October 6, 2006.

Internal Contamination Considerations

Internal contamination is radioactive material that has entered the body through, for example, ingestion, inhalation or through a wound. In a nuclear detonation scenario, a radiation dose received from internal contamination will not be a major concern relative to burn and traumatic injuries received or relative to potentially large external radiation doses from initial radiation or nuclear fallout. However, there is potential for internal contamination and regardless of how significant or insignificant it may be, internal contamination can be a source of anxiety and concern for the public. After all, while people can self decontaminate themselves from external contamination, any internal contamination stays with them and does not go away quickly.

While certainly not an immediate priority following a nuclear detonation, having accurate information about the levels of internal contamination is important in deciding whether medical intervention is warranted.[11] If possible, contamination should be tracked within shelters. The methods and equipment needed for assessing internal contamination are more advanced than the equipment required to conduct external monitoring. Collectively, internal contamination monitoring procedures are referred to as 'bioassays,' and in general these bioassays require off-site analysis by a clinically certified commercial laboratory or hospital. Although some results will be available quickly, monitored individuals should be advised that depending on the size of the population monitored and the radionuclides involved, it may be some time, perhaps weeks or months, before all results are available. Knowledge of the physical location of the individuals during the incident or the extent of external contamination on their bodies prior to washing can be helpful indicators of the likelihood and magnitude of internal contamination. However, laboratory results can provide definitive information, especially in the case of alpha-emitting radionuclides.

Registry – Locator Databases

State and local agencies should establish a registry system as early as possible. This registry will be used to contact people in the affected population who require short-term medical follow-up or long-term health monitoring. Initially, the most basic and critical information to collect from each person is his or her name, address, telephone number, and contact information. If time permits, other information can be recorded, including the person's location at time of the incident and immediately afterwards and other epidemiological information, but this is not essential and should not become a bottleneck in the registration process. Additional information can be collected later as individuals are processed and evacuated out of the area, sent to shelters or when they report to community reception centers. Extensive resources will be required, and Federal agencies, specifically CDC and the Agency for Toxic Substances and Disease Registry (ATSDR), will provide assistance in establishing, coordinating, and maintaining this registry. Emergency responders should be registered and monitored through a mechanism provided by their respective employers.

State and local authorities must work with Emergency Support Function #6 (Mass Care, Emergency Assistance, Housing, and Human Services) and the American Red Cross to establish an evacuee tracking database system. This system will assist in promptly locating

[11] NCRP 2008; DHHS 2010

evacuees, patients, fatalities, and any survivors or displaced persons. Extensive experience from response to hurricanes can be used to meet this need.

State and local agencies should establish a survivor registry and locator databases as early as possible. Initially, the most basic and critical information to collect from each person is his or her name, address, telephone number, and contact information.

Volunteer Radiation Professionals

As stated in the National Response Framework, population decontamination activities are accomplished locally and are the responsibility of local and State authorities.[12] Federal resources to assist with population monitoring and decontamination are limited and will take some time to arrive. Radiation control staff employed by local and State governments are few in number. However, there are tens of thousands of radiation protection professionals across the country that can be tapped into and encouraged to volunteer and register in any one of the Citizen Corps programs in their community (www.citizencorps.gov). Specifically, the Medical Reserve Corps (www.medicalreservecorps.gov) offers a mechanism to recruit and train radiation professionals already in the community who can assist public health and emergency management agencies in population monitoring or shelter support operations. The Emergency System for Advance Registration of Volunteer Health Professionals (ESAR-VHP) is a program to establish and implement guidelines and standards for the registration, credentialing, and deployment of medical professionals in the incidents of a large scale national emergency. The same infrastructure can be used to recruit and register radiological health professionals (e.g., health physicists, medical physicists, radiation protection technologists, nuclear medicine technologists, etc.) for response to a potential nuclear emergency. The ESAR-VHP program is administered under the ASPR within the Office of Preparedness and Emergency Operations of DHHS (www.hhs.gov/aspr/).

Planners should identify radiation protection professionals in their community and encourage them to volunteer and register in any one of the Citizen Corps or similar programs in their community.

Mutual Aid Programs

Many States, especially those with nuclear power plants, have established mutual aid agreements with their neighboring and other States to provide assistance in case of a radiation emergency. The ***Emergency Management Assistance Compact (EMAC)*** is a Congressionally ratified organization that provides form and structure to interstate mutual aid and addresses key issues such as liability and reimbursement (www.emacweb.org). Through EMAC, a disaster impacted State can request and receive assistance from other member States quickly and efficiently. EMAC has been used effectively to respond to natural disasters, but resources specific to nuclear emergency response has not yet been incorporated into EMAC.

[12] DHS 2008

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Chapter 6 - Public Preparedness - Emergency Public Information

KEY POINTS

1. Communicating after a nuclear detonation will be difficult. The blast and ***electromagnetic pulse*** will damage communications infrastructure and devices for the population in the blast damage zones and potentially cause cascading effects in the surrounding areas, including the most critical region for communications – the dangerous ***fallout*** (DF) zone.
2. Planners in adjacent communities should collaborate in advance to determine the assets necessary to reestablish communications after a nuclear detonation. They should also identify and remedy gaps in their capabilities.
3. After a nuclear detonation, use all information outlets when conveying messages including, but not limited to, television, radio, e-mail alerts, text messaging, and social media outlets.
4. Planners must consider options for communicating in areas where the infrastructure for electronic communications has been disabled or destroyed. Any remaining operational communications systems will be severely overloaded. Communications into and out of the impacted area via these systems will be extremely difficult. Radio broadcasts may be the most effective means to reach the people closest to and directly downwind from the nuclear explosion site.
5. Pre-incident preparedness is essential to saving lives. After a nuclear detonation, public safety depends on the ability to quickly make appropriate safety decisions. Empowering people with knowledge can save thousands of lives.
6. Messages prepared and practiced in advance are fundamental to conveying clear, consistent information and instructions during an emergency incident.
7. Planners should select individuals with the highest public trust and confidence to deliver messages and should be prepared to deliver key information to the public in the affected areas about protection almost immediately in order to maximize lives saved.

Overview

Effective messaging, before and after a nuclear detonation, will be critical to saving lives and minimizing injury. During this type of response, all levels of government share responsibility for coordinating and communicating information regarding the incident to the public. State, Tribal, and local authorities retain the primary responsibility for communicating health and safety instructions to their populations. Clear, concise, and consistent messages will help build trust, comfort a nation in distress, and relay essential information.

This chapter addresses planning considerations for developing and implementing the use of life-saving messages for the public. It begins with a summary of communications infrastructure and emphasizes the importance of re-establishing communications capabilities expediently. Coordination between communication infrastructure and public information planners is essential to an effective response. These planning experts need a mutual understanding of how communications infrastructure will be re-established based on feasibility and the priority of getting information to the public.

Communicating about a high-stress, life-threatening emergency is always a difficult task; however, communicating about a nuclear detonation poses two unique challenges:

1. Many people do not believe that a nuclear detonation is survivable. The sense of futility, fatalism, and hopelessness severely impacts the public's desire and even ability to absorb information and follow instructions.[1]
2. A nuclear explosion will more than likely destroy or severely disable the communications infrastructure (any mechanism or system used to give or receive information) in the blast damage zones where people need to act quickly and appropriately to protect themselves. Residual power failures and overloaded systems could cause a cascade of communications failures into the surrounding area, including the dangerous fallout zone (DF zone) where fatal levels of fallout must be avoided to save lives.

To successfully address these challenges, a well-planned and prepared approach to both pre-incident preparedness and post-detonation messaging is essential.

Communications Infrastructure

To fully appreciate the importance of pre-incident preparedness and the challenges of post-detonation communication, it is necessary to understand the impacts that a nuclear detonation will have on our ability to communicate. This section looks at the impacts on three distinct audiences: the people in the blast damage zones, people in the surrounding areas, including the dangerous fallout zone, and the national and international communities. The impacts stated below are based on modeling of the blast and ***electromagnetic pulse (EMP)*** effects of a 10 KT nuclear detonation and real-world experience from emergency responses, like 9/11 and Hurricane Katrina.

Blast Damage Zones

There will be minimal, if any, ability to send or receive information in the blast damage zones (LD, MD and SD zones). It may be days before communications capabilities are reestablished. Within this area, all communications capabilities will be destroyed or severely hindered. The blast will cause physical damage to communications systems – electrical, phone and cellular systems will be down. The EMP will devastate electronics. Televisions, computers, cell phones, and personal digital assistants (PDAs), such as BlackBerry devices, may all be impacted. Cell phones or PDAs that do withstand the EMP impact will likely be in

[1] Homeland Security Institute 2009

the hands of survivors, because the person possessing it is sufficiently confined in a substantial underground location such as a basement, underground parking garage, or subway system. The sufficiency of the ***shelter*** could render the cell phone or PDA useless until a survivor finds a way to the surface. However, if the person were to do so, they could subject themselves to life-threatening radiation exposure.

Communicating after a nuclear detonation will be difficult. The blast and ***electromagnetic pulse*** will damage communications infrastructure and devices for the population in the blast damage zones and potentially cause cascading effects in the surrounding areas, including the most critical region for communications – the dangerous fallout (DF) zone.

Along with commercial systems, public safety systems in this area (e.g., land and mobile radio and 911 call centers) may also suffer communications failures. Although these systems are typically less susceptible to failure and more robust than their commercial counterparts, they can be expected to be severely damaged or degraded in the blast and surrounding areas. These systems are critical to emergency responders in performance of life saving and rescue operations and need to be restored as quickly as possible.

As part of the Federal response to a major disaster, such as a nuclear detonation, FEMA will activate the Communications Annex of the National Response Framework, Emergency Support Function #2, to coordinate with the private sector, State, and local entities in restoring the commercial communications infrastructure, public safety and emergency responder networks.

Timely response to any large-scale incident is critical. Industry continually monitors their networks for outages and reduced capabilities and will usually begin recovery operations within a very short period of time. Commercial providers typically have transportable restoration capabilities (e.g., cellular on wheels and cellular on light truck) strategically located around the country to minimize response times. With proper planning and preparedness public safety, emergency responder networks can be augmented and/or temporarily restored by utilizing assets that the State, National Guard, and surrounding localities may be able to provide. As part of the Federal response, FEMA can typically have communications assets on the ground in the contiguous 48 states within 24-48 hours after an incident.

Surrounding Area

The surrounding area may include surrounding communities, counties, bordering states, and people in the path of the radioactive plume, including the DF zone. After a nuclear detonation, there is the potential for cascading effects along transmission lines in this area. This could mean electrical, phone, and Internet outages. These cascading effects may extend for hundreds of miles from the detonation site. The EMP should have limited, if any, effect on electronic devices in the surrounding area and DF zone outside of the blast damage zone. Electronic devices may only require resetting switches and circuit breakers. See Chapter 1 for specific information on EMP effects and impacts.

Planners in adjacent communities should collaborate in advance to determine the assets necessary to reestablish communications after a nuclear detonation. They should also identify and remedy gaps in their capabilities.

National and International Communities

For any major national emergency, a sudden increase in the need for information and human connectivity severely stresses and exceeds the capacity of the communications infrastructure. This will hinder the ability to communicate into or out of the blast damage and DF zones and potentially in the immediate surrounding areas. During the 9/11 response, this influx and overloading of the system affected not only public communications, but also affected responder-to-responder communications in the northeastern United States. Since 9/11, many local, State, and Federal emergency response organizations have adopted technology to enhance responder-to-responder communications capabilities. Planners need to know what types of systems are in place to enable responder communications in case normal communications methods are unavailable.

Message Outlets

After a nuclear detonation, it is essential to use every information outlet to get health and safety guidance out to the public as quickly as possible. There will be a need to use both traditional media outlets (e.g., television, radio, online news sources) and other means. E-mail alerts, text messaging, and social media outlets like Facebook and Twitter may help quickly disseminate accurate protective action guidance. Low-tech messaging methods may be necessary as well, such as flyer drops and loudspeakers. Emergency management officials need to reach out with consistent messages using as many means possible to reach the largest number of people.

After a nuclear detonation, use all information outlets when conveying messages including, but not limited to, television, radio, e-mail alerts, text messaging, and social media outlets.

The National Oceanic and Atmospheric Administration (NOAA) Weather Radio (NWR) may serve as an effective means of getting safety guidance to the public. These radios are located at schools and hospitals across the nation. NWR broadcasts constant weather information, but also works with emergency officials and responders to broadcast warnings and post-incident information for all types of hazards.

Numerous State, local, and Tribal governments use the Emergency Alert System (EAS) to provide public alerts and warnings to ensure public safety. EAS is available for rapid dissemination of emergency information. Many cities also have siren warning systems, highway message boards, and reverse 911 systems. Planners are encouraged to have pre-scripted messages ready for immediate use (see Preparing Messages section of this chapter).

Planners must consider options for communicating in areas where the infrastructure for electronic communications has been disabled or destroyed. Any remaining operational communications systems will be severely overloaded. Communications into and out of the impacted area, via these systems, will be extremely difficult. Radio broadcasts may be the most effective means to reach the people closest to and directly downwind from the nuclear explosion.

Pre-Incident Messaging Preparedness

Pre-incident preparedness is essential to ensuring that people act in ways to minimize their exposure. After a nuclear explosion, people inside the blast damage and DF zones may not have information or help from the outside. In this situation, victims become first responders and first responders become victims. People will have a significantly greater chance of survival if they know the appropriate actions to take. **Without pre-incident knowledge, people will be more likely to follow the natural instinct to run from danger, potentially exposing themselves to fatal *doses* of radiation that could have been avoided by sheltering.** Planners must foster a public that is informed and empowered to make effective decisions for the safety of themselves and those around them.

Pre-incident preparedness is essential to saving lives. After a nuclear detonation, the public's safety depends on their ability to quickly make appropriate safety decisions. Empowering people with knowledge can save thousands of lives.

When working on a pre-incident preparedness campaign, it is important to know your audience. There are ways to reach out to entire communities and ways to target audiences most likely to act on the information and influence those around them. For example, including informational material with power and water bills will reach a large portion of a community. In addition to the larger population, target audiences need specialized messages. Target audiences may include grade school students who can bring the information home to their families, religious leaders who can inform their congregations, and business owners who can help encourage their employees to be prepared.

There are pre-incident preparedness campaigns already in place. Nuclear power facilities and the Federal Emergency Management Agency's (FEMA's) Radiological Emergency Preparedness (REP) Program provide information to people living around commercial nuclear power facilities. The REP program has worked with schools to provide preparedness material in the form of school calendars and book bags labeled with safety tips as a way to reach out to both parents and students.

Pre-incident preparedness will be a difficult task. There is a legacy of public emergency preparedness campaigns, such as the Cold War's '***duck and cover***' and the more recent 'plastic sheeting and duct tape,' that leave the public skeptical of preparedness messages. In addition, with a public that associates nuclear detonations with certain death, the sense of futility, fatalism, and hopelessness severely impacts their desire and even their ability to absorb information and follow instructions. According to research recorded in the Homeland Security Institute's (HSI) *Nuclear Incident Communication Planning: Final Report*, prepared for the Department of Homeland Security's Office of Health Affairs, just initiating communication regarding a possible nuclear detonation is "*met with skepticism, concern about hidden intelligence information, and accusations of government propagandizing*."[2]

Based on the public's resistance to open discussions on nuclear detonations and the fact that the public is overwhelmed with instructions for each type of potential threat, one recommendation in HSI's report is to pursue an 'all-hazards' public education communication strategy. Similar to the United Kingdom's emergency preparedness campaign, 'Go In, Stay In, Tune In,' all-hazards guidance must be applicable to all types of emergencies, easy to remember, and action-oriented.

Preparing Messages

Messages drafted in advance of a nuclear detonation will enhance responders' ability to provide timely, accurate information and to manage misinformation that may be going to the public through news and social media.

Messages prepared and practiced in advance are fundamental to conveying clear, consistent information and instructions during an emergency incident.

Officials, planners, and responders are also members of the public and can anticipate the types of questions they will receive and prepare answers in advance. When anticipating questions, planners must keep in mind both the broad audiences (e.g., people in the blast damage zones, in the DF zone and in the surrounding area, and the national and international community) and more targeted audiences (e.g., non-English speakers, hospital and nursing home staff and patients, the homeless population, farmers, etc.). To some extent, each audience will have specialized information needs.

The following are specific information needs of the three broad audiences discussed in the Communications Infrastructure section of this chapter:

Blast Damage and DF Zones: People in these areas need life-saving information. People in the dangerous fallout zone must remain inside or get inside ***adequate shelter*** as quickly as possible to avoid potentially fatal doses of radiation. See Chapter 3 for additional information on sheltering.

Surrounding Area: People in this area will be concerned for their immediate health and safety and may be required to take protective measures if they are in the path of the radioactive plume. Surrounding communities may also be tasked with assisting evacuees. There will be a large population of people displaced from their homes after a nuclear explosion. As people evacuate, the surrounding communities will be faced with concern about contaminated people and vehicles entering their area.

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[2] Homeland Security Institute 2009

National and International Communities: People across the world will be looking for information and trying to get in touch with their loved ones. Both nationally and internationally, the public will be turning to media and the Internet for information. This is an opportunity to provide situation and response updates and to educate the population about safety measures in the case of additional nuclear detonations.

For messages to be effective they must be understood by the intended audience. It is important to keep messages simple, accurate and consistent, using plain language as much as possible. Research has shown that terms and phrases commonly used in the emergency response field, like '***shelter-in-place***,' are not understood by the public. Avoid jargon, technical terms, and acronyms.[3]

Message delivery is as important as message development. Identify and train spokespersons who can communicate your messages effectively. Local spokespersons, such as fire and police chiefs, are considered credible sources of information. Local broadcast meteorologists also are credible sources of emergency information because they are the public's source of information during weather incidents like snow storms, floods, hurricanes, and tornados. [4]

Planners should select individuals with the highest public trust and confidence to deliver messages and should be prepared to deliver key information to the public in the affected areas about protection almost immediately in order to maximize lives save.

The Federal government, led by the National Security Staff, developed a fact based messaging document, which is a plain language, technically accurate communications resource for emergency responders and Federal, State, and local officials to use when communicating with the public and media during the first 72 hours following a nuclear detonation in the United States. This document includes key messages for the impacted community and the nation and anticipated questions and answers. This document is still in interagency development, but once it is finalized it will be added to the FEMA website where this planning guidance will be maintained (www.fema.gov/CBRNE). Below are samples from the messaging document.

[3] CDC 2009
[4] Becker 2003

Sample Key Message from Federal Government IND Messaging Effort

Impacted Community: Immediate Action Message
Suggested for local or state spokesperson: Fire Chief, Mayor, Governor

- We believe a nuclear explosion has occurred at [Location] here in [City].
- If you live anywhere in the metropolitan area, get inside a stable building immediately.
- You can greatly increase your chance of survival if you take the following steps.
    - **Go deep inside:**
        - Find the nearest and strongest building you can and go inside to avoid radioactive dust outside.
        - If better shelter, such as a multi-story building or basement can be reached within a few minutes, go there immediately.
        - If you are in a car, find a building for shelter immediately. Cars do not provide adequate protection from radioactive material.
        - Go to the basement or the center of the middle floor of a multi-story building (for example the center floors (e.g., 3 – 8) of a 10-story building).
        - These instructions may feel like they go against your natural instinct to evacuate from a dangerous area; however, health risks from radiation exposure can be greatly reduced by:
            - Putting building walls, brick, concrete or soil between you and the radioactive material outside, and
            - Increasing the distance between you and the exterior walls, roofs, and ground, where radioactive material is settling.
    - **Stay inside:**
        - Do not come out until you are instructed to do so by authorities or emergency responders.
        - All schools and daycare facilities are now in lockdown. Adults and children in those facilities are taking the same protective actions you are taking and they will not be released to go outside for any reason until they are instructed to do so by emergency responders.
    - **Stay tuned to television and radio broadcasts for important updates**
        - If your facility has a National Oceanic and Atmospheric Administration (NOAA) Weather Radio, this is a good source of information.
        - If you have been instructed to stay inside, stay tuned because these instructions will change.
            - Radiation levels are extremely dangerous after a nuclear detonation, but the levels reduce rapidly in just hours to a few days.
            - During the time when radiation levels are the highest, it is safest to stay inside, sheltered away from the material outside.
        - When evacuating is in your best interest, you will be instructed to do so.
        - People in the path of the radioactive plume – downwind from the detonation - may also be asked to take protective measures.

Sample Q&A from Federal IND Messaging Effort

What should I do if I think I have been contaminated with radiation (have radioactive dust on me)?

- Remove your clothing to keep radioactive dust from spreading.
  - You should act as if you are going home covered in mud and you do not want to track mud into your home.
  - Place your clothing in a plastic bag and seal or tie the bag. This will prevent the radioactive material from spreading.
  - Place the bag as far away as possible from humans and animals to limit exposure.
  - Removing the outer layer of clothing can remove up to 90% of the radioactive dust.
- When possible, take a shower with lots of soap and water to limit radiation contamination. Do not scrub the skin.
  - Wash your hair with shampoo or soap and water.
  - Do not use conditioner on your hair because it will bind radioactive material to your hair, keeping it from rinsing out easily.
  - Gently blow your nose and wipe your eyelids and eyelashes with a clean wet cloth. Gently wipe your ears.
- If you cannot shower, use a wipe or clean wet cloth to wipe your skin that was not covered by clothing.
- Put on clean clothing, if available.

The challenges and opportunities presented in this chapter apply to all aspects of response to a nuclear detonation, not just public messaging. The success of every communication, from providing technical expertise to political appointees to safety information to field teams, depends on the ability to develop clear, consistent messages and deliver those messages effectively.

The reference and additional resources sections of this chapter include information on radiation and crisis communication research, guidance on developing messages, information on trusted spokespersons, and pre-existing messages on radiation and for radiological emergencies.

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Interagency Members	Department or Agency
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