Student Guide Improvised Nuclear Device (IND) Modeling and Response Planning: National Capital Region

Prepared for DHS FEMA by Lawrence Livermore National Laboratory

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Acronyms

ALARA	as low as reasonably achievable
ARA	Applied Research Associates
ARS	acute radiation syndrome
BWI	Baltimore Washington International Airport
DC	Washington DC
DFZ	dangerous fallout zone
DHS	Department of Homeland Security
EMP	electromagnetic pulse
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
HAZUS	FEMA-developed software for natural hazard loss estimation
IMAAC	Interagency Modeling and Atmospheric Assessment Center
IND	improvised nuclear device
kT	kiloton
LDZ	light damage zone
MACWG	Modeling and Analysis Coordination Working Group
MDZ	moderate damage zone
MT	megaton
NCR	National Capital Region
PF	protection factor
R	Roentgen
RDD	radiological dispersal device
SCBA	self-contained breathing apparatus
SDZ	severe damage zone
UASI	Urban Areas Security Initiative

Goals of this document

Response planning for an improvised nuclear device (IND) as an important part of all-hazards response planning. The goals of this *Student Guide* are to explain the impacts that might occur from an IND in the National Capital Region (NCR) and to orient emergency response personnel on current IND response planning activities within the Federal government as well as preparedness issues relevant at state and local levels. Much of the content explains key life-saving actions for response personnel and members of the public along with the rationale behind those actions. Also identified are further tools and information on the topic of response planning, available to the general public.

Objectives of training

- Identify key aspects of Federal IND-specific response guidance.
- Review recent studies highlighting our current understanding of low-yield nuclear effects.
- Define prompt effects from a low-yield nuclear explosion.
- Understand fallout effects from such an explosion.
- Define planning guidance (damage) zones.
- Understand shelter and evacuation strategies together with state and local response plans and strategies critical to reducing the initial loss of life.
- Know key aspects of how medical countermeasures can be most usefully applied to save lives.
- Know where to find additional tools and information on nuclear preparedness.

Notes

DHS IND Modeling and Response Planning

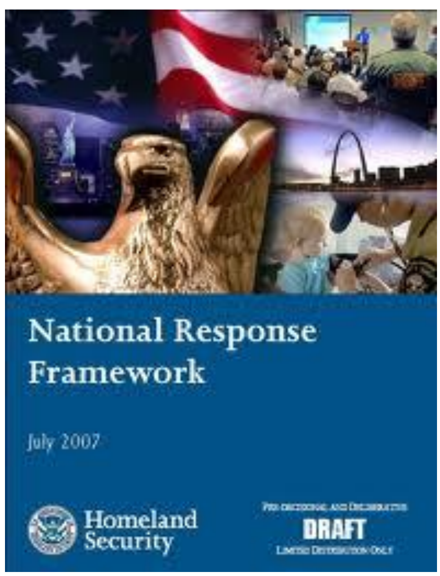
IND Response: A Fundamental Part of Federal Response Planning

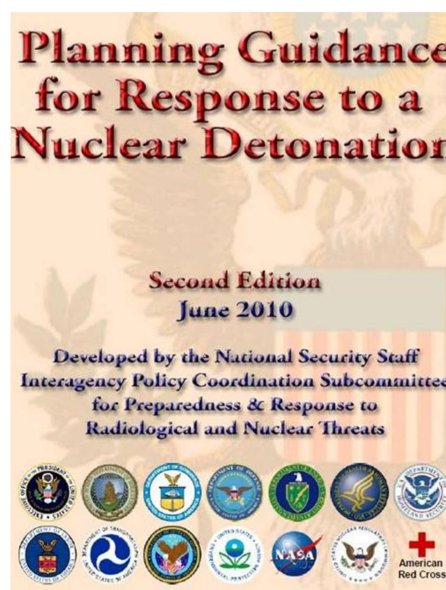
Improvised nuclear device (IND) response planning is a fundamental part of Federal response planning. The nuclear detonation scenario is one of 15 national planning scenarios that are considered to be the foundation for identifying key response tasks and capabilities.

<u>15 National Planning Scenarios</u>

1. Improvised Nuclear Device
2. Aerosol Anthrax
3. Pandemic influenza
4. Plague
5. Blister agent
6. Toxic industrial chemical
7. Nerve agent
8. Chlorine tank explosion
9. Major earthquake
10. Major hurricane
11. Radiological dispersal device
12. Improvised explosive device
13. Food contamination
14. Foreign animal disease
15. Major cyber attack

The *National Response Framework* (formerly the *National Response Plan*) incorporates aspects of nuclear terrorism response planning in the Nuclear/Radiological Incident Annex. The need for preparation is clear with publication in the *Federal Register* of “Preparedness Directorate: Protective Action Guides for Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents” on January 3, 2006 (updated August 1, 2008) and expanded on January 2009 with *Planning Guidance for Response to a Nuclear Detonation*, which was further revised in the June 2010 edition.



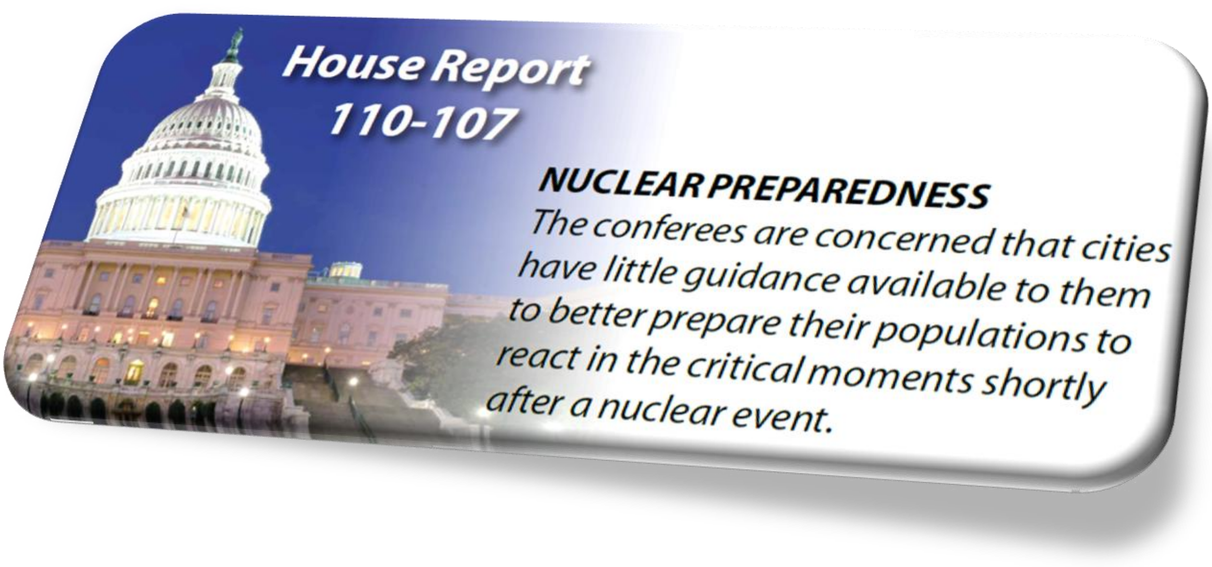


Congressional Guidance

The Federal Budget Supplemental in FY07 provided funding to the Department of Homeland Security (DHS), Office of Health Affairs, to support IND response planning. Congress has continued to provide funding to the Federal Emergency Management Administration (FEMA) to support this effort because preparation for a nuclear attack is integral to the survival of countless American lives. Spending the money wisely and efficiently will continue to help the planning and preparedness process to better protect American people.

The act shown below is just one of the ways that Congress has recognized the need to prepare American cities for a nuclear attack.

An initial effort focused on modeling and analysis to support tier 1 Urban Area Security Initiative (UASI) preparedness planning.



Nuclear Response Communication Strategy Common Tasking for FEMA and OHA

"The **Office of Health Affairs…shall ..set a strategy … to ensure consistent and sufficient delivery of information to the public, medical community, and first responders on appropriate protective actions to prepare for and respond to a nuclear attack."**

One of the key tasks is to develop a communication strategy. As daunting as that task is, it cannot begin until appropriate actions are defined and communicated. A major roadblock to creating a communication strategy was the consensus on what the proper actions are.

Knowing what should be done and what to expect from a nuclear event is the first step needed to create a communication strategy for the public, medical community, and first responders. Chicago responder Joseph Newton may have said it best when he stated:

"We don't know what perfect looks like."

-Quote from Joseph Newton on August 8th during the 2008 National Academy of Science, Institute of Medicine Workshop, entitled "Assessing Medical Preparedness for a Nuclear Event."

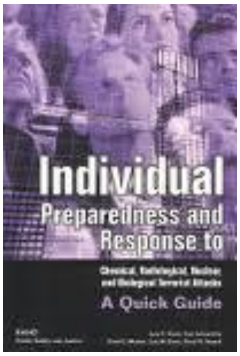
Initial Lack of Scientific Consensus on Actions

The lack agreement about appropriate actions arises from a general absence of scientific consensus and conflicting recommended actions. Many Cold War assumptions about nuclear detonation response actions are not appropriate for an IND.

Conflicting guidance is found in common preparedness guides, even for basic questions regarding initial shelter or evacuation recommendations.

Ready.gov (DHS) says, "**Take cover** immediately, as far below ground as possible…"

RAND says, "Avoid radioactive fallout: **evacuate** the fallout zone quickly.."

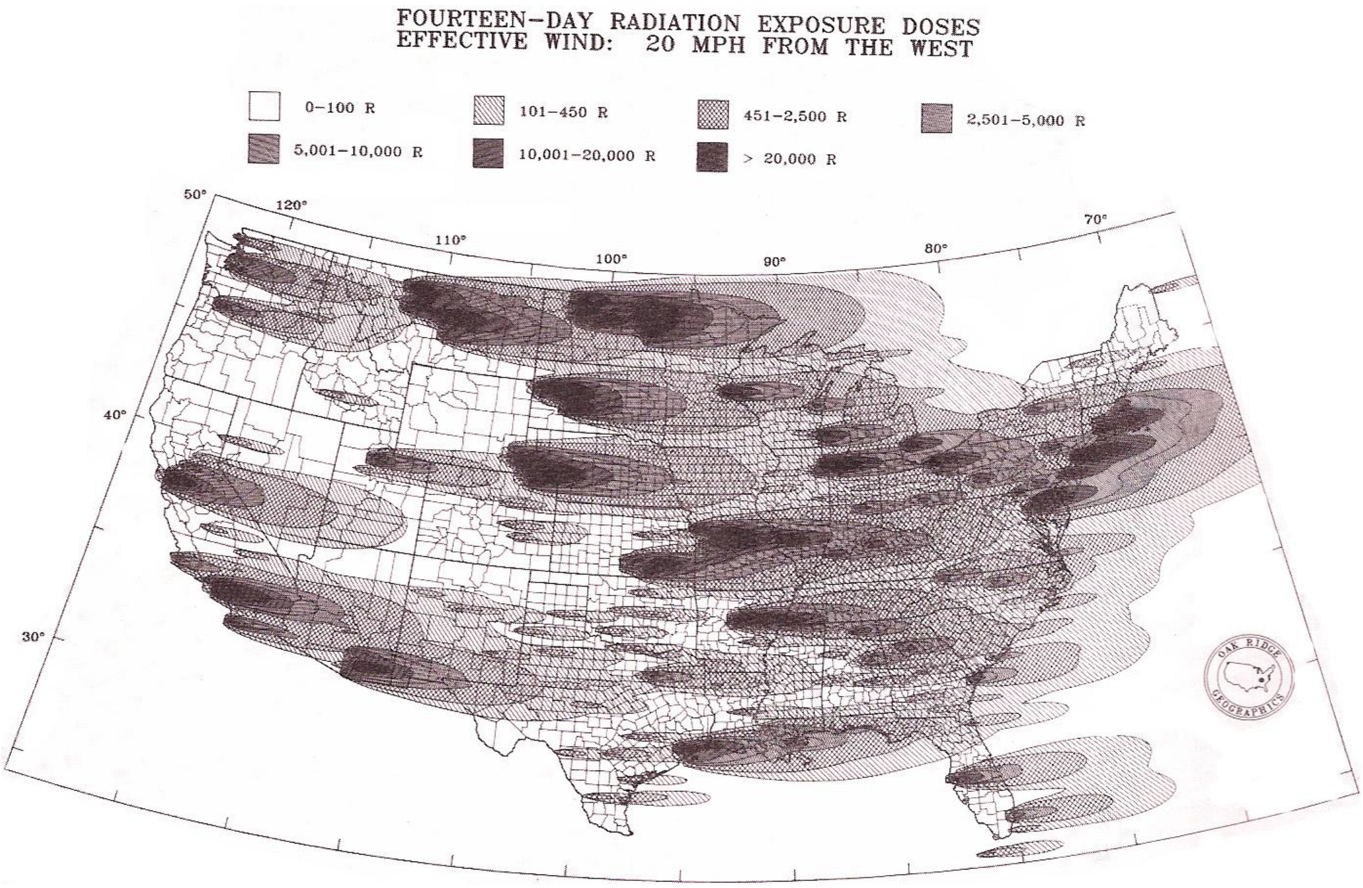


[1]US Department of Homeland Security, http://www.ready.gov/america/beinformed/nuclear.html
[2]Individual Preparedness Response to Chemical, Radiological, Nuclear, and Biological Terrorist Attacks: A Quick Guide Lynn E. Davis, Tom LaTourrette, David E. Mosher, Lois M. Davis, David R. Howell 30 pp. • 2003 • ISBN: 0-8330-3487-1

Perceptions Are Shaped by the Cold War

It is important to understand the context in which many response planners have approached nuclear terrorism response. The map shown below represents the aftermath of thermonuclear war.

Shaded areas represent fallout radiation* levels that would be enough to severely injure or kill people who remain outdoors. Planning for the aftermath of such a nuclear catastrophe seems futile.



*Fallout radiation is generated when dust and debris created from an explosion are combined with radioactive fission products, potentially exposing people to ionizing radiation after falling to the ground.

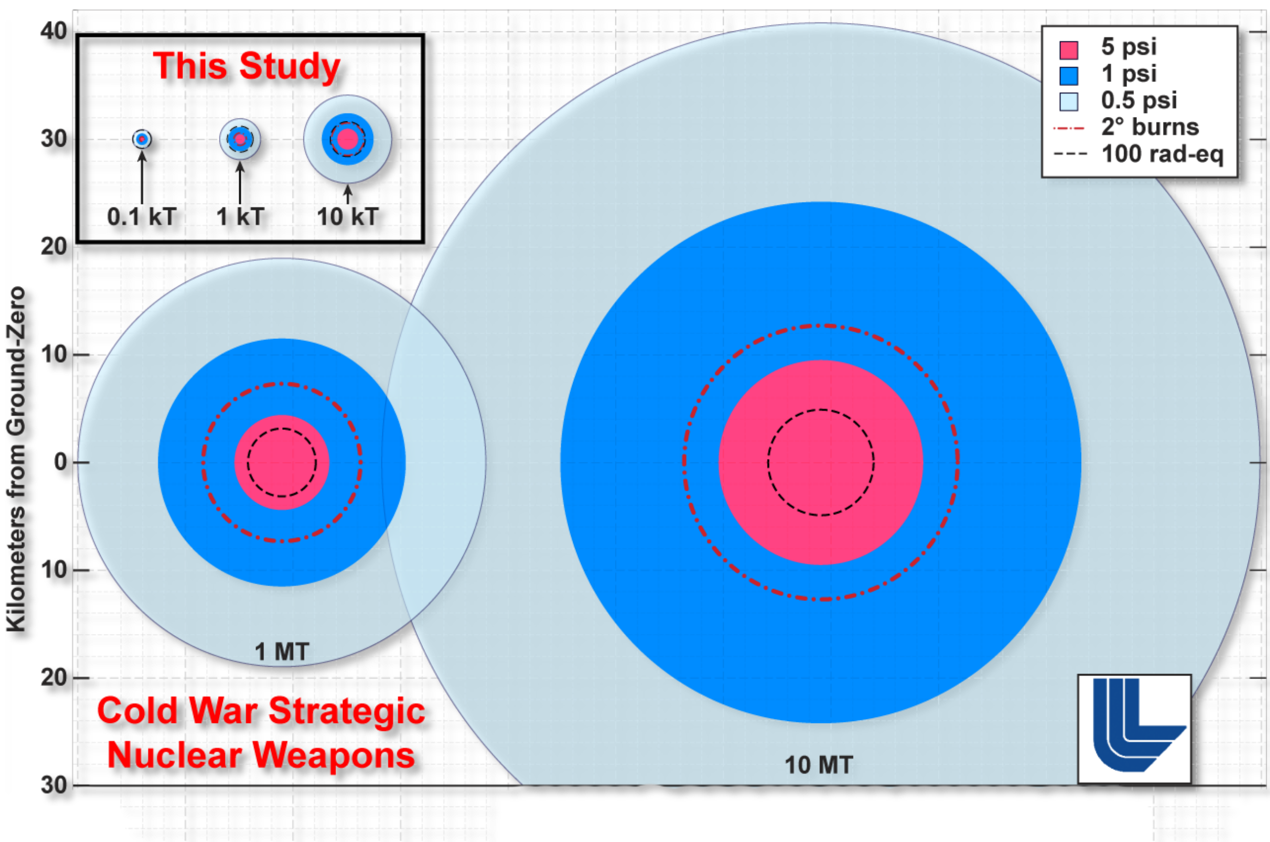
Figure from National Council on Radiation Protection and Measurements, 1982, *The Control of Exposure of the Public to Ionizing Radiation in the Event of Accident or Attack.* NCRP Symposium Proceedings, Session C, Topic 2; Radiological Instrument Requirements for a National Emergency Such As Nuclear Attack, FEMA.

Difference Between Terrorism and the Cold War

*"Today, the Cold War has disappeared, but thousands of those weapons have not. In a strange turn of history, the threat of global nuclear war has gone down, but **the risk of a nuclear attack has gone up. Testing has continued**. Black market trade in nuclear secrets and nuclear materials abound. The technology to build a bomb has spread. **Terrorists are determined to buy, build or steal one."***

President Barack Obama
Prague, April 5, 2009

Differences between terrorism and the Cold War are notable and should be considered when determining appropriate actions after an attack. The graphic below shows the relative size difference of prompt effects* from both Cold War strategic thermonuclear weapons (1 and 10 MT) and improvised nuclear weapons (0.1, 1, and 10 kiloton or kT). Clearly, the ranges of prompt effects for improvised devices are much smaller.



*Prompt effects are those that radiate outward from the detonation location (ground zero), and usually occur within the first minute after detonation.

Observations on Starting Conditions

From workshops conducted during 2008 across the United States, some observations allowed researchers to see the starting conditions of local and state communities.

- ✓ No communities had a coordinated regional response plan for the aftermath of nuclear detonation, and there was a general lack of understanding about what response needs were and the roles that Federal, state, and local authorities would play.

- ✓ Many response planners assumed that there would be no survivors or that the response would be led by the Federal government. Unfortunately such assumptions have led to apathy in planning that could get 100,000’s of people killed or injured unnecessary. Critical decisions made at local levels in the first few hours represent the greatest opportunity for saving lives.

- ✓ Currently such decisions are not likely to be technically informed, and the correct actions tend to be counter-intuitive.

Scientific Working Group Established

To help address the lack of scientific consensus, the Department of Homeland Security established a scientific working group called the IND Modeling and Analysis Coordination working group, or MACWG for short. Comprised of technical organizations that support Federal government agencies, this group is working to collaborate and come to consensus on as many issues as possible to support IND response planning.

The MACWG was created for three main purposes:

1. To establish a scientific consensus, where possible, on IND effects and issues.

2. To bound uncertainty and identify unknowns.

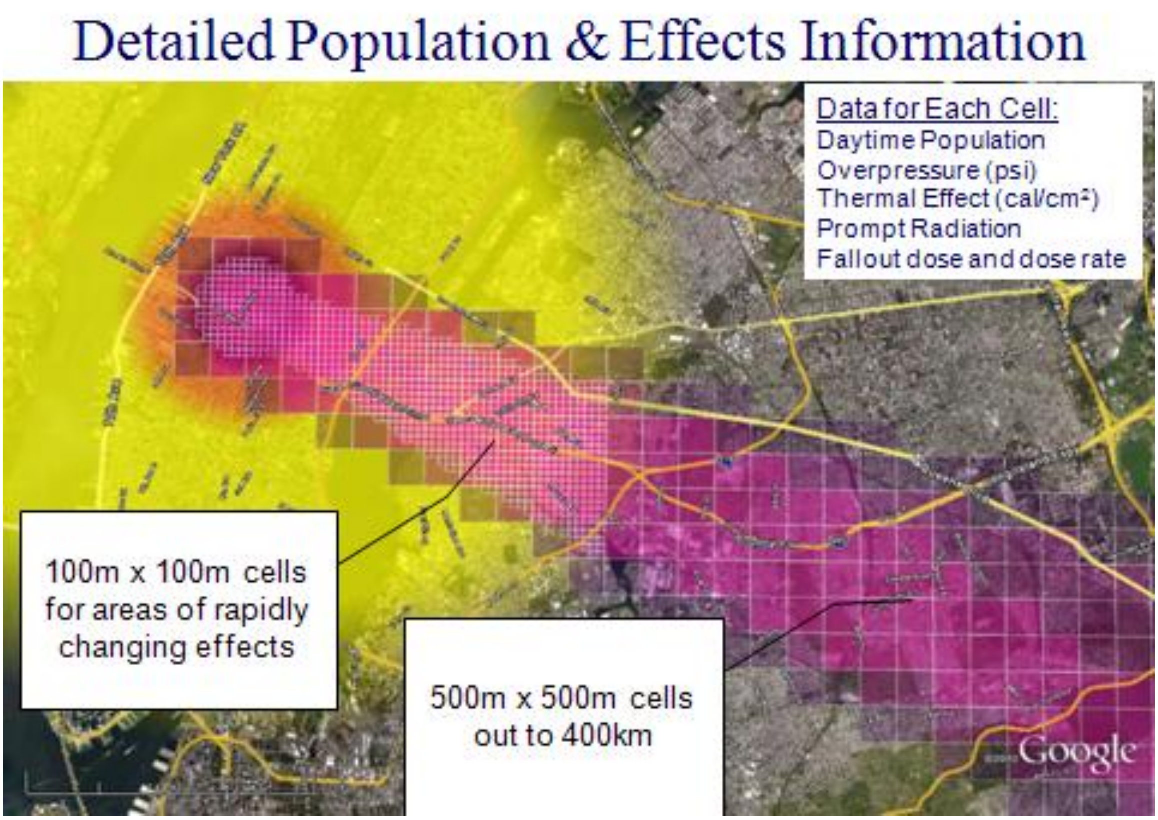
3. To eliminate conflicting recommendations related to IND response actions.

Examples of some recent modeling and related discoveries follow.

Advanced, Detailed Analysis

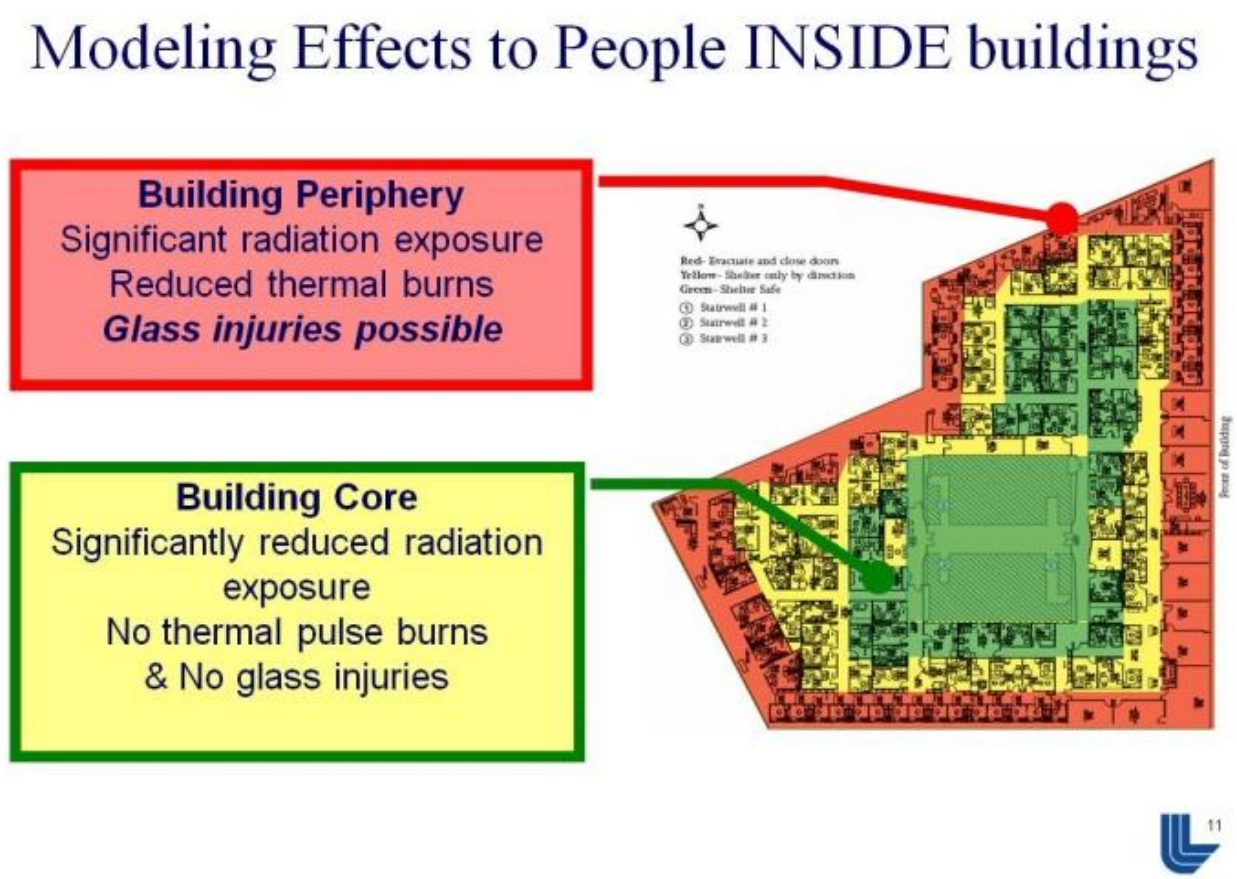
Detailed urban information combined with advanced modeling capabilities have resulted in unprecedented improvements in our understanding of nuclear detonation effects in a modern urban environment. For example, detailed day- and night-time population density and 3-dimensional urban terrain modeling allow for an unprecedented, “block-by-block,” analyses of nuclear detonation effected in an urban environment. Each 100-m x 100-m block in a city can be evaluated for prompt blast, thermal, and radiation effects. Fallout arrival and decay can also be evaluated in each block of a city, allowing for unprecedented and community-specific optimization analysis of response strategies.

Building-specific information can provide detailed injury assessment to facilitate advanced public health response planning.



Modeling the Effects to People Inside Buildings

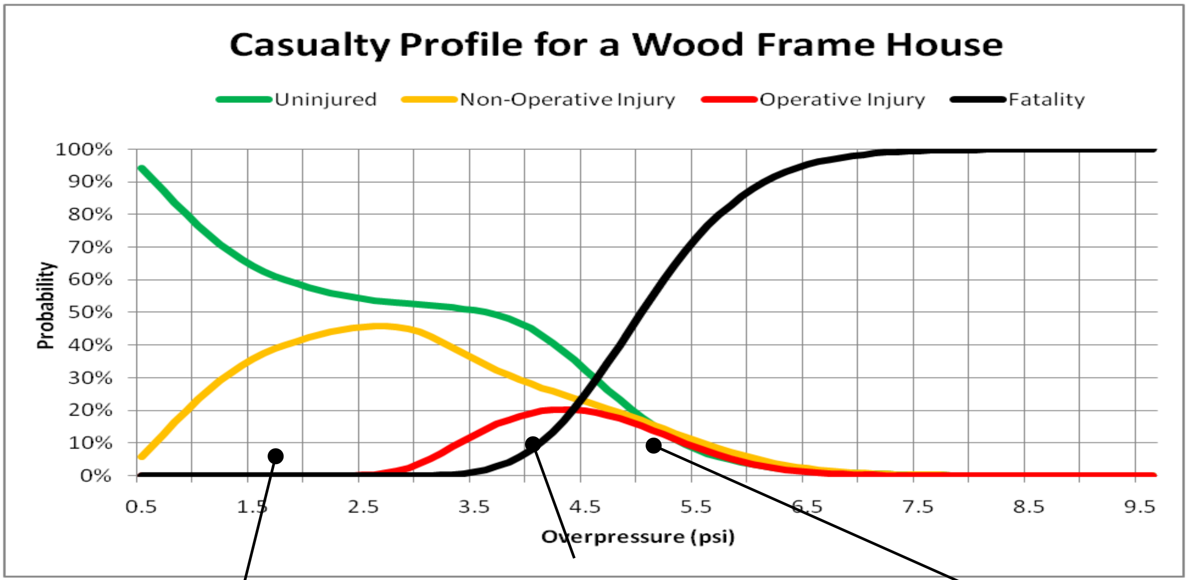
Buildings can both protect and injure occupants from the effects of a nuclear weapon. In addition to modeling how modern urban buildings interact with blast effects, the distribution of people within buildings is being evaluated for an overall assessment of injury.

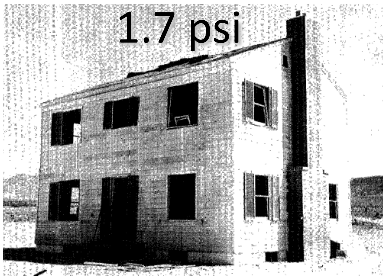


Blast and Glass Injury

"… 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."
- NATO medical response planning documents for nuclear detonations

Previous models for human effects from a blast stop at 5 psi (the threshold for eardrum rupture), yet a house can be easily destroyed at 5 psi, as shown below. **An occupant might get more than an eardrum rupture**. Advanced modeling now accounts for the collapse, severe damage, or glass breakage to a structure and subsequent effects on occupants.



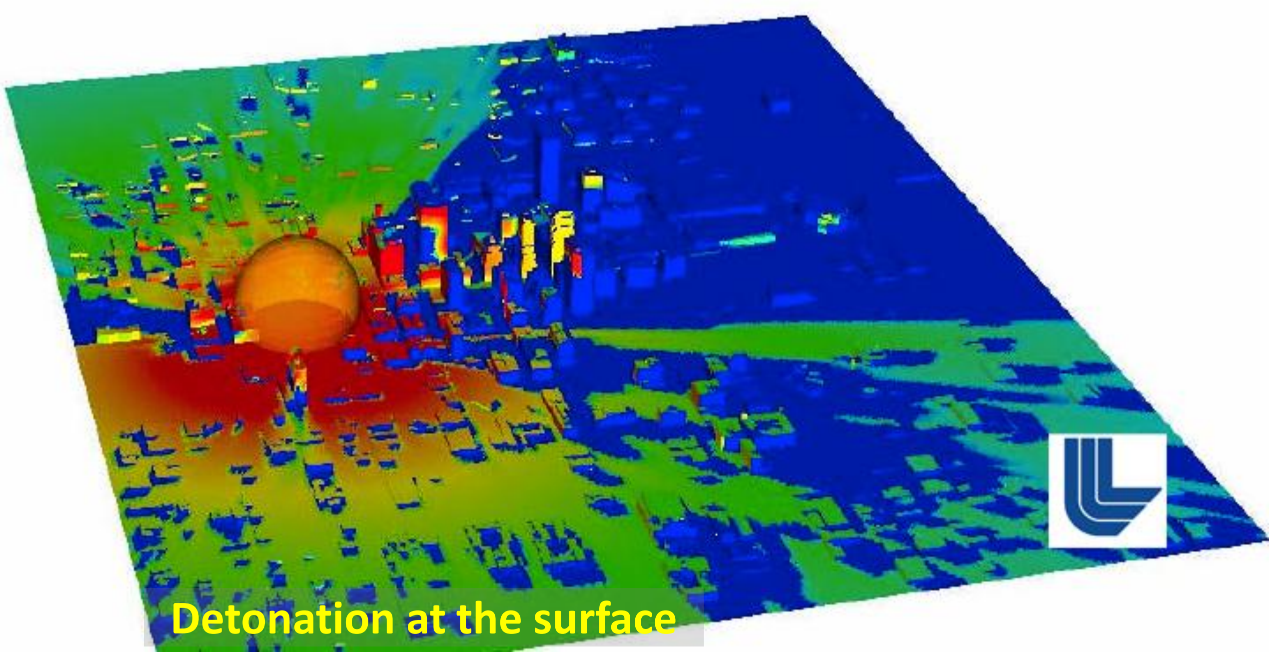


Recent analysis work help us to better understand the relationship between people and an urban environment. Most injuries outside the Murrah building in the 1995 Oklahoma City bombing were caused by glass injury, not direct blast effects. Numerous victims from Hiroshima and Nagasaki arriving at field hospitals exhibited glass breakage injuries, but the effect has not been previously modeled.

Evaluating Line-Of-Sight Exposures

Evaluating line-of-sight exposures in an urban environment leads to a reduction in the number of previously calculated burns that have been cited in many previous studies. A ground-level detonation would reduce the range of both lethal radiation and thermal burns.

The image below demonstrates how much thermal energy from the fireball is blocked by the urban environment. Areas of green and blue represent regions of little thermal injury.

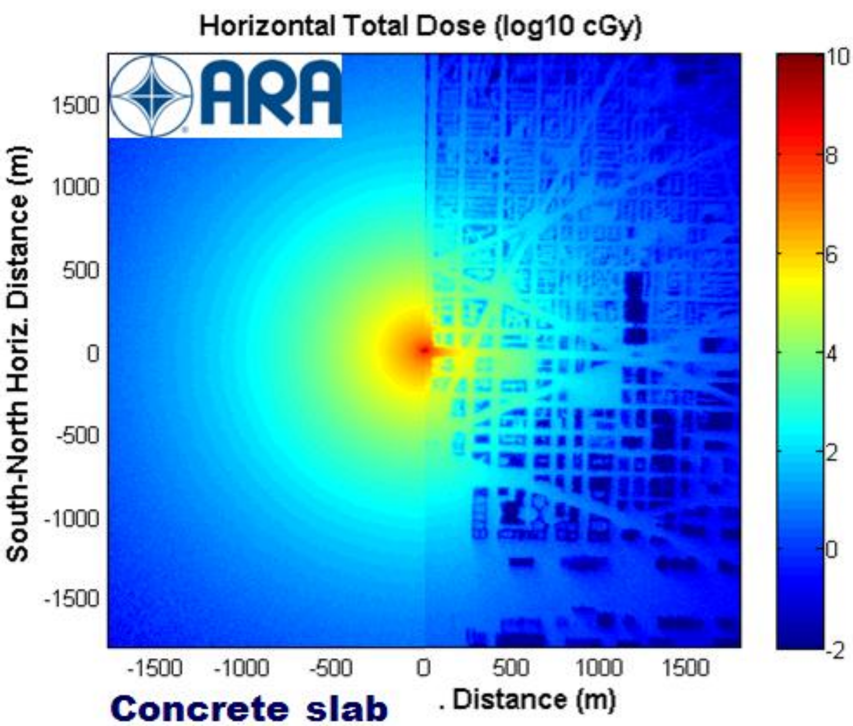


R. E. Marrs, W. C. Moss, and B. Whitlock, *Thermal Radiation from Nuclear Detonations in Urban Environments*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-TR-231593, June 7, 2007.

J.

Advanced Radiation Analysis

Models developed at Applied Research Associates (ARA) and Los Alamos National Laboratory have shown similar reductions in injuries from the initial radiation produced in the first minute of a nuclear explosion. This figure demonstrates the nonsymmetrical reduction in radiation exposure by the urban environment. The left side represents an unobstructed exposure from a 10-kT surface detonation, compared to the reduction of outdoor radiation levels indicated in the right side of the image. Like the thermal analysis, these studies indicate that ambient radiation levels from a low-yield, ground-level nuclear detonation in an urban environment could be greatly reduced. For example, the unobstructed range for a potentially lethal radiation exposure of 400 rad (cGy) is about 1,200 yards. Initial results by ARA indicate that the range might be reduced by as much as half, down to 500 to 700 yards from the detonation point in highly built-up areas.



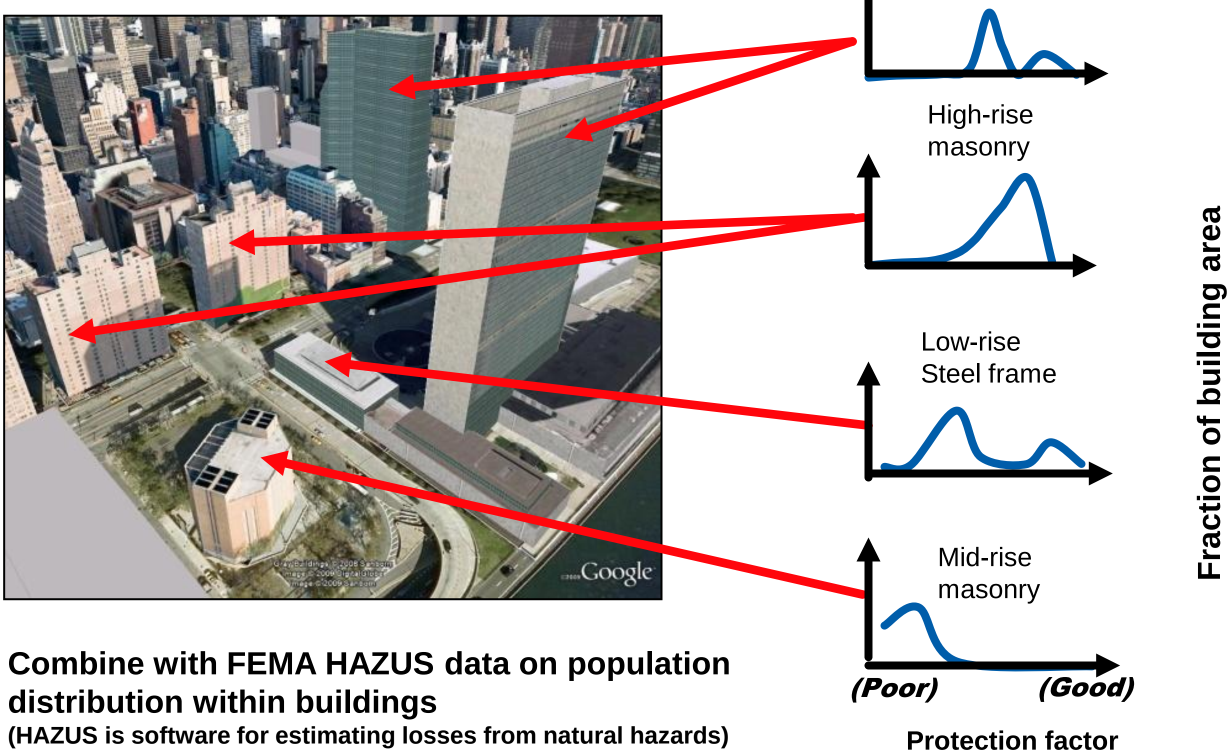
Analysis of the reduction of prompt radiation in the urban environment.

J. Bergman, K. Kramer, B. Sanchez, J. Madrigal, K. Millage, and P. Blake, The Effects of the Urban Environment on the Propagation of Prompt Radiation Emitted from an Improvised Nuclear Device, 56th Annual Meeting of the Health Physics Society, June 29, 2011.

Analysis of Local Building Protection

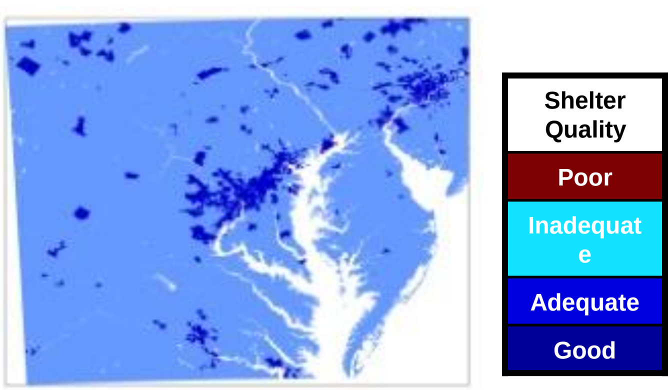
Maps of indoor fallout exposures can be created by combining assessments of regional shelter quality with estimates of outdoor radiation. The assessments are being done at Lawrence Livermore National Laboratory by integrating national geospatial building information with an updated assessment and analysis of building protection factors.

Analyze individual building protection to estimate shelter quality



Combine with FEMA HAZUS data on population distribution within buildings
(HAZUS is software for estimating losses from natural hazards)

Generate map of regional shelter quality for shelter-in-place (best shelter within a building)



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Analysis of Local Building Protection—continued

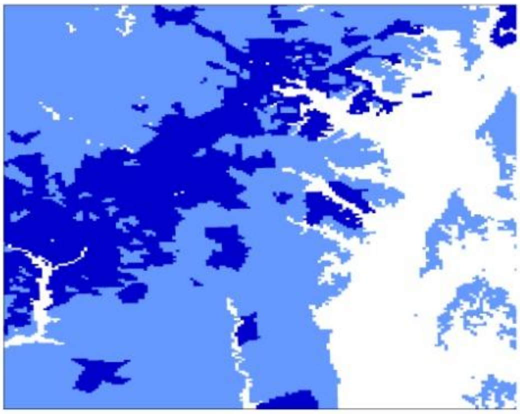
From data on the previous page, combine regional shelter quality with outdoor radiation estimates to determine the efficacy of various shelter or evacuation strategies. The left-hand image, below, shows outdoor exposures exceeding 10 R in 24 hr. The calculated indoor exposures that exceed 10 R (shown in the bottom image) demonstrates the dramatic reduction of exposures.

Outdoor radiation

Potential 10 R gamma exposure (outdoor)

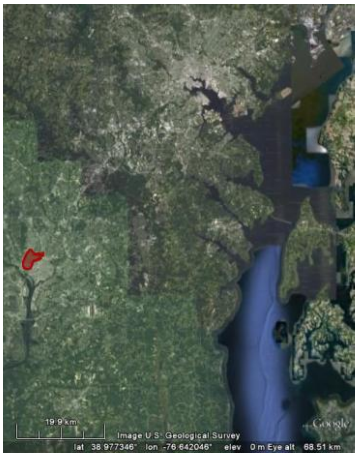
×

Regional shelter quality



Local shelter

Indoor radiation

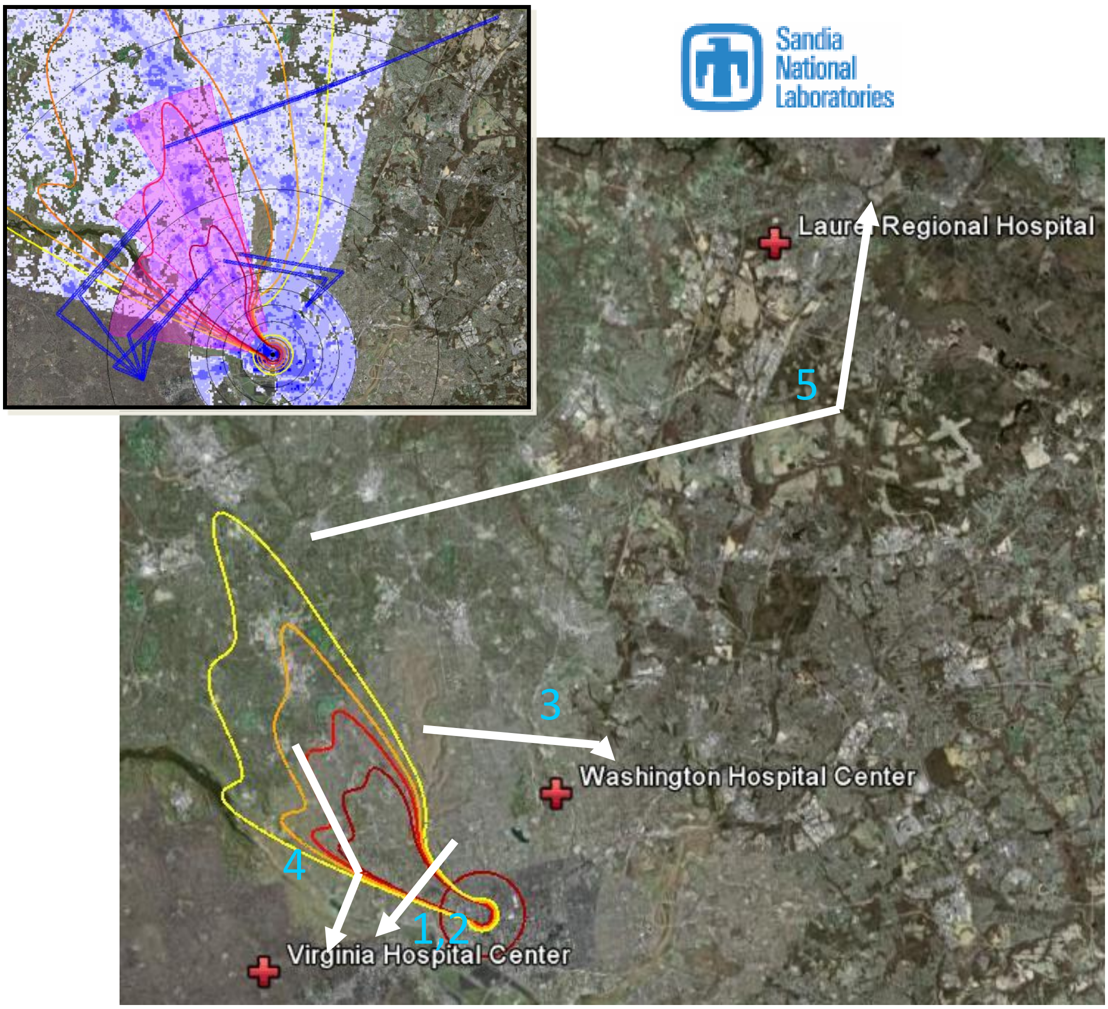


Potential 10 R gamma exposure (indoor)

Note greatly reduced area of exposure, shown in red.

Shelter and Evacuation Evaluation

New analyses and tools developed at Sandia National Laboratories have taken the detailed 100-m x 100-m prompt (shown earlier) and fallout analysis files generated at Lawrence Livermore National Laboratory and provided optimized analysis of community-specific shelter and evacuation. More is explained about evacuation later.



1. Brandt, L.D. 2009. Mitigation of Nuclear Fallout Risks Through Sheltering and Evacuation. Report SAND2009-7367C. November 18, 2009. Sandia National Laboratories, Albuquerque, N.M.

2. Brandt, L.D., and A.S. Yoshimura. 2009a. Analysis of Sheltering and Evacuation Strategies for an Urban Nuclear Detonation Scenario. Report SAND2009-3299, June 2009. Sandia National Laboratories, Albuquerque, N.M.

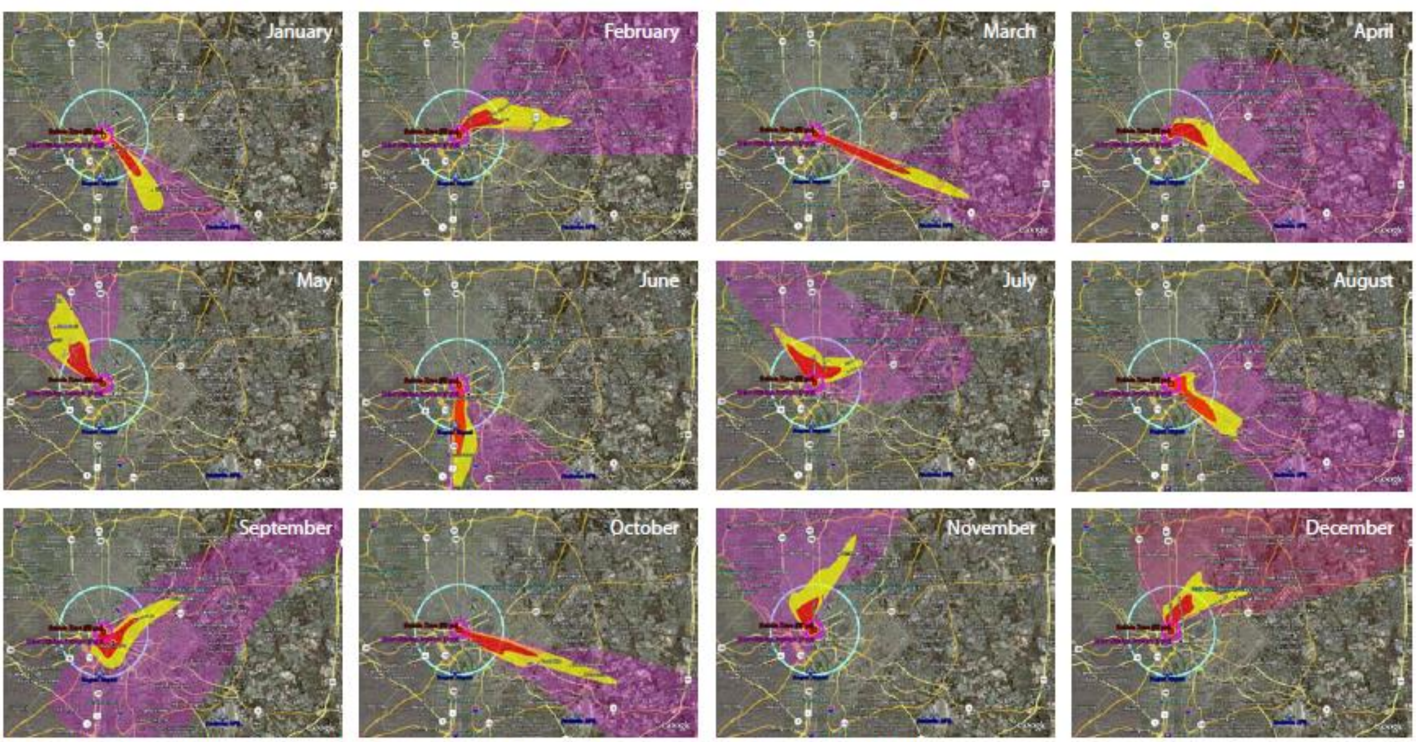
3. Brandt, L.D., and A.S. Yoshimura. 2009b. NUclear EVacuation Analysis Code (NUEVAC): A Tool for Evaluation of Sheltering and Evacuation Responses Following Urban Nuclear Detonations. Report SAND2009-7507, November 2009. Sandia National Laboratories, Albuquerque, N.M. For more information email *lbrandt@sandia.gov*.

Weather Variations

A major consideration for planning is the fact that **weather matters.** The ability to do 3-dimensional atmospheric dispersion modeling has been a key technological advancement in recent decades. Previous models assumed uniform wind directions and speed at all atmospheric levels. The result was “Gaussian fallout patterns” (the classic cigar shape) that gave us the false impression that fallout patterns would always be conveniently shaped in a long, narrow pattern, such as the one pictured below for March.

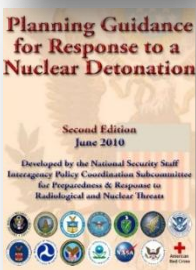
Real atmospheric patterns have different wind directions and speeds at different altitudes. Each day is different from the previous one, so it is difficult to calculate precisely the range and size of a fallout cloud. Understanding the variability in patterns, shapes, and directions supports realistic planning assumptions.

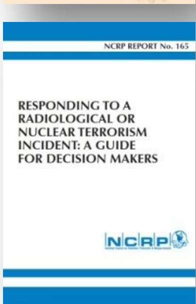
To demonstrate weather variability, here are modeling examples using real weather recorded in the NCR at noon on the 15th day of each month in the year 2006.

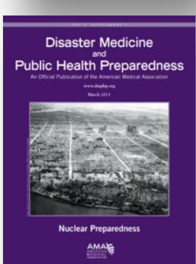


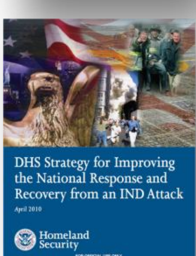
Buildings © District of Columbia (GS GIC), © 2008 Europa Technologies, Image © 2008 Sanborn, © 2008 Tele Atlas

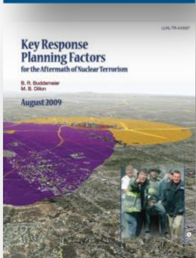
Notice that the typical “Gaussian” only occurs three or four times in the year, and much more complex fallout patterns are a regular occurrence.











DHS IND Modeling and Assessments Informing National Strategies

Research over the last few years has help greatly improve our understanding of appropriate actions for the public and responder community after a nuclear detonation. Much of this research was recently highlighted in a National Academies Bridge Journal on Nuclear Dangers. This research points out the potentially misleading shelter/evacuation conclusions that can be drawn from using oversimplified modeling assumptions (e.g., circles of prompt effects and cigar-shaped Gaussian fallout patters using surface wind conditions).

Planning Guidance for Response to a Nuclear Detonation was developed by the Homeland Security Council, 2nd Ed, June 2010. This interagency consensus document provides excellent background information on the effects of a nuclear detonation and key response recommendations. Its definition of zones (damage and fallout) are becoming the standard for response planning and should be integrated in the planning process.

The National Council on Radiation Protection and Measurement (NCRP) Report No. 165, Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers, was released Feb 2011 and is a national standard that supplies the science and builds on many of the concepts of the Planning Guidance.

For public health information, an entire edition of the journal, Disaster Medicine and Public Health Preparedness, is dedicated to public health issues associated with the aftermath of nuclear terrorism. All of the articles are available for free download from the internet link.

DHS Strategy for Improving the National Response and Recovery from an IND Attack, April 2010, is an Official Use Only document that breaks the initially overwhelming IND response planning activity down into 7 manageable capability categories with supporting objectives. This is a valuable document to guide state and regional planning process, as much work has already gone into time-phased capability requirements for Doctrine/Plans, Organization, Training, Materiel, Leadership, Personnel, Facilities, and Regulations/Authorities/ Grants/Standards. Contact Dave Sheehan, David.Sheehan@FEMA.gov ,or call 202-212-1608 for more information or a copy of the document

Key Response Planning Factors for the Aftermath of Nuclear Terrorism developed by Lawrence Livermore National Laboratory in support of the DHS preparedness activity was released in August 2009. This document reviews the science behind many of the recommendations noted in the above doctrine.

Check Your Understanding

1. Name two common myths about a low-yield nuclear detonation that inhibit regional planning.

2. What is the name of the scientific working group established by the Department of Homeland Security to support IND response planning?

3. Name two prompt effects, and explain how updated modeling is changing assumptions about response planning needs.

4. How does the common urban environment offer more protection from fallout radiation than more open terrain?

5. How can planning assumptions about cigar-shaped, Gaussian fallout patterns cause poor response plans?

6. Name some of the guidance documents that have been issued to help state and local emergency response organizations.

Notes

IND Prompt Effects Summary (National Capital Region)

Example of a 10-kT Detonation in Downtown Washington DC

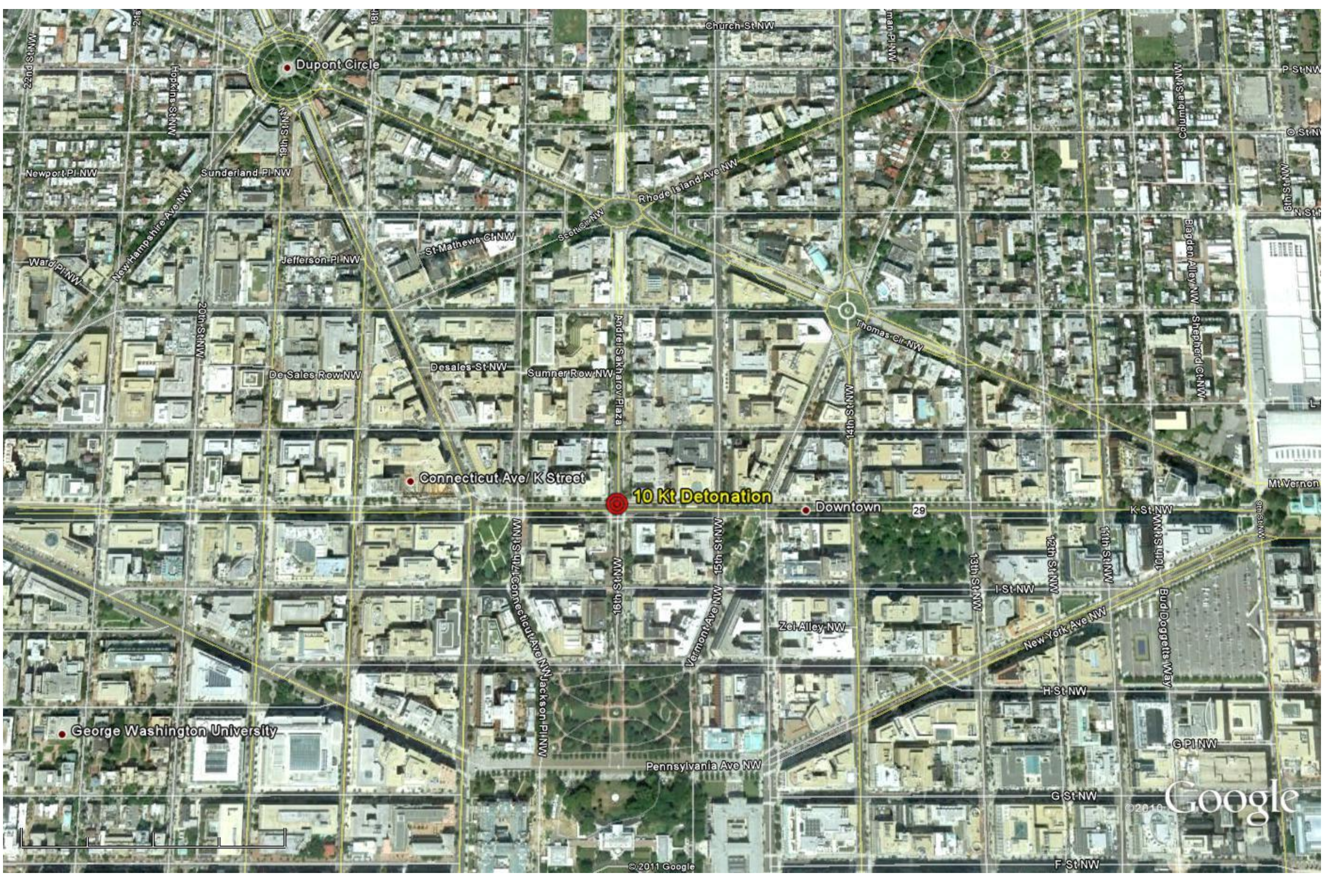
This section explains “prompt” effects for a scenario in which a 10-kT IND is detonated in downtown Washington DC. Prompt effects are those that radiate outward from ground zero, usually within the first minute after detonation. It is important to recognize certain aspects of such a scenario.

- Detonation of an IND would produce a flash of light, that when viewed at a mile from the detonation will be the equivalent brightness of 1,000 mid-day suns.
- A 10-kT yield is equivalent to the explosive power of about 5,000 Oklahoma City truck bombs.

For the following scenario:

- **The hypothetical detonation takes place on ground level at 1600 K St NW.**
- **Population estimates are based on a typical workday in Washington DC.**
- **The weather profile is taken from actual weather conditions recorded at noon on February 14, 2009.**

Although such details may seem specific, the following information can be used to help response planning for other Tier 1 cities.



Accidents and Congestion Caused by Flash blindness

The bright flash would temporarily “blind” anyone who sees it at a distance 6 to 10 miles away (daytime). Such blindness could last for several seconds to a couple of minutes, an issue arguably less consequential if standing on a street corner, but highly problematic if driving on a freeway.

Most roads within a range of about 6 miles would likely be snarled with accidents, and many injuries would occur.

The potential for flash blindness would be worse at night and could cause accidents much further away than 6 miles.

Damage Zones

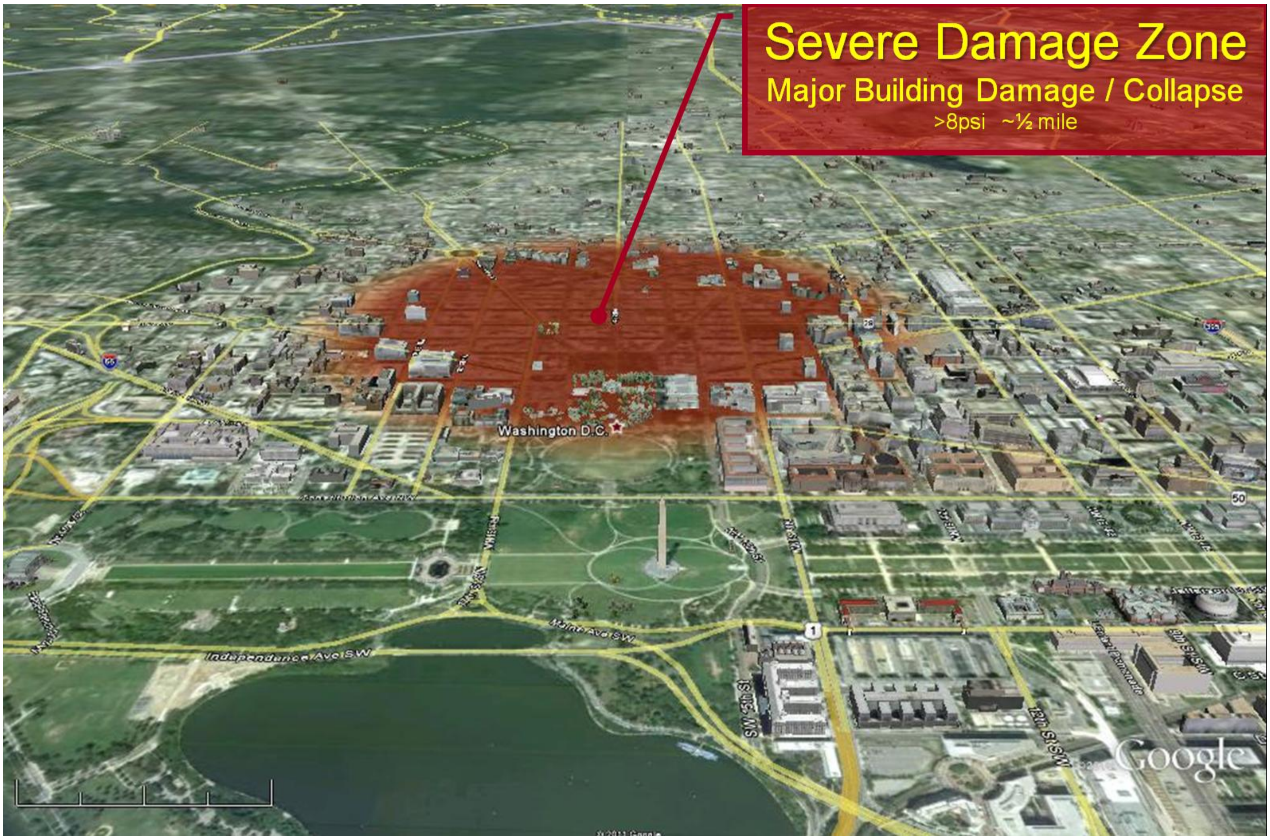
Three major blast damage zones are defined by the Federal *Planning Guidance for Response to a Nuclear Detonation* (2010). Be aware of these zones when assessing the best course of action following a nuclear detonation. The three zones are:

- Severe damage zone (SDZ).
- Moderate damage zone (MDZ).
- Light damage zone (LDZ).

Severe Damage Zone

Zones are defined by the amount of observable damage. To understand the damage zones, the definition of blast effects is important. Blast effects are damage or injuries done to structures or people following a detonation.

For a 10-kT detonation, the severe damage zone extends to about half a mile from the blast site. This zone will see severe structural damage from the initial blast wave and most likely fatal injuries from the blast, thermal pulse, and prompt radiation.

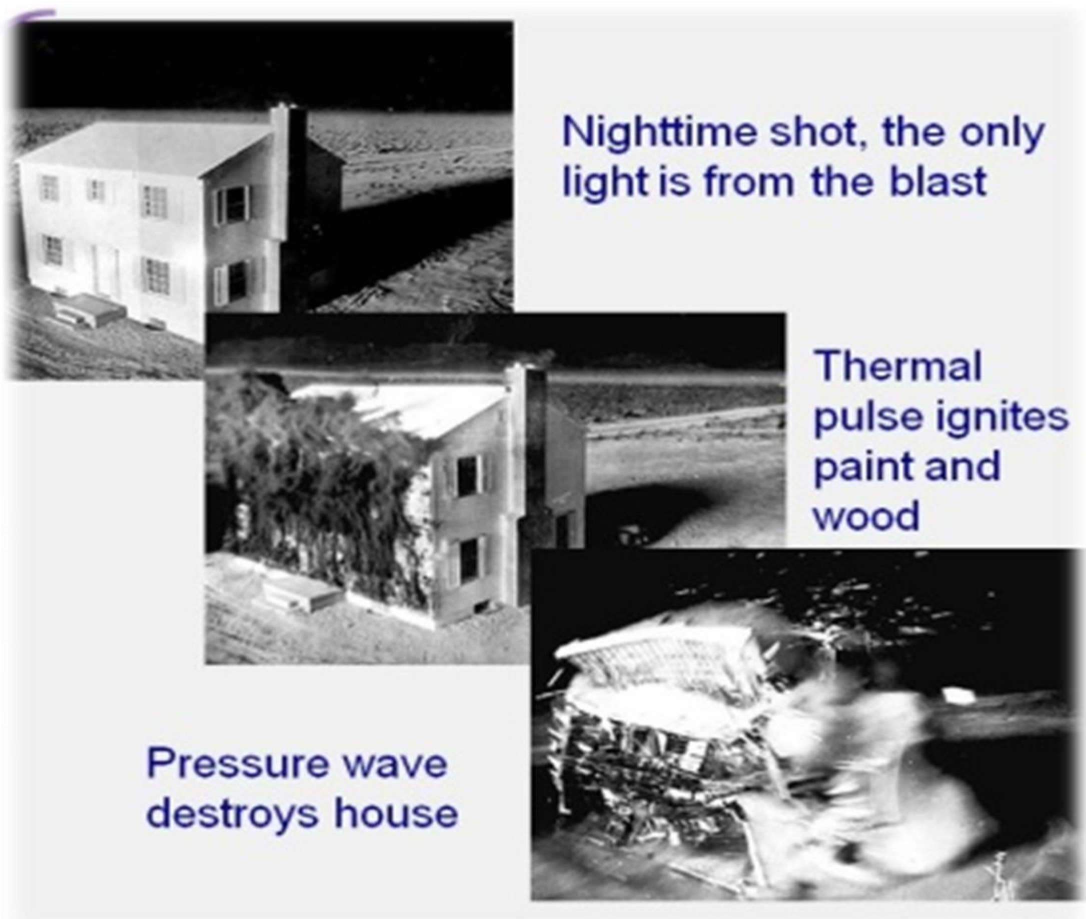


Outer Edge of the Severe Damage Zone

The pictures shown here are from a test detonation in the Nevada Desert. They illustrate the type of damage done to buildings at the outer edge of the severe damage zone.

Given a clear line of sight to the fireball, the initial thermal pulse initiates fires. The blast wave comes first as positive pressure wind, followed by negative pressure moving the opposite way.

Severe radiation and burn injuries will occur, especially to those outdoors in the severe damage zone.



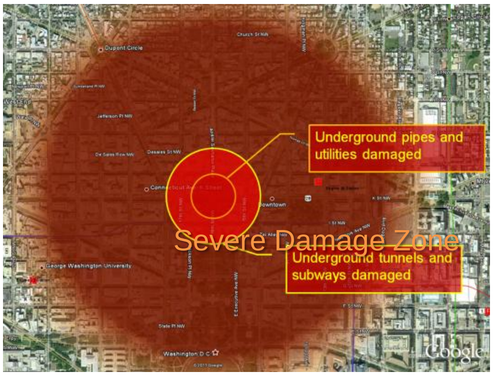
Underground Infrastructural Damage

Figure 2: Buried pipelines under earthquakes - ductile iron pipes with seismic joints surviving large permanent ground deformation (left) and brittle failure of cast iron pipes (right)

The shockwave movement underground also creates damage to tunnels, such as subway systems, and infrastructure such as water mains, power, telecommunications, and gas conduits. Analysis by Los Alamos National Laboratory using data from nuclear tests at the Nevada Test Site and extrapolation from earthquake damage of the effects on these systems indicate that:

- Water, power and telecommunications conduits could be damaged out to 120 meters from a 10-kT surface detonation.
- Larger tunnels, such as subway systems, could be damaged out to 250 meters (~2 city blocks) from a 10-kT detonation.

Collapsed tunnel for the Nevada Test Site

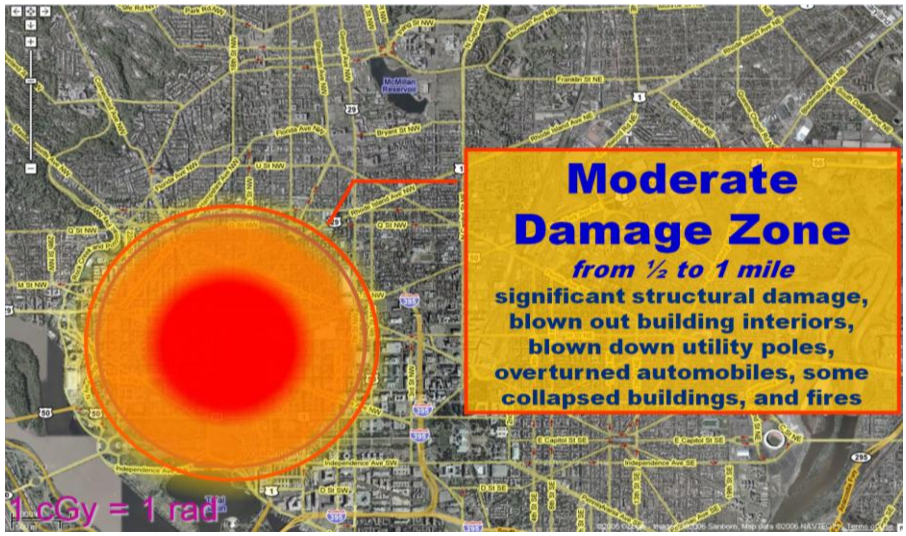


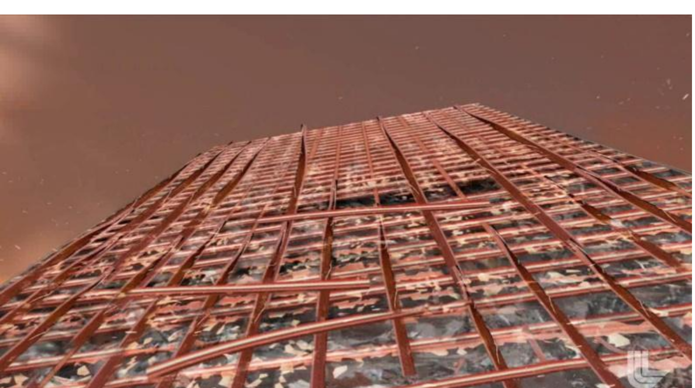
Because the severe damage zone extends ~½ mile (~800 m), primary underground infrastructure damage is contained by the severe damage zone.

References
T. N. Dey and R. J. Bos, Underground Infrastructure Damage for a Chicago Scenario, LA-UR-11-00566.
H. Kameda, “Engineering Management of Lifeline Systems under Earthquake Risk,” Proc. 12th World Conf Earthquake Engineering, 2000.
Chapter 8, *Effects of Nuclear Earth-Penetrator and Other Weapons*, Committee on the Effects of Nuclear Earth-Penetrator and Other Weapons, Nat. Res. Council of the National Academies, National Academies Press, Washington, D.C., 2005.

Moderate Damage Zone

The orange annular ring denotes the moderate damage zone. For a 10-kT device, it will extend from 0.5 to 1 mile from the detonation site. This area has the most potential life-saving opportunities. However, it will also see major structural damage and fires.



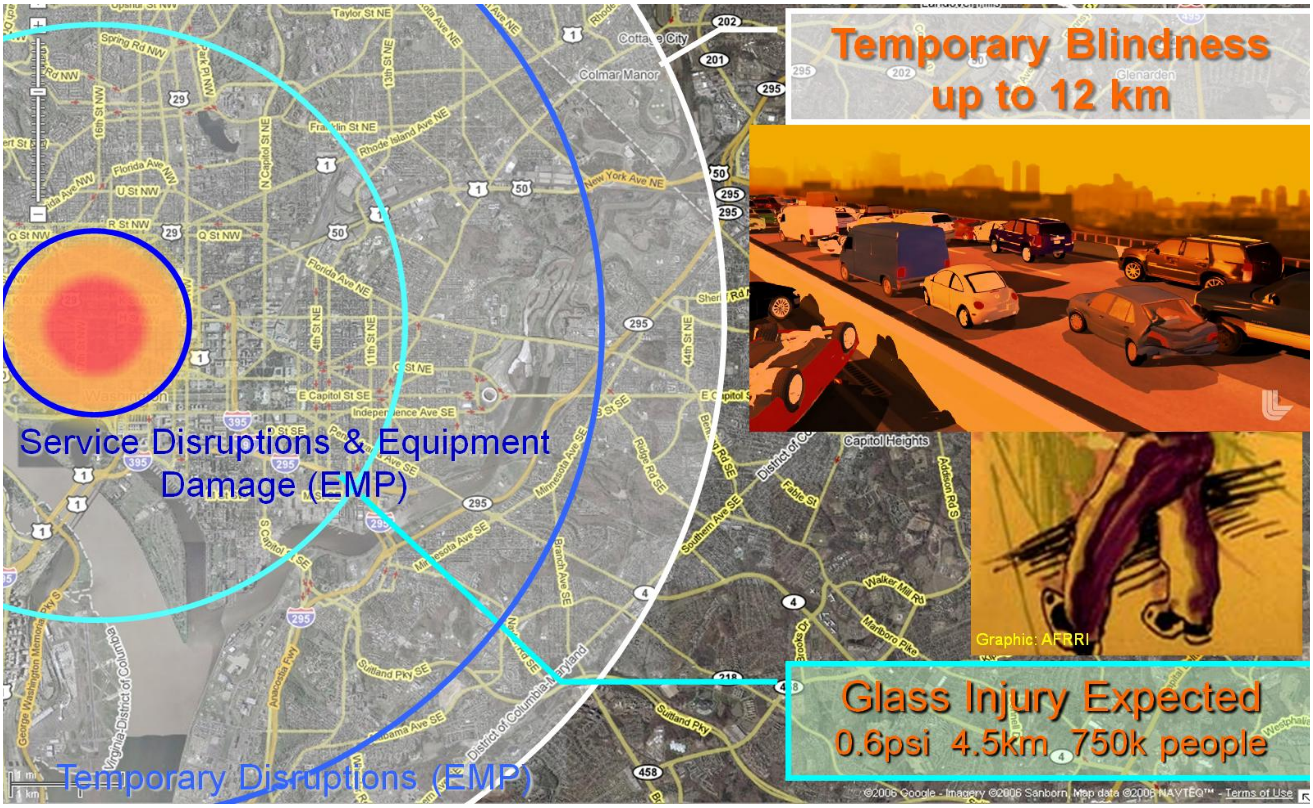


Outer Edge of the Moderate Damage Zone

The outer edge of the moderate damage zone would have building damage consisting of broken glass along with external panel damage and partial destruction of weaker structures.

The PowerPoint animation shows the timing and types of effects that might be observed at the outer edge of the moderate damage zone. A bright flash will be followed by a “thump” as the shock is transmitted through the earth. Several seconds later, an air blast will severely damage many structures and blow glass into buildings causing injuries and bringing the facades of many buildings to the ground. Ruble and debris in streets would impede the movement of responders and evacuees.

Other Long-Range Effects



The light-blue line indicates where glass would be broken with enough force to cause injuries. The workday population of Washington DC in this area is about 750,000 people.

The area within the outer, white circle shows where people outside have the potential to be blinded by the flash during detonation. Blindness could last for several seconds or as long as a few minutes. Drivers would be unable to see the road or other vehicles, which could potentially cause additional accidents clogging major thoroughfares. Most roads in about a 10-km range would likely be snarled with accidents.

Another area of concern is the EMP range. EMP is the electromagnetic pulse that will radiate outwards from the blast site. The most damaging EMP effects would be limited to within a mile. An EMP blast will disrupt most electronics, but cause little direct harm to people.

Although a “firestorm” is not likely to occur, numerous small fires started from thermal and blast effects (generally within a 1-mile perimeter) could spread and coalesce if not mitigated.

Light Damage Zone

The light damage zone extends from 1 to 3 miles from a 10-kT detonation and represents the largest of the three blast zones. Most injuries in this zone will consist of cuts from broken glass. There will also be minor structural damage to windows and other weak or flat surfaces.
Damage in this zone is caused by the "shockwave" following the blast, similar to a sonic boom and consisting of free-field overpressure.

The images below are from an accidental explosion at a booster rocket manufacturing facility in Henderson, Nevada. The explosion was estimated as equivalent to about 1 kT. Office glass was blown into the building, and ceiling tiles caved in. The large, flat roof of the warehouse collapsed.

Check Your Understanding

1. What are prompt effects?

2. What are some specific examples of prompt effects?

3. Will Prompt Effects be represented by "Perfect Circles"? Why or Why not?

4. Name the characteristics of the Light Damage Zone.

5. Name the characteristics of the Moderate Damage Zone.

6. Name the characteristics of the Severe Damage Zone.

7. How will rubble play a factor in emergency responses?

8. What parts of the LDZ or MDZ should be initially avoided?

Notes

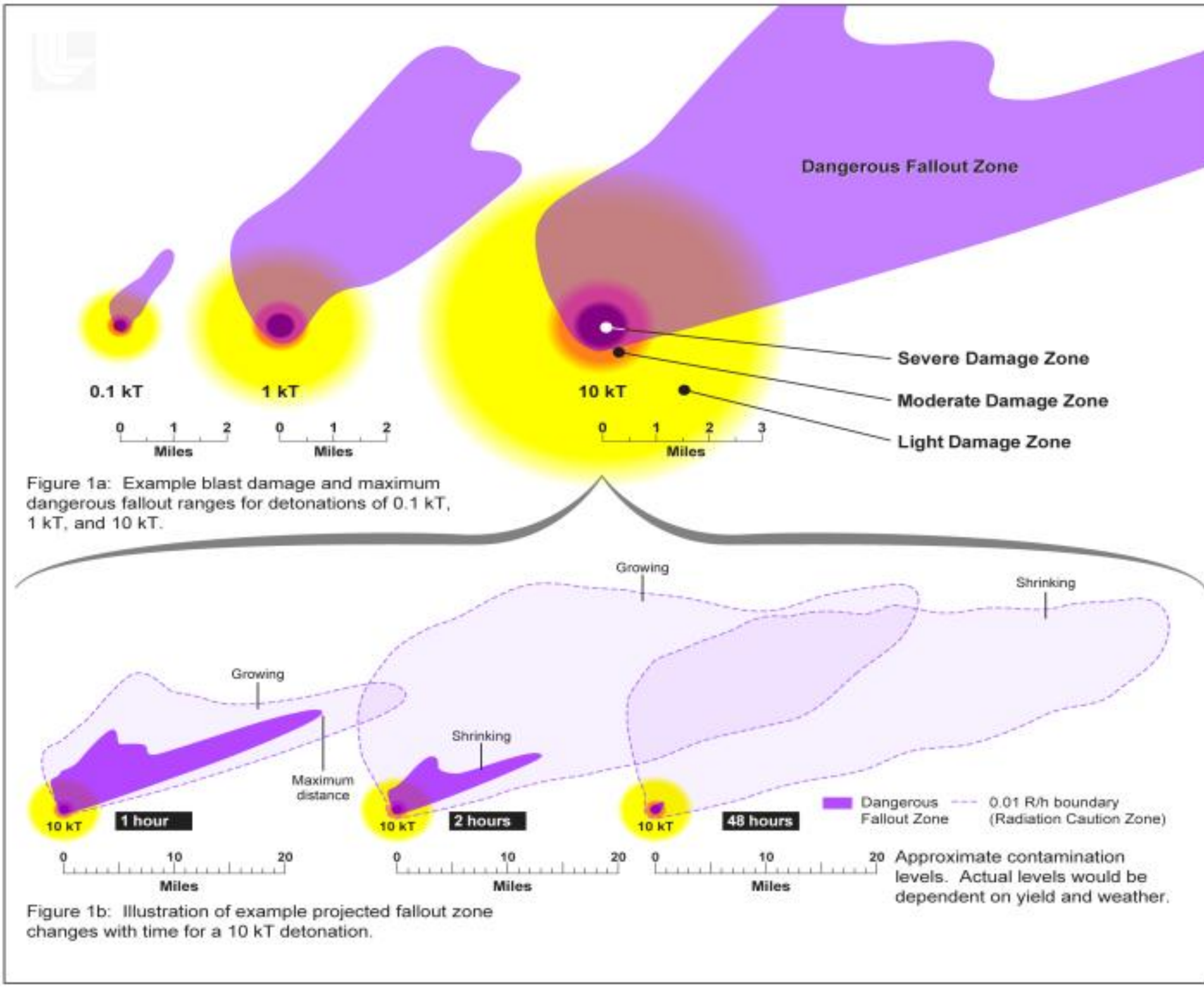


Figure 1a: Example blast damage and maximum dangerous fallout ranges for detonations of 0.1 kT, 1 kT, and 10 kT.

Figure 1b: Illustration of example projected fallout zone changes with time for a 10 kT detonation.

IND Fallout Effects

(National Capital Region Version)

Video

This video gives a quick introduction on how dangerous radiation is formed within a fallout cloud. Fallout begins to form immediately following a detonation.

Fallout clouds are not like smokestack "plumes." Rather, they are thousands of tons of material lifted by the heat of the explosion that fall back to earth as particles. Radiation from these particles is the dangerous aspect; not breathing it.

For a 10-kT detonation, Nevada Tests predict the cloud will rise 5miles into the upper atmosphere; however. more recent models of detonations in built-up areas indicate that the fallout cloud may not rise far.

Larger particles will fall out first, and within several miles of the detonation they may be the size of table salt or sand. The farther from the detonation, the smaller the particles will become.

The smallest (respirable) particles may remain trapped in the upper atmosphere and are not a primary local fallout hazard.

Explanation of Fallout

The primary delayed effect from a ground-level nuclear detonation is from fallout. Fallout is generated when the dust and debris excavated by an explosion is combined with radioactive fission products and drawn upward by the heat of the detonation. The cloud rapidly climbs through the atmosphere, up to 5 miles high for a 10-kT IND based on atmospheric tests shots performed in the Nevada Desert and South Pacific, and highly radioactive particles coalesce and drop back down to earth as they cool.

Dust and debris at the base is generated from blast effects and is generally **not** radioactive. The material in the “stem” and “cap” of the fallout cloud is highly radioactive. Under ideal circumstances, a "mushroom" shaped cloud is formed; however, this may not be the case for low-yield or non-ideal wind conditions.

Fallout particles move away in various directions and speeds.

Upper-level (high-speed) winds sweep the cap of the cloud to the east in the example shown here of a detonation in Washington DC. Lower-altitude (low-speed) winds move the stem and particles coming down from the upper atmosphere to the north.

Fallout Particles Move in Various Directions and Speeds

Fallout travels over the first few hours according to specific weather conditions in effect at the time. Depending on weather conditions and wind speed, dangerous fallout particles move away from the initial blast site in different directions and at different speeds. To visualize how a cloud would appear over the first few hours, scientists at the Interagency Modeling and Atmospheric Assessment Center (IMAAC) at Lawrence Livermore National Laboratory created an animation of the fallout cloud image represented by purple balls that move over time.

Bird's Eye View

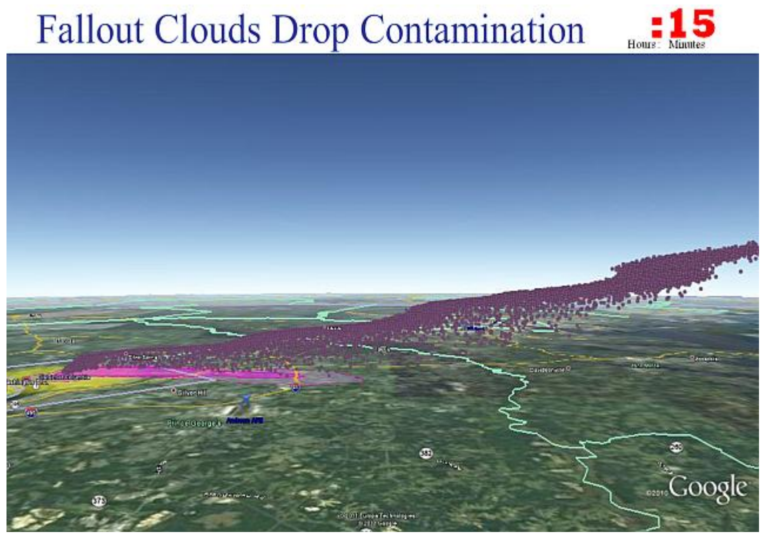
The images on the right show two features after a 10-kT detonation:

(1) Purple balls demonstrate movement of the fallout cloud.

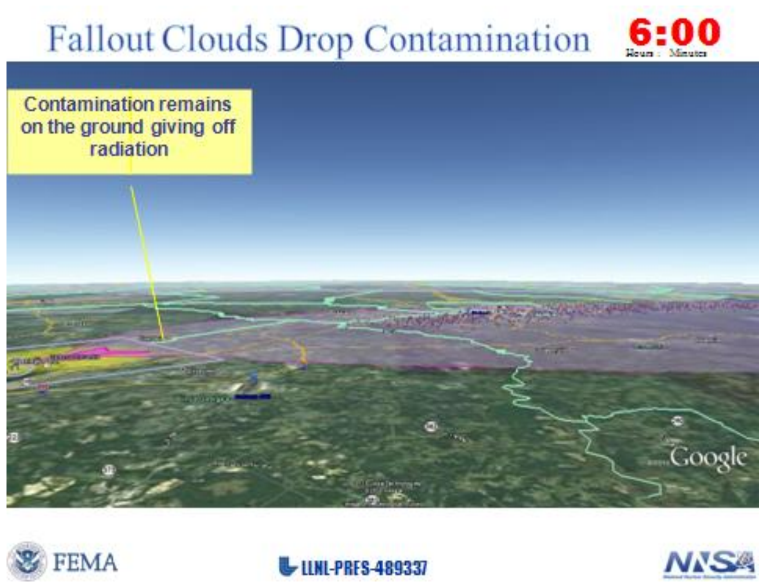
(2) Colored contours on the ground represent different radiation levels given off by particles that have fallen to the ground.

After 15 minutes, upper-atmospheric winds push the cloud to the east, while parts of the fallout in the lower atmosphere push it to the north. The different colors represent fallout levels on the ground. After the first hour, most of the cloud moves away, but dangerous radiation remains present on the ground.

The image to the right shows the situation after 6 hours. It is important to remember that even though a person might not be able to see any type of cloud after the first hour, dangerous radiation levels will remain. Understanding how radiation stays behind following a detonation is a key response issue.



View from the south, 15 minutes after detonation.



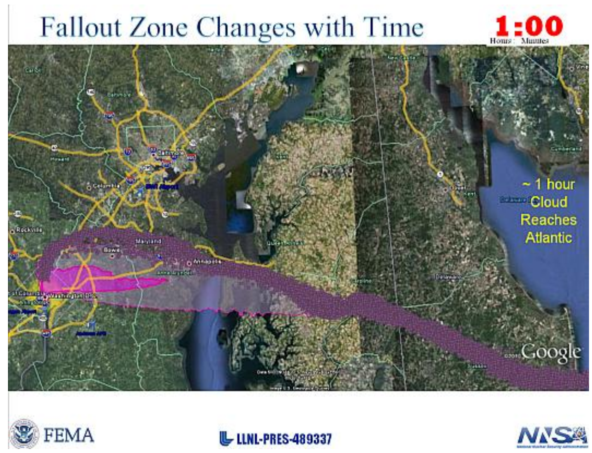
View from the south, ~6 hour after detonation.

Fallout Cloud Movement–Continued: Regional View

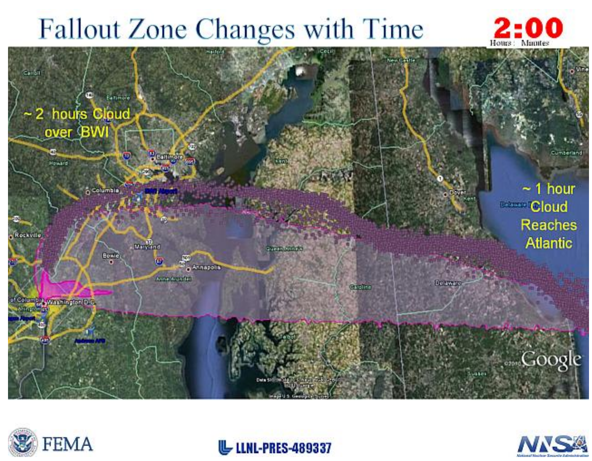
The images on this page show a regional view of how the fallout cloud spreads across the region.

Fallout clouds spread rapidly. Notice how radiation levels on the ground lag significantly behind movement of the fallout cloud. The reason is that fallout particles must fall from several miles in the upper atmosphere.

First hour: cloud over the Atlantic
The cloud moves away quickly but has already deposited dangerous levels of radiation over areas near the detonation site. At 1 hour the top of the cloud is over the Atlantic Ocean.

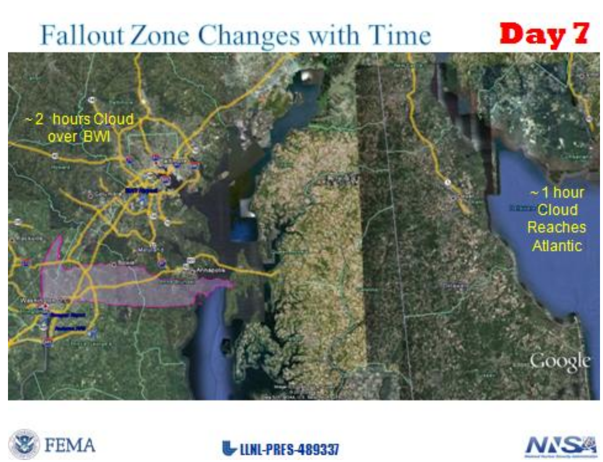


Two hours: cloud over BWI
The lower half of the cloud continues to move away from the detonation site and continues to deposit some fallout. This part of the cloud reaches Baltimore Washington International Airport (BWI) after ~2 hours.



Seven days:
Even though the cloud continues to spread over large areas, the radiation dose to areas below continues to lessen.

The good news about fallout is that it decays quickly. This means that radiation levels in areas where fallout has already been deposited will lessen over time.



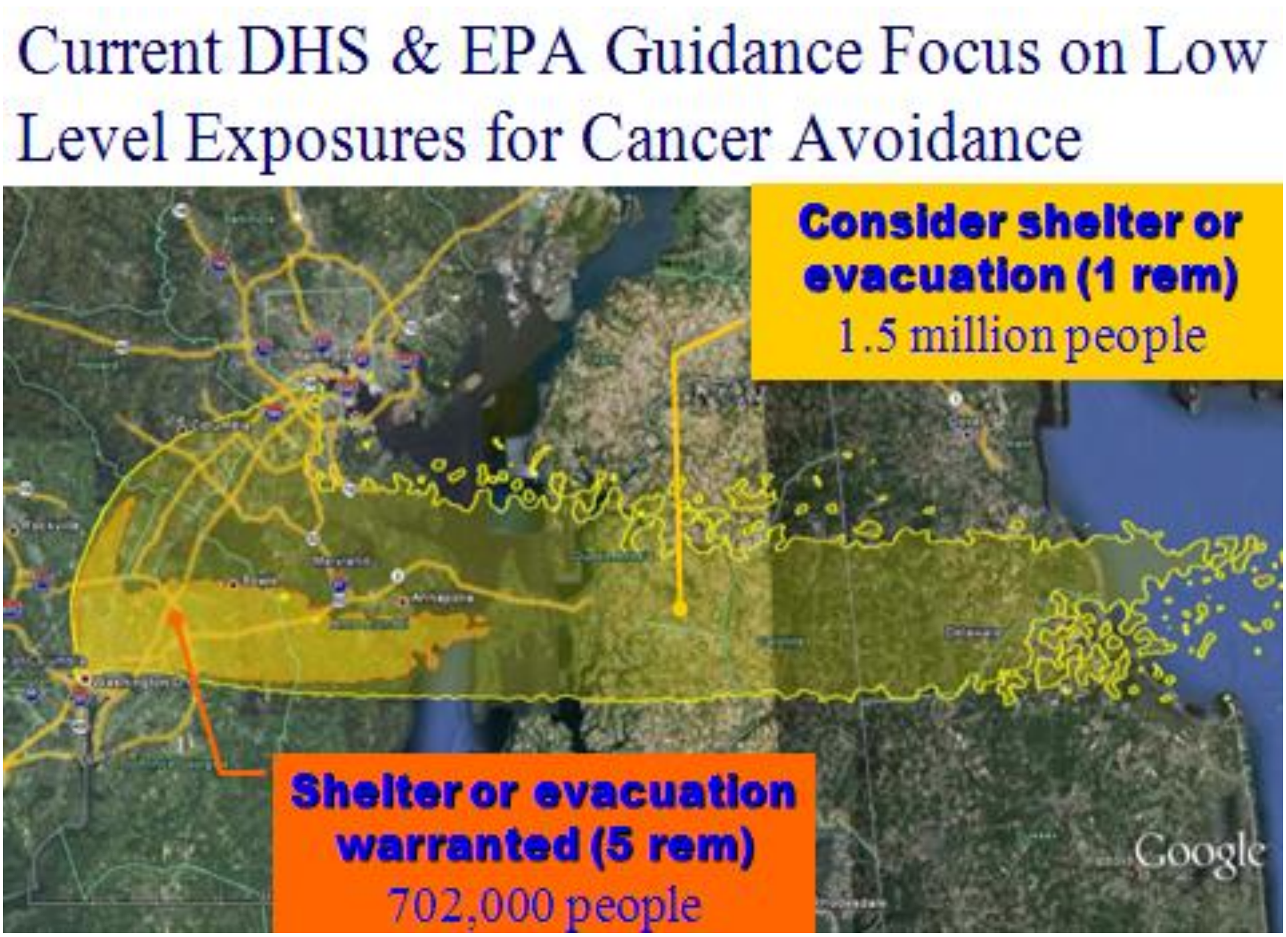
DHS and EPA Guidelines on Exposure Levels

Current guidelines for shelter or evacuation were designed for slowly evolving events, such as a possible nuclear power accident. The recommendations indicate that a person should:

"consider shelter or evacuation when a 4-day outdoor exposure would exceed 1 rem, and shelter or evacuation is warranted if expected exposure exceeds 5 rem."

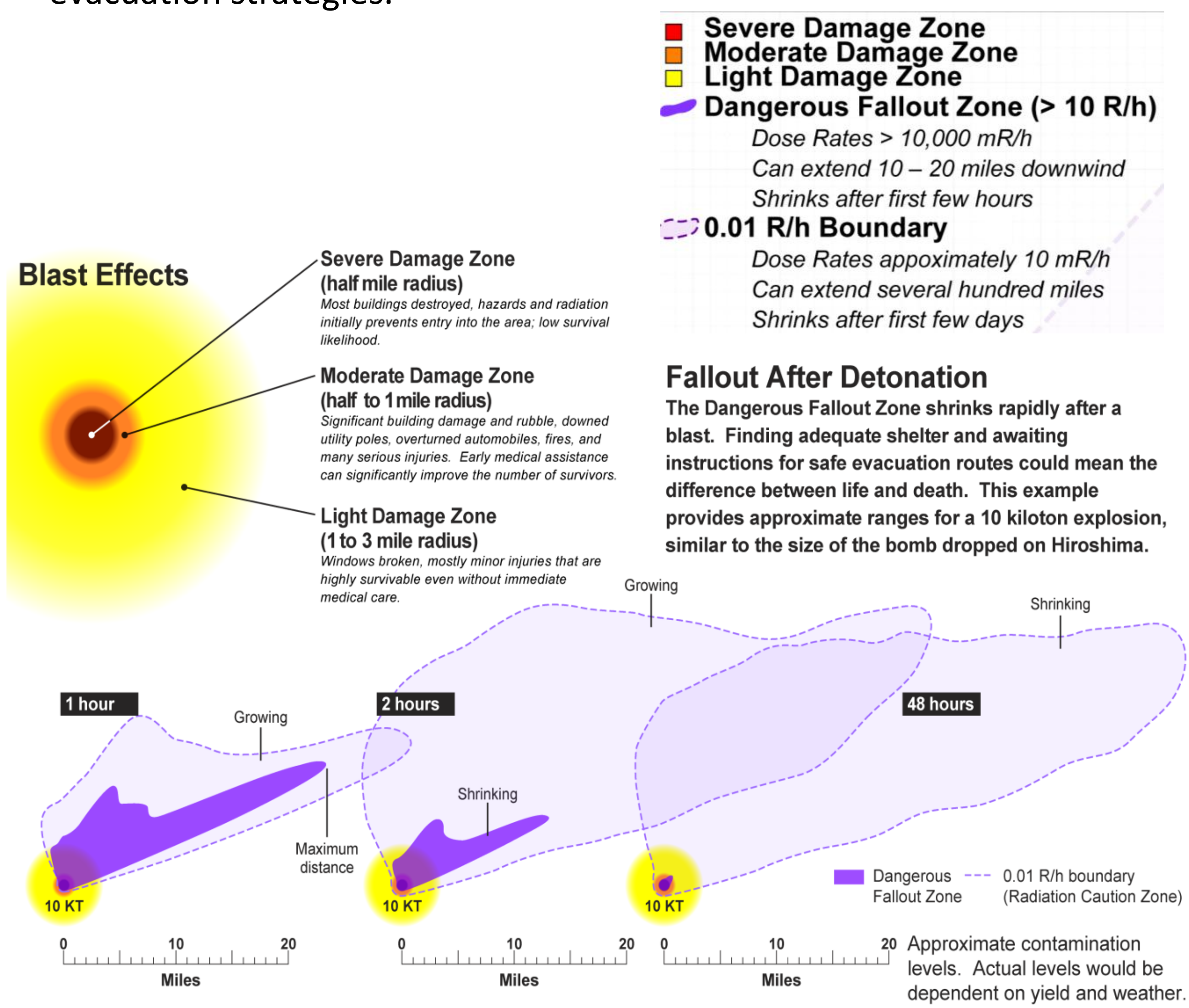
Unfortunately the guidelines fail to tell us which (shelter or evacuation) is the better option, instead stating that a person should choose the option that leads to the lowest possible exposure. Such advice leaves the evaluation to be performed during the midst of an actual incident.

The image below shows why having response plans **in advance** is so crucial to saving lives. Figuring out what is the appropriate action for several million people **after a detonation** is likely to be extremely difficult, if not impossible.



Review the Planning Guidance Zones

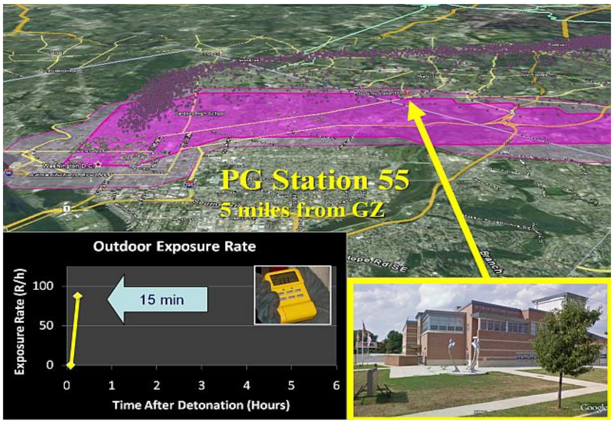
Use the illustration below to review the five planning guidance zones. three types of blast damage zones that were first introduced and defined in the discussion of IND prompt effects (severe, moderate and light damage zones). Next there were two fallout zones defined, the Dangerous Fallout Zone, and the Hot Zone. These zones can be used to help plan and guide shelter and evacuation strategies.



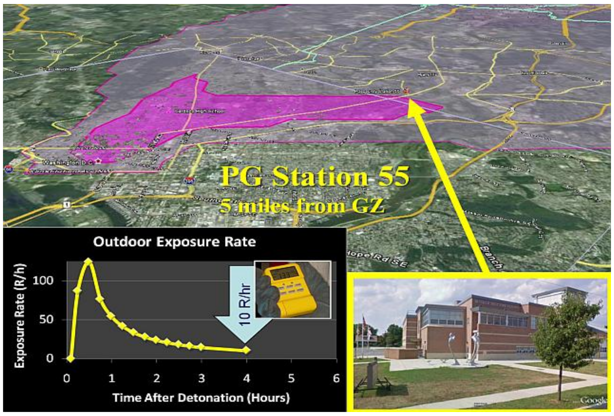
Dose Rates Decay Quickly

The details associated with a detonation area must be understood. Simply understanding how fallout works is not enough. It is important to understand what the incident will look like from a first-person perspective. The images on this page show a “bird’s eye” view of cloud movement and feature radiation levels at a particular area and time.

View from the south
Frames from an animation show how things would look at the Prince George’s County Firehouse #55. The station is located 5 miles from the hypothetical detonation.

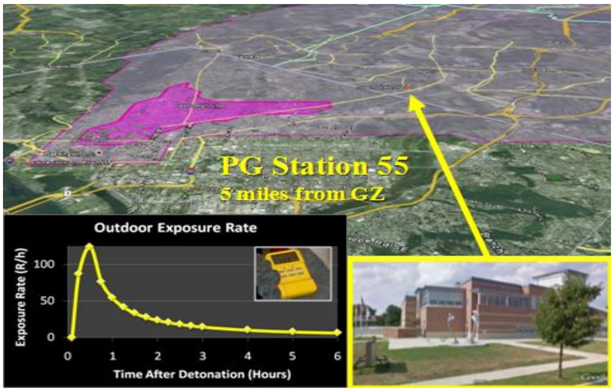


Fallout cloud appears; dose rate in first 15 minutes appears
The fallout cloud is already overhead, but not all of the fallout has reached the ground, so radiation levels will continue to rise for several minutes. As the cloud reaches the station, dose rates shoot up to more than 100 R/hr at the half hour mark. This is more than 10 times the 10 R/hr value of the dangerous fallout zone.



Animation continues, showing dispersing fallout cloud and different dose rates
While initial dose rates are high, notice how fast the rates begin to drop. The reason is that radiation has an extremely short half-life, so it decays very quickly. Over half of the dangerous radiation dose comes from the first hour of exposure.

After 4 hours the dangerous fallout zone “shrinks” past the station as dose rates fall to less than 10 R/h.



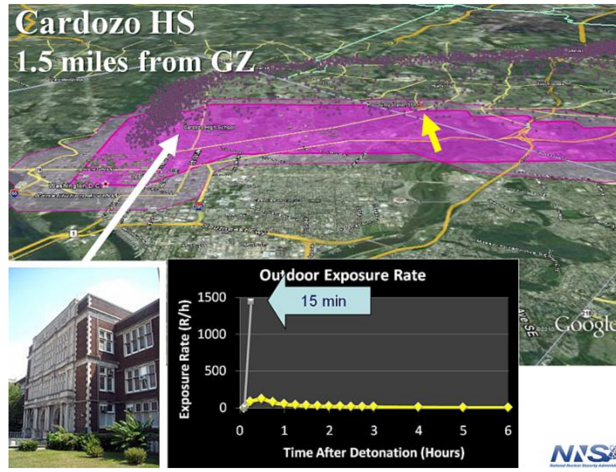
Dose Rates Decay Quickly

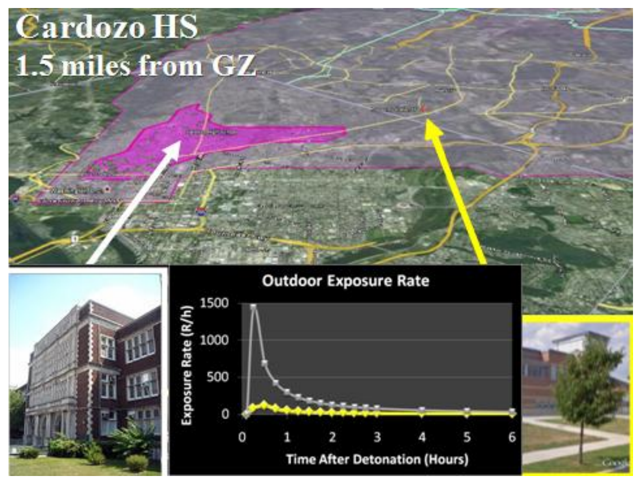
Cardozo High School measurements

To understand the difference that distance makes, consider a location only 1.5 miles from the detonation, Cardozo High School. Because the school is much closer to ground zero than is Firehouse #55, the vertical scale is expanded on the dose rate chart.

15 minutes after detonation, fallout has already fallen at the school, and exposure rates are ~1,500 R/hr.

Once again, notice the trend over the first several hours. See how rapidly dangerous levels of radiation fall off with time.

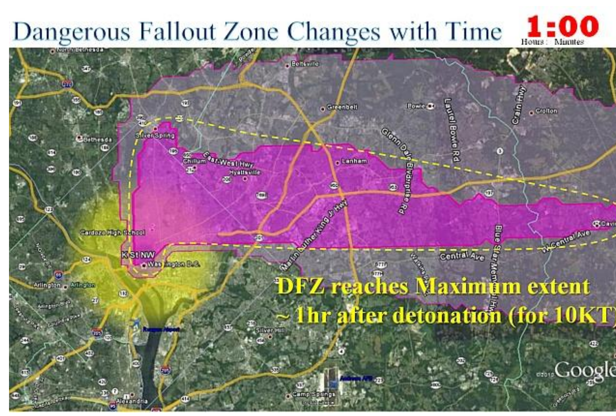




Dangerous Fallout Zone Changes with Time

Here are the dangerous fallout zone and hot zone 1 hour after detonation.

For a 10-kT detonation, the DFZ reaches its maximum extent after about 1 hour. The yellow border (dashed line) represents the maximum extent of the DFZ. As time progresses, the DFZ continues to shrink, and after a few days the zone actually disappears.



Key Fallout Considerations

Fallout decays rapidly, releasing more than half of its energy in the first hour.

- Radiation levels are very high initially, but more than 50% of the energy is given off in the first hour, more than 80% in the first day.

The primary hazard from fallout is being exposed to penetrating radiation from fallout particles.

- The hazard is penetrating radiation energy. Getting as much distance and mass between you and the particles is the best protection. By remaining indoors and seeking the best possible shelter in a structure, people can dramatically reduce the radiation dose to which they are exposed.

Dangerous levels of fallout are readily visible as they fall.

- Dangerous levels of fallout are not invisible; visible quantities of material would rain down, often the size of salt or sand.

Fallout is not a significant inhalation hazard.

- Because they are so large, breathing in the particles is not very likely and is a much lower concern than external exposure from particles on the ground.

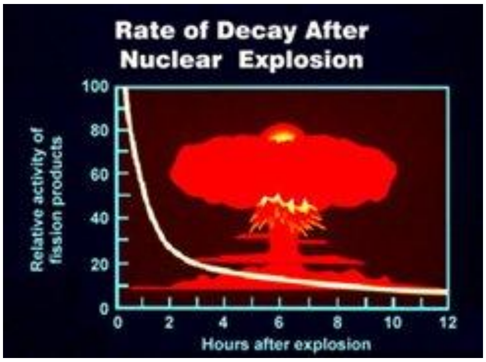
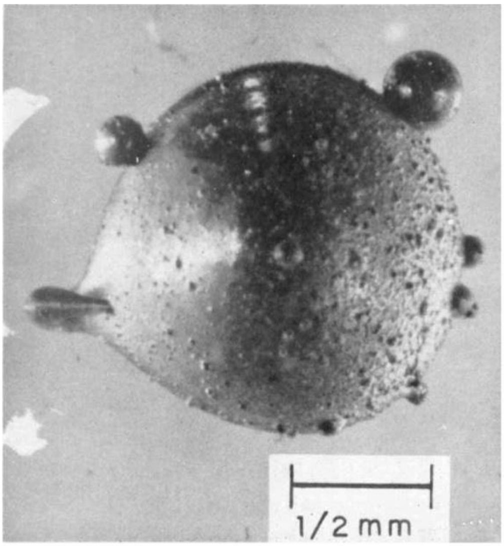


Image courtesy of Armed Forces Radiobiological Research Institute



IG. 1. A radioactive fallout particle from a tower shot in Nevada. The particle has a dull, metallic luster and shows numerous adhering small particles.

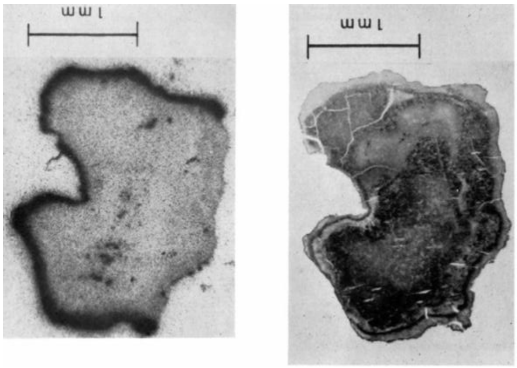
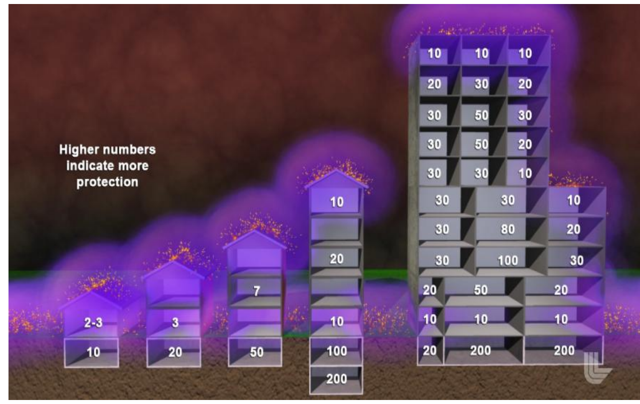


FIG. 4. Photograph (left) and autoradiograph (right) of a thin section of an irregular particle from a ground-surface shot at Bikini. The radioactivity is concentrated on the surface of the particle.

Fallout Images from:
G. R. Crocker, J. D. O'Connor, and E. C. Freiling, 1966, "Physical and Chemical Properties of Fallout Particles," *Health Physics* **12**, Pergamon Press, pp. 1099–1104.

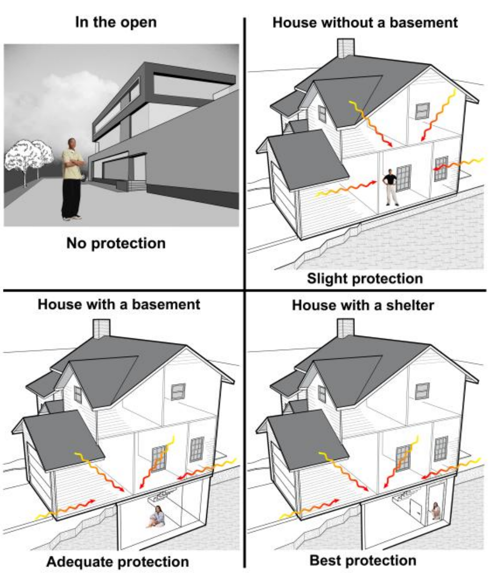
Key Fallout Considerations

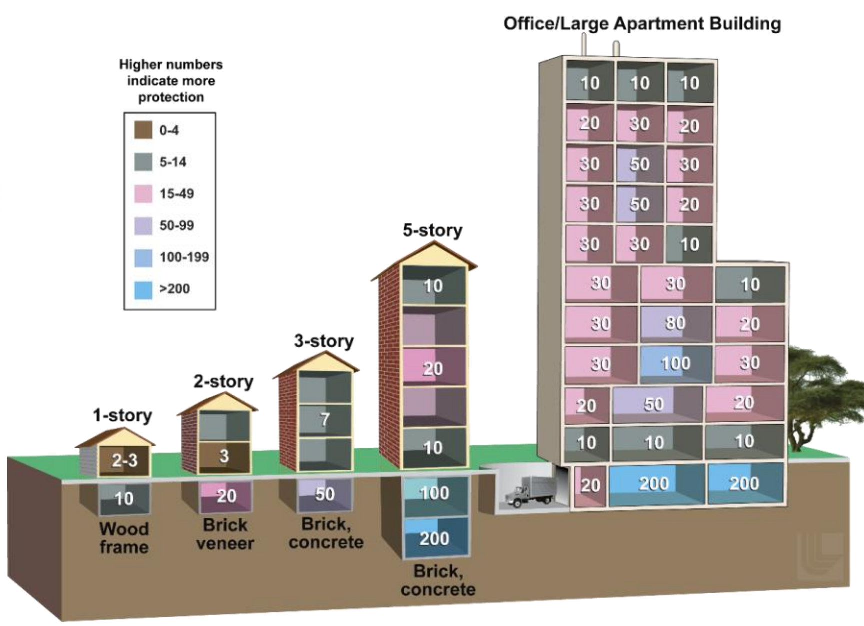


Protection Factors

Particles coat the ground and rooftops as shown to the right. Hazardous areas are near the places where fallout accumulates. Radiation penetrates through windows and walls, but exposure decreases with distance and intervening materials.

Similar to the SPF of sunscreen; the higher the protection factor (PF), the lower the exposure that a sheltered person would receive compared to an unsheltered person in the same area. To obtain the sheltered exposure, divide the outdoor exposure by the PF. These images show presumed protection factors for a variety of buildings and locations inside. For example, a person on the top floor or periphery at ground level of a high-rise office building would have a PF of 10 and would receive only 1/10th (10%) of the exposure that someone outside would receive. A person in the core of the building halfway up would have a PF of 100 and receive only receive 1/100th (1%) of the outdoor exposure. In fallout areas, knowing locations with adequate protection factors could prevent a potentially lethal exposure.



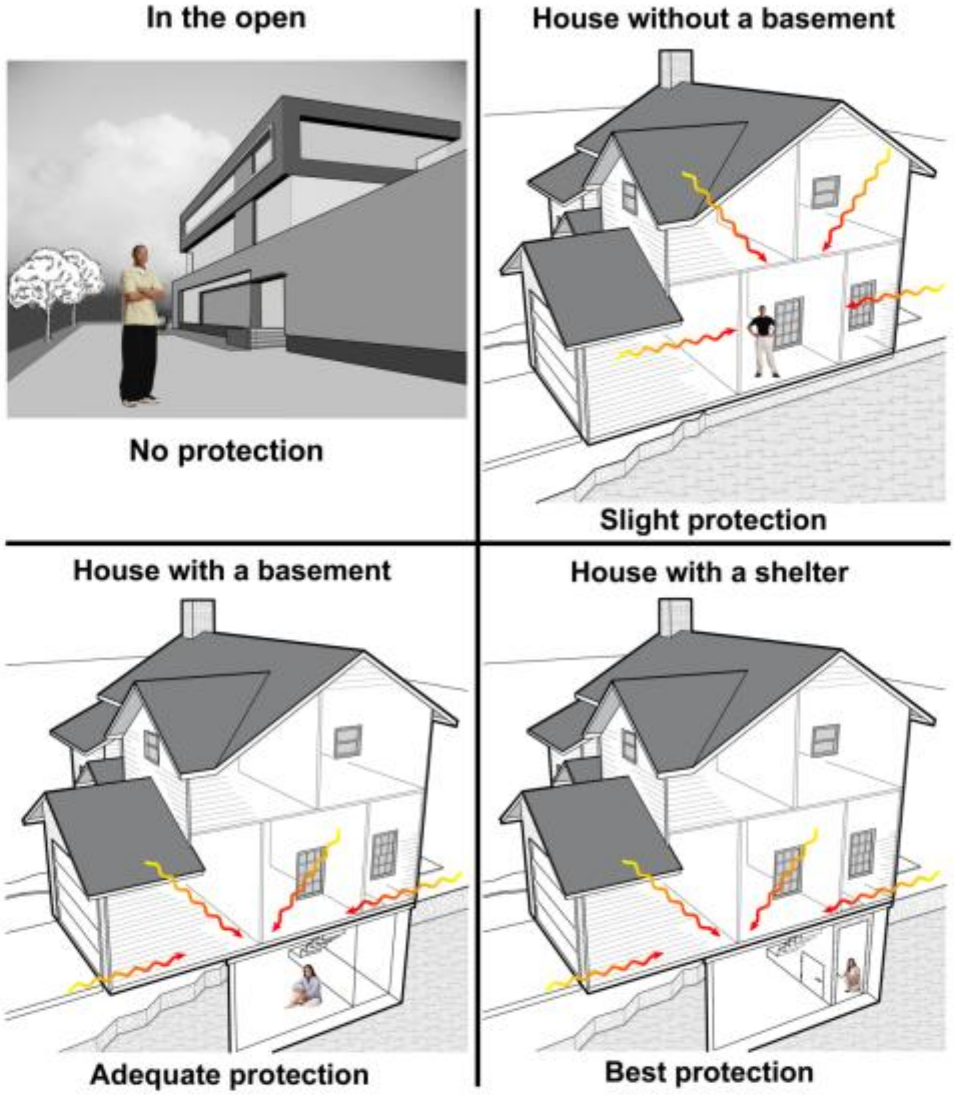


A protection factor of 10 or higher is considered adequate protection against fallout radiation. For simple, wood-frame houses, going into a basement is enough to offer adequate protection. For those in large office or apartment buildings, going into the center of the building or deep underground offers very high levels of protection against radiation.

Check Your Understanding

1. What is Fallout?
2. How high will a 10kT fallout cloud rise in the atmosphere?
3. Is it true that if you don't see the radiation cloud, then it is safe to be outside? Why or why not?
4. How much energy does fallout lose in the first hour?
5. Name the boundary dose rates of the 2 fallout zones.
6. Does Fallout radiation only appear in these zones?
7. About how far do the zones extend to?
8. When do they reach their maximum?

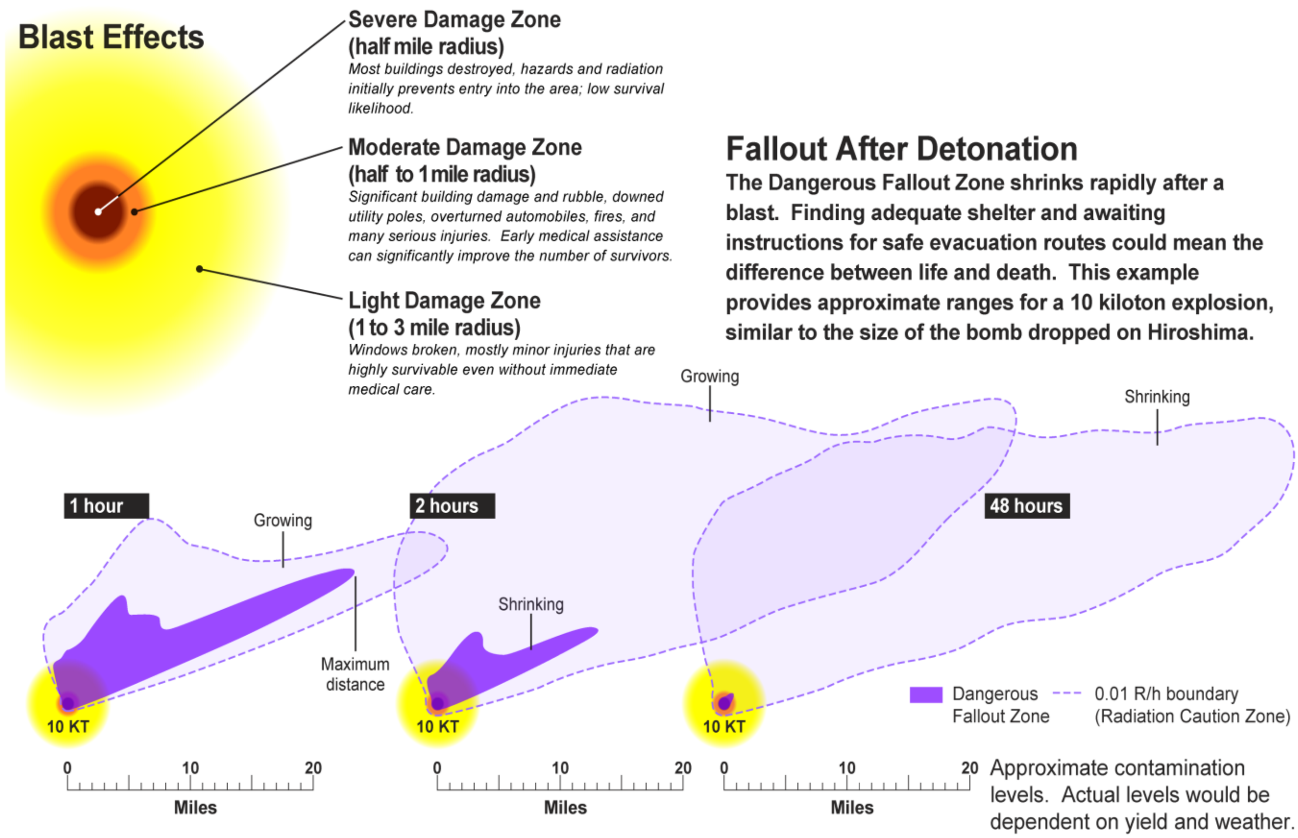
Notes



Shelter and Evacuation Strategies (NCR)

Review the Planning Guidance Zones

Use the illustration below to review the five planning guidance zones. three types of blast damage zones that were first introduced and defined in the discussion of IND prompt effects (severe, moderate and light damage zones). Next there were two fallout zones defined, the Dangerous Fallout Zone, and the Hot Zone. These zones can be used to help plan and guide shelter and evacuation strategies.

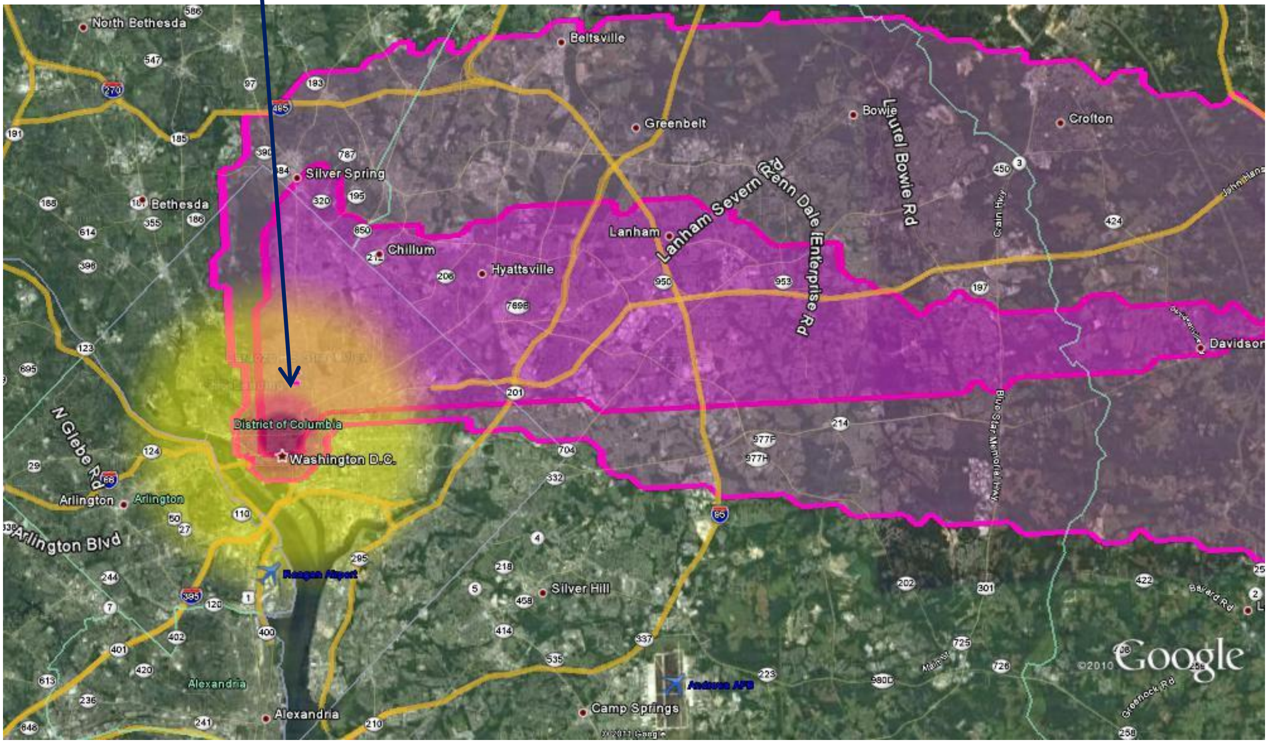


Example Neighborhood

To help illustrate the types of buildings that can be found in a typical Washington DC neighborhood, once again consider a neighborhood around Cardozo High School.

- This area is ~ 1.5 miles from the detonation and in the light damage zone.
- The area is also located in the dangerous fallout zone (DFZ).

Location of Cardozo High School



Fallout Exposure Reduction

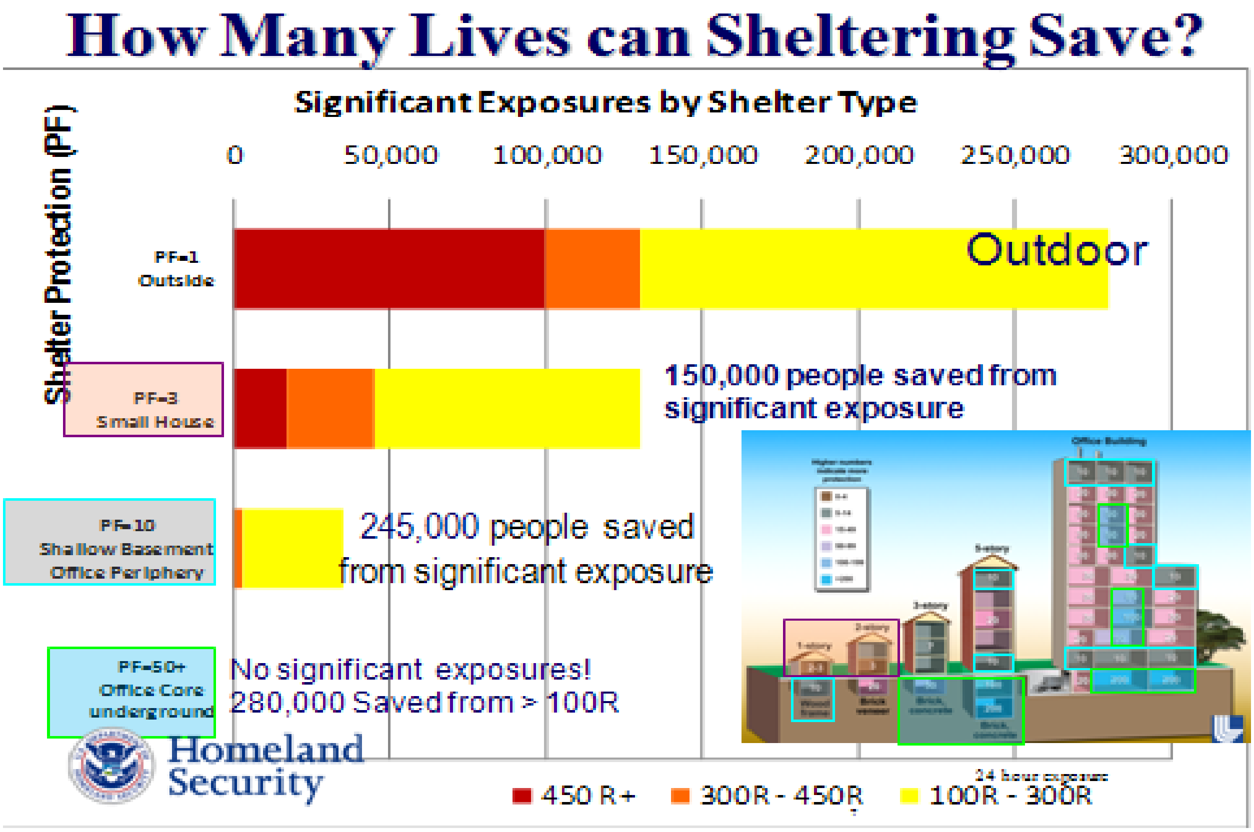
For anyone standing outside in the first 12 hours following detonation, their dose rate would be 2,000 rem. As shown in the image below, a dose that high would be enough to almost certainly kill you.

- If the only available shelter was a 1- or 2-story wood-frame house with no basement, there would still be a reduction in dose. However, at this particular location, it is not enough to prevent a significant exposure.
  (Note: single-story wood-frame houses are rare in this DC neighborhood.)

- Those seeking shelter in a brick residential location, like the brownstone row homes pictured, or smaller commercial facility could find protection factors of up to 50.
  - Top floor: PF of 5 to 15
  - 1st and 2nd floor: PF 10 to 50
  - English basement: PF 20 to 50

  People in these types of structures would have survivable exposures.

- Those finding shelter in a large, multi-story commercial building, such as the high school, would have a radiation dose so minimal that they would not likely experience any acute symptoms from radiation.

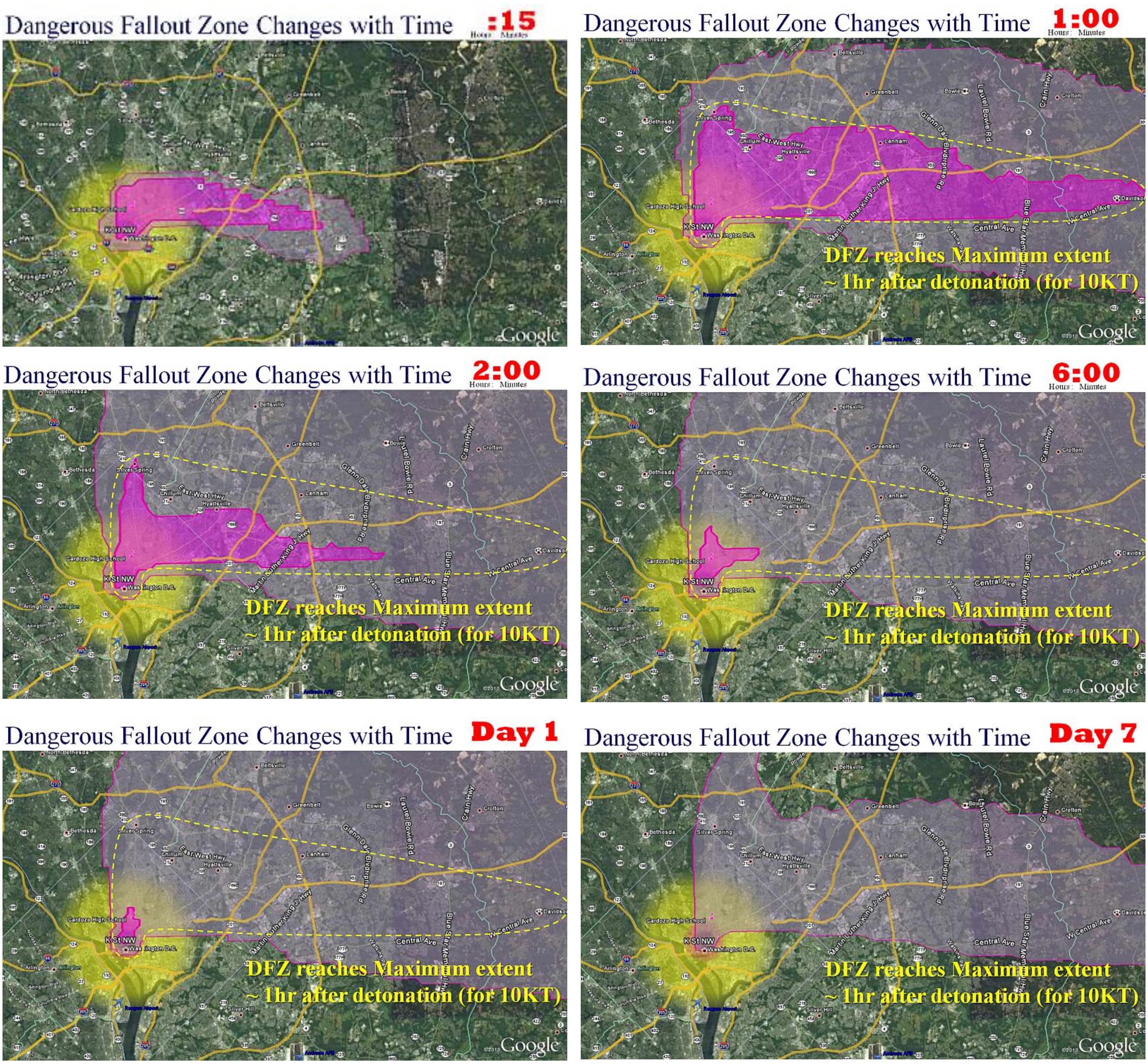


Sandia National Laboratories conducted an analysis of potential exposures from a variety of sheltering options for the first 24 hours after detonation of a 10-kT device. The estimates shown here are only fallout injuries for those located outside the moderate damage zone.

- If everyone in this area just stood outside (PF = 1) for the first 24 hours, ~280,000 people would receive enough radiation exposure to either make them sick (yellow/orange) or kill them (red).
- Even if everyone went into an inadequate structure such as a car or small house (PF = 1 to 3), 150,000 people would be saved from significant exposure levels.
- If everyone entered a “just adequate” shelter (PF = 10) like a shallow basement, 245,000 people (out of 280,000) would be saved from significant exposure. The 40,000 remaining exposures would fall into the “sick, but not dead” category. This is why PF = 10 is considered adequate.
- If everyone could get into the core of an office or an underground basement (PF = 50+), there would be no significant exposures to deadly radiation levels.

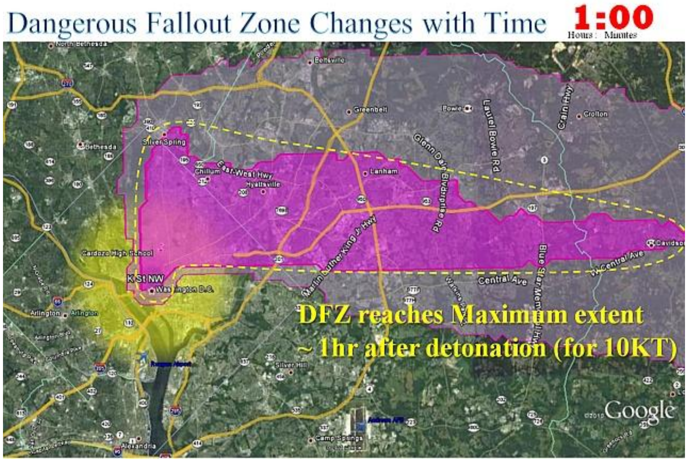
Dangerous Fallout Zone Changes with Time

- Here are the DFZ and Hot Zones 15 minutes after detonation.
- For a 10-k, the DFZ reaches its maximum extent after about 1 hour.
- The yellow border represents the max extent of the DFZ. Notice what happens as time progresses. The DFZ continues to shrink, and after a few days the zone disappears**.**



Dangerous Fallout Zone Changes with Time

The key question is: "how long should people remain in their shelter?"



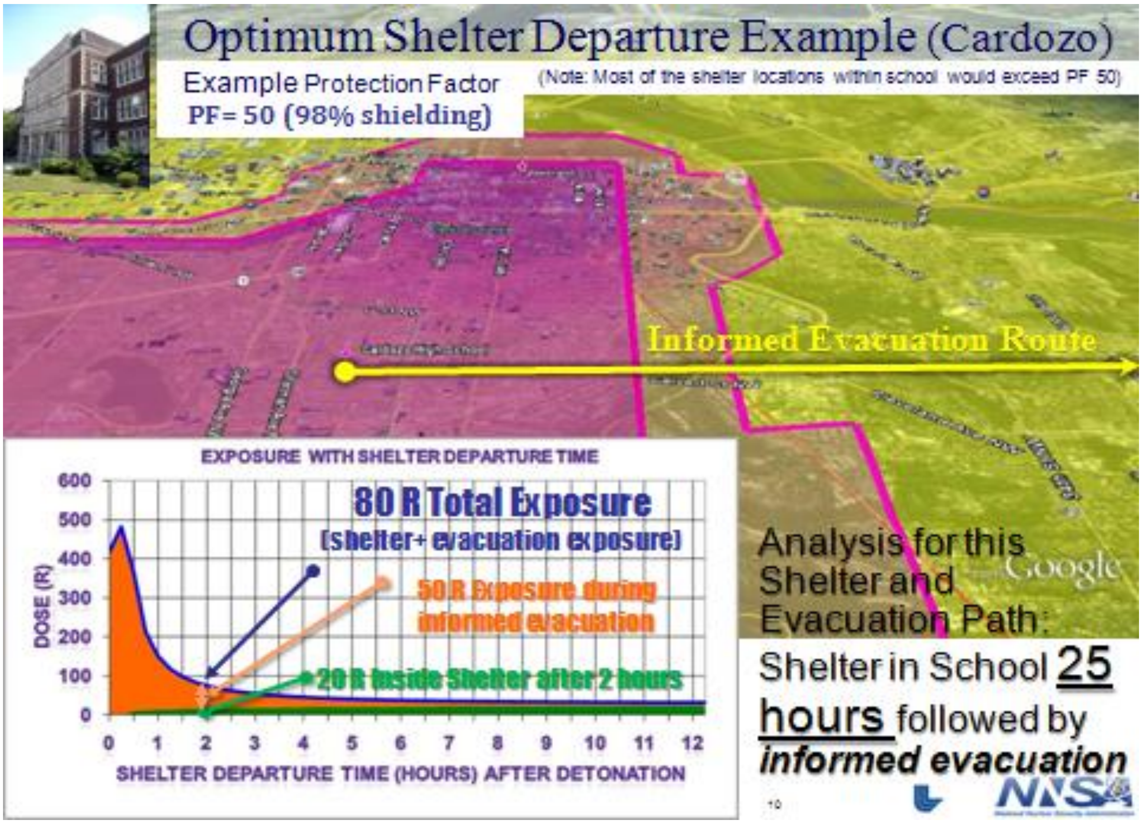
Example of Optimal Shelter and Departure

Most people in the DFZ will likely receive some exposure to fallout; this is, unfortunately, unavoidable. However, knowing how long to shelter and the direction to evacuate can greatly lower exposures.

The example, below, presumes an informed evacuation. Here, the best possible route out of the area is west, across Rock Creek Park. Unfortunately, victims in this area would not know that without outside help because other routes (away from the blast, to the north) would seem equally viable. However, the result would be much higher evacuation exposures.

Example of Optimal Shelter and Departure–continued

The graph below shows the total radiation dose received by someone sheltering inside a school with a PF of 50 (98% shielding). Dose rates would continue to rise, depending on how long a person remained inside the school.



Orange on the graph represents the additional exposure a person would receive while trying to evacuate the area **at the time specified.**

Notice how high the evacuation dose is if the person were to leave in the first hour. The reason is that evacuation occurs while radiation levels are highest outside.

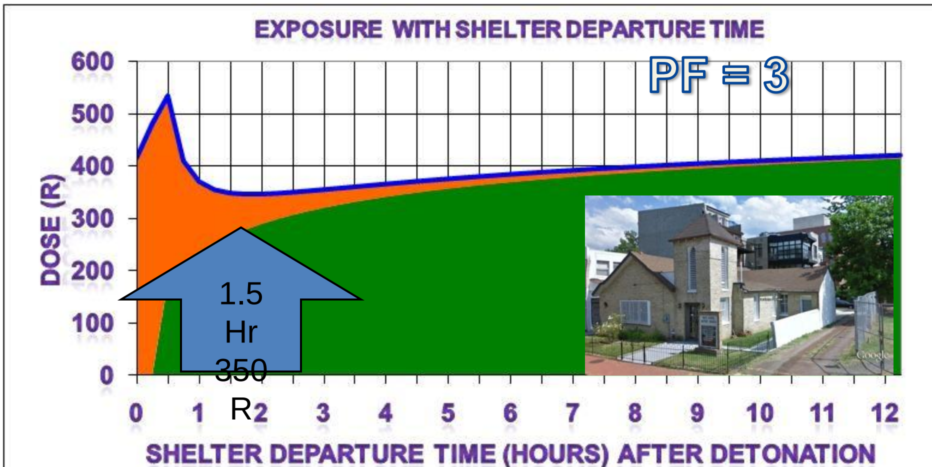
By waiting 4 hours to evacuate (the optimal departure time in this case), the person receives the lowest possible dose of radiation.

Although there is an apparent minimum dose around 4 or 5 hours, the slight increase in exposure with time after this point is minimal compared with the hazards of early evacuation.

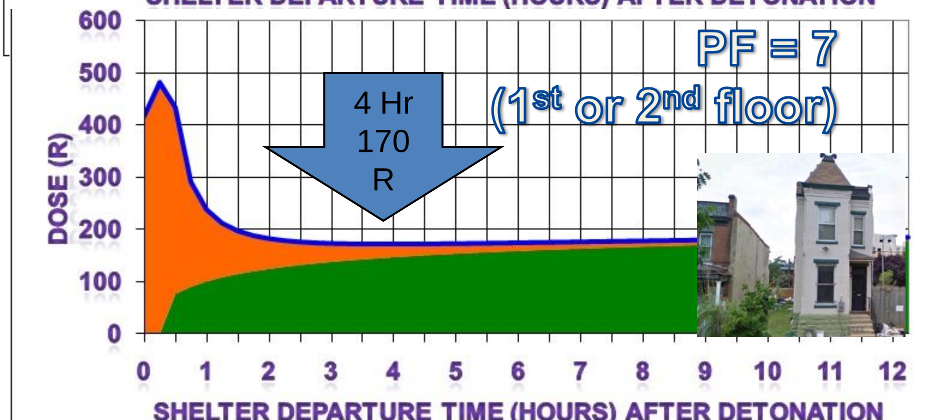
Optimal Shelter Departure Time
Depends on Shelter and Evacuation Route

When to evacuate a shelter depends on how much protection a person receives from the structure and how long it takes an average person to complete the evacuation route. Knowing the answer to both questions is crucial to creating informed evacuation routes.

In this example, the wood-frame house offers poor protection. Although it reduces outside exposure by a factor of 3, it is still not enough to warrant staying in the structure for very long. In fact, if the opportunity arises a person should consider moving to a structure with more shielding.

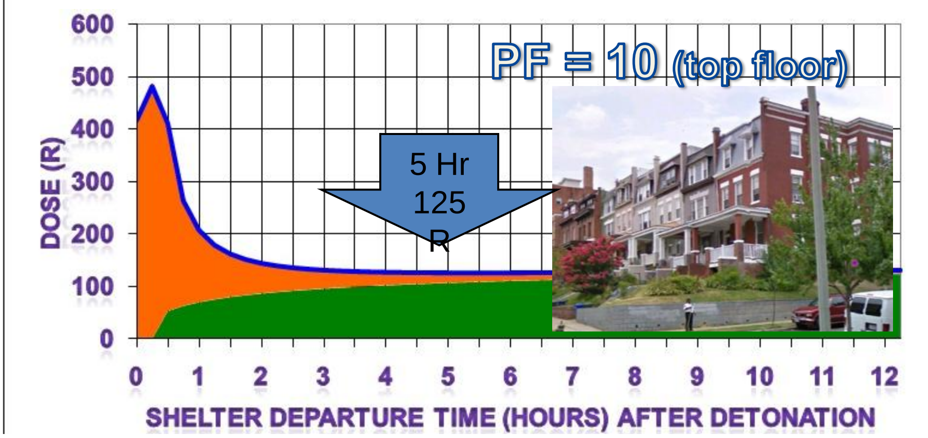


An inadequate shelter (2-3 story, stand-alone, residential house with no basement) might only offer a PF of 7, which would have an optimized evacuation of 4 hours.



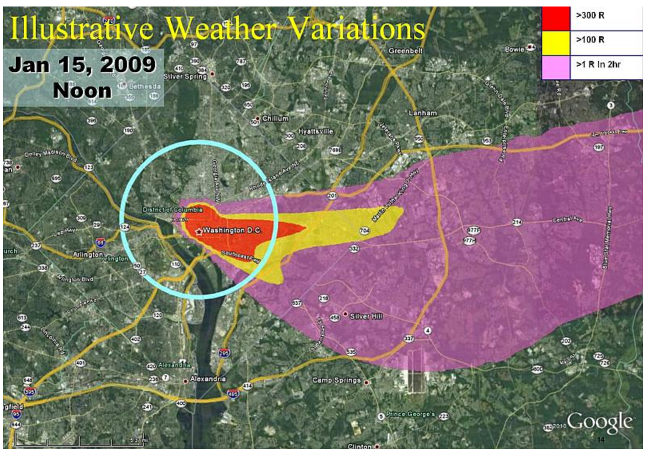
Although Brownstones offer a PF greater than 10 in the middle floors or English basement, a PF of 10 (adequate shelter) was considered for this analysis and resulted in a 5-hour departure time.

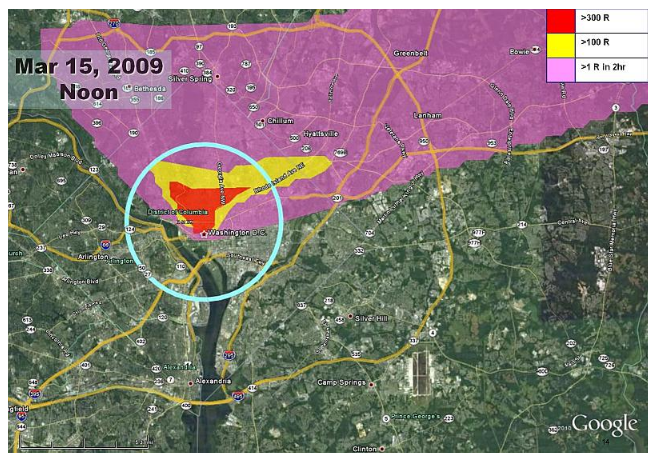
Note: whether a person waits for 5 hours or 3 days, the difference in exposure is slight compared to the dangerous evacuation doses received in the first few hours.

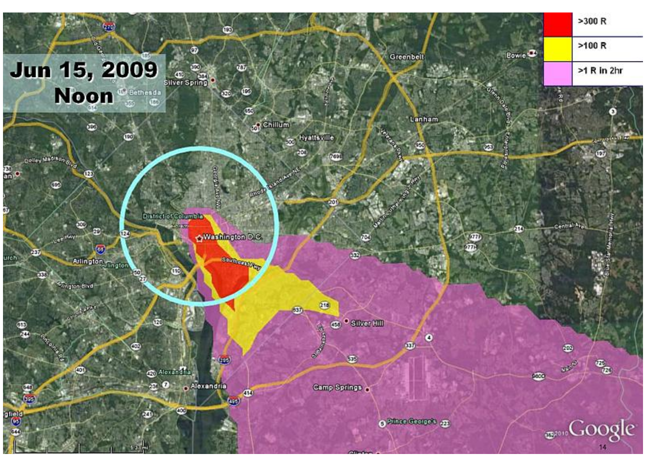


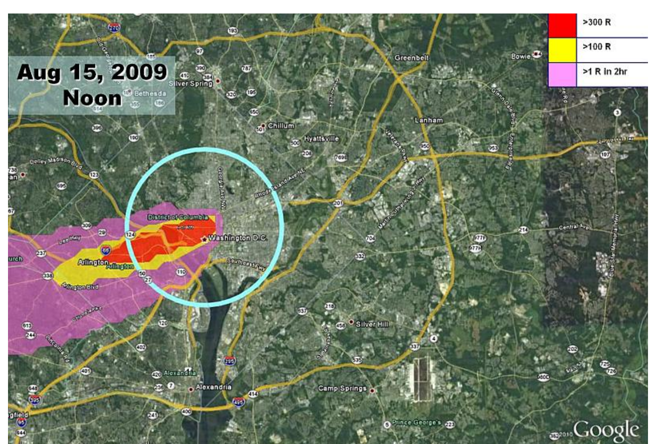
Weather Matters

Remember that no IND response can be completely preplanned. Weather and yield will greatly affect the direction, extent, and shape of the fallout pattern. As can be seen by the images below, which illustrate fallout patterns from a 10-kT modeled detonation using weather in the NCR on the 15th day of four months in 2009, weather effects can be highly variable.









Preliminary Shelter and Evacuation Analysis

Spending the first hour in an urban shelter (multi-story building) can keep exposures nonlethal. For anyone who can seek some type of shelter, the chances of significant, deadly radiation exposure levels is dramatically reduced.

Determining informed evacuation routes and optimum length of shelter stay depends on shelter quality and time required to evaluate the area.

Depending on what type of shelter a person is in, certain guidelines should be followed. An individual should spend:

- The first few hours in a poor shelter (small homes without basements).
- Several hours to a day in moderate shelters (residential basements, office buildings, or small commercial buildings).
- Several days in good shelters (underground garages, office buildings, or deep basements).

Additional and city-specific analyses must be performed, taking into account the types of structures available and ease of evacuation to be used for planning purposes.

Check Your Understanding

1. What is a protection factor and how is it used?

2. When are the radiation levels highest outside?

3. What does the optimum shelter departure time depend on?

4. What is the best action to take to avoid lethal radiation exposure?

5. How and why does the weather matter?

Notes

Response Strategies to a Nuclear Detonation

Emergency Alerts

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 way to reach people closest to and directly downwind from the nuclear explosion.

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.

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

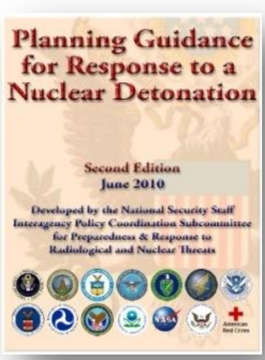
Planners should select individuals with the highest public trust and confidence to deliver messages. They should be prepared to deliver key information almost immediately to the public in affected areas about protection to maximize lives saved.

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.

For more information and sample messages, please read Chapter 6 of the *Planning Guidance*: Public Preparedness–Emergency Public Information.



Zone Recognition

Recognize the Severe Damage Zone (SDZ) in these ways:

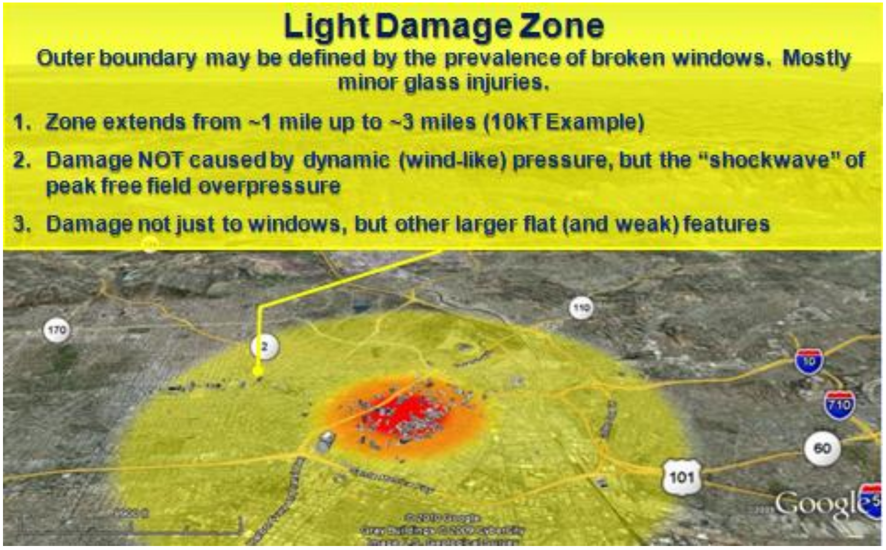
- Few, if any, buildings are expected to be structurally sound or standing.
- Few people would survive; however, some individuals protected within stable structures (e.g., subterranean garages or subway tunnels) at the time of the explosion may survive an initial blast.
- Very high radiation levels and other hazards are expected, significantly increasing risks to survivors and responders. Responders should enter this zone with great caution, only to rescue known survivors, and with appropriate radiation monitoring equipment.
- Rubble in streets is estimated to be impassable in the SDZ making timely response impracticable.
- The SDZ would have a radius on the order of a 0.5 mile (0.8 km) for a 10-kT detonation. Blast overpressure in the SDZ is expected to be 5 to 8 psi or greater.

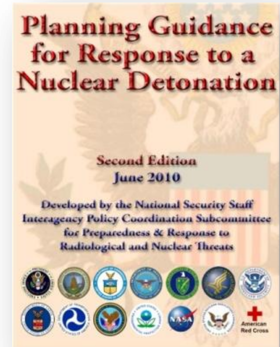
Recognize the Moderate Damage Zone (MDZ) in these ways:

- Responders can expect to transition into the MDZ when building damage becomes substantial. Damage may correspond to a distance of about 1 mile (1.6 km) from ground zero for a 10-kT nuclear explosion. The determination is made by ground-level or overhead imagery, or both.
- Observations in the MDZ include significant structural damage, blown out building interiors, blown down utility lines, overturned automobiles, caved roofs, some collapsed buildings, and fires. Some telephone and street light poles will be blown over. In the MDZ, 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 MDZ, rubble will completely block streets and require heavy equipment to clear.
- Within the MDZ, broken water, gas, electrical, and communications lines are expected, and fires will be encountered.
- The MDZ is expected to have the highest proportion of **survivable victims** requiring medical treatment.
- The MDZ poses major 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, along with sharp metal objects and broken glass, for which consideration and planning are needed.

Excerpts from *Planning Guidance for Response to a Nuclear Detonation* (June 2010).

Zone Recognition





Excerpts from *Planning Guidance for Response to a Nuclear Detonation* (June 2010).

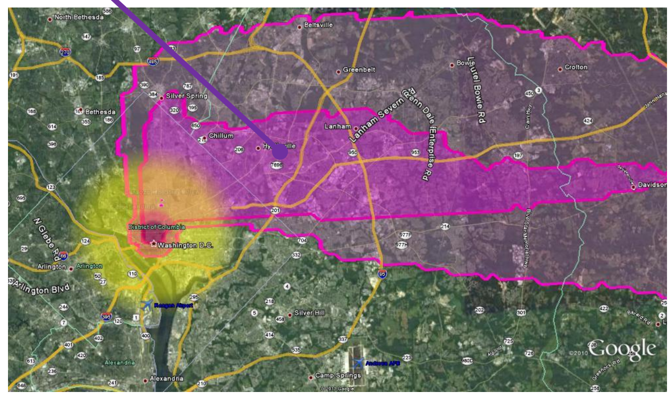
Recognize the Light Damage Zone (LDZ) in these ways:

- 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 more than 10 miles (16 km) away, the injury associated with flying glass will generally occur at overpressures above 0.5 psi. Such damage may correspond to a distance of about 3 miles (4.8 km) from ground zero for a 10-kT nuclear explosion. Damage in this area will be highly variable as shock waves rebound many times off buildings, 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, making emergency vehicle passage difficult.
- Blast overpressures that characterize the LDZ are calculated to be about 0.5 psi at the outer boundary and 2 to 3 psi at the inner boundary. More significant structural damage to buildings will indicate entry into the moderate damage zone.
- Much of the LDZ may be essentially nonradioactive. 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 LDZ.
- The severity of injuries responders will encounter in the LDZ should be relatively light and consist of mostly superficial wounds with occasional flash burns. Glass and other projectile penetrations are expected to be superficial (i.e., about ¼ inch in 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 as well as crush, translation, and tumbling injuries.

Dangerous Fallout Zone

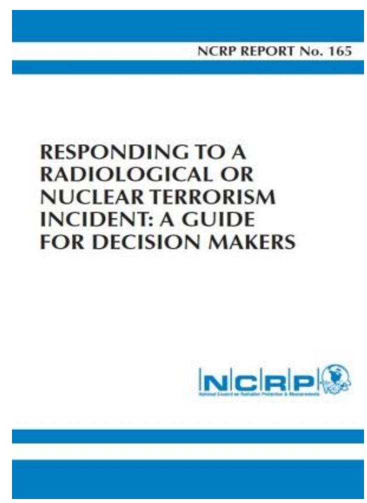
Here is some crucial information about the dangerous fallout zone (DFZ):

- **This zone is bounded by radiation levels of 10 R/hr.** Determining dose rates early helps to identify the **perimeters of the DFZ.**
- **The DFZ could reach 10 to 20 miles downwind before the decay of radiation causes the zone to shrink after about 1 hour.**

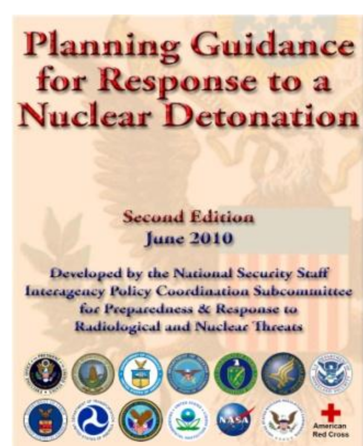


After establishing the perimeter of the DFZ, be aware that entering that area can cause acute radiation injuries or death. Responders should enter this area only voluntarily and only after being fully informed of the risks.

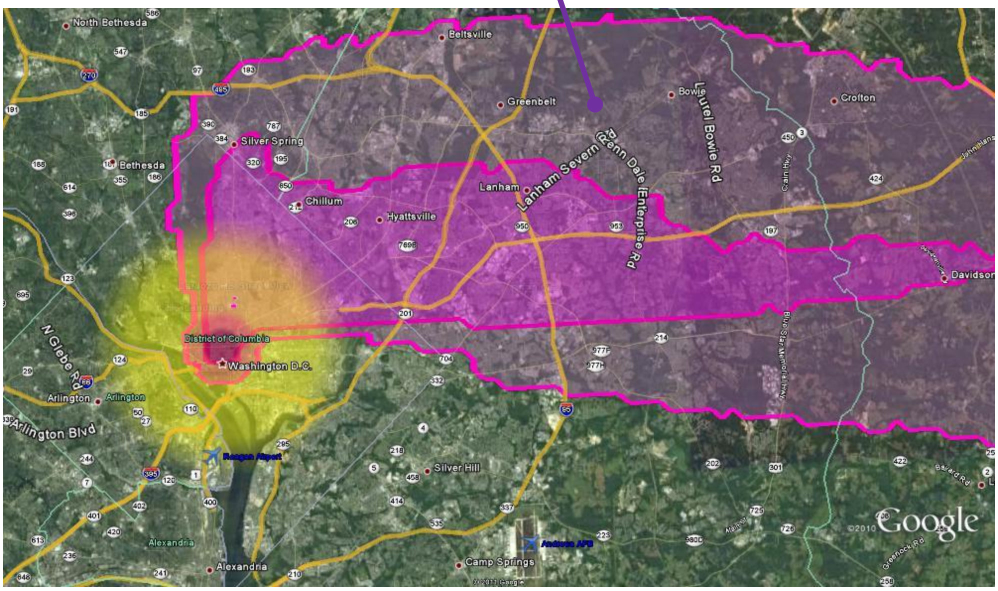
> "Identifying the dangerous-radiation zone [exposure rate ≥10 R/h] will have critical implications on response activities in or near fallout areas. The dangerous-radiation zone is an area where large doses could be delivered to emergency responders in a short period of time."
>
> *~National Council of Radiation Protection and Measurement, Report #165*



> 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.
>
> 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.
>
> *~OSTP, Planning Guidance for the Response to a Nuclear Detonation (2010)*



Hot Zone (Bounded by 0.01 R/h)

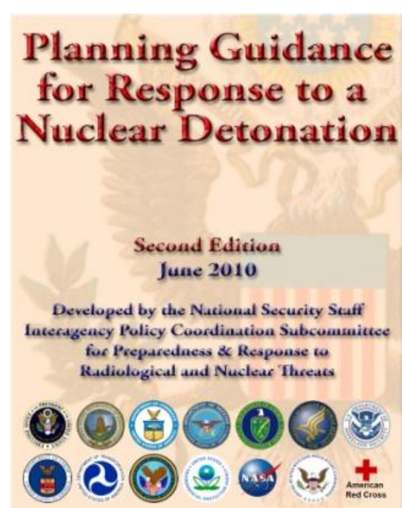


The 0.01 R/h boundaries, often referred to as the hot zone, are areas extending from the DFZ that have radiation levels of 10 mR/hr. This is only 1/1000th of the rate found in the DFZ.

For a 10-kT detonation, the hot zone could extend in several directions for hundreds of miles, but it will reach its full potential after one day.

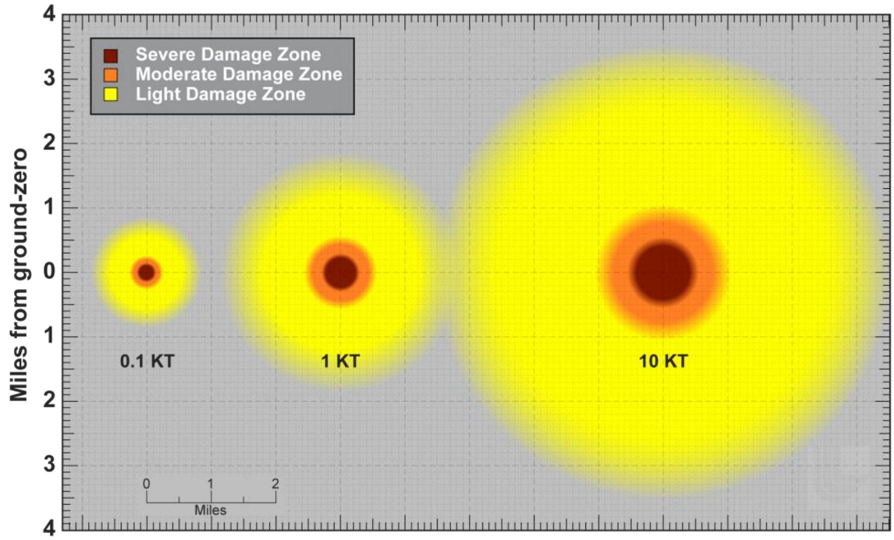
Response actions in hot zones will **not** result in exposures of 100 rem and higher (which have the potential of causing acute radiation syndrome). Caution should still be taken along edges of the Hot Zone closest to the DFZ.

> 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.
> *~OSTP, Planning Guidance for the Response to a Nuclear Detonation (2010)*



Damage Zone Ranges Change with Yield

The yield of an IND determines the area covered by each damage zone.

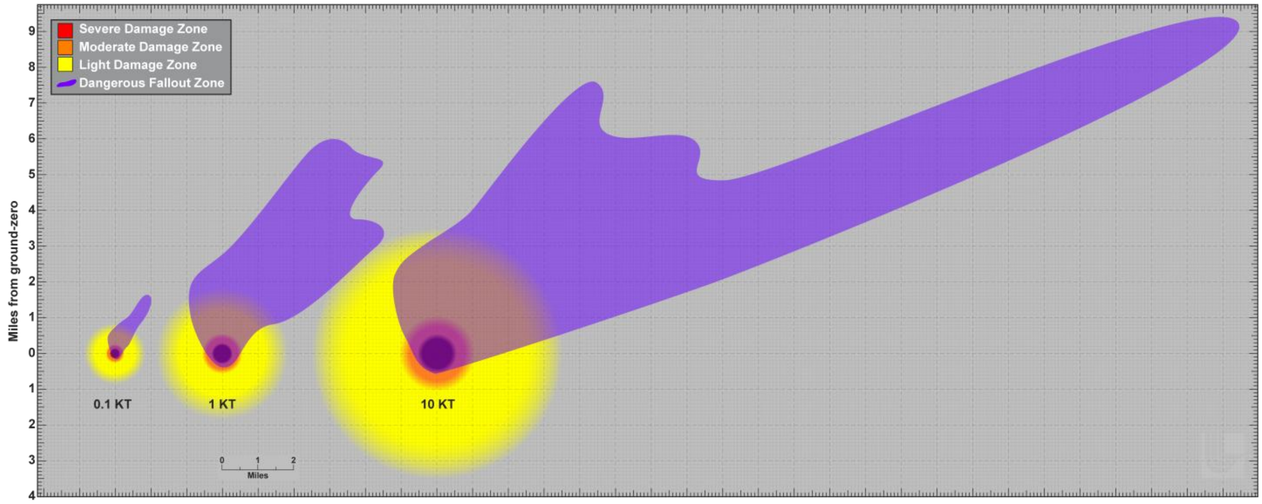


Radiation Hazards Take Precedence

When determining damage zones, radiation levels must also be taken into account. After determining the path of the dangerous radiation zone from fallout, certain rules apply, as follows:

- **The dangerous radiation zone from fallout will overlap damage zones.**
- **When zones overlap, radiation precautions take precedence.**
  Even if responders know there are victims within the moderate and light damage zones, they should not enter until dangerous radiation levels are no longer present.

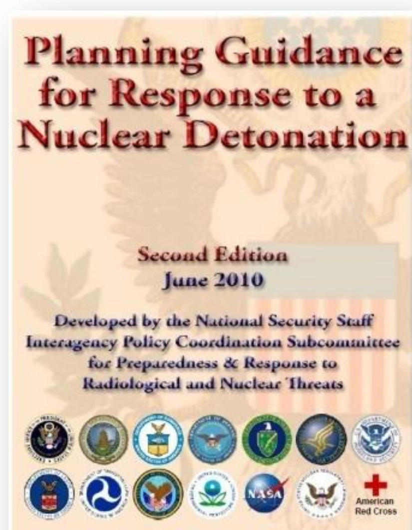
- **Initial efforts should focus on portions of the damage zones that are outside dangerous radiation areas.**
  Responders should initially wait to enter areas within the light and moderate damage zones, and focus on responding to areas outside of the DFZ.



Zone Priorities from the document, *Planning Guidance for Response to a Nuclear Detonation*

- Most of the injuries incurred within the LDZ are not expected to be life threatening and would be associated with flying glass and debris from the blast wave and traffic accidents.
- The benefits of rescue of ambulatory survivors in the LDZ 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, then proceed towards the MDZ where victim rescue will be needed most.
- The MDZ should be the focus of early life-saving operations. Early response activities should focus on medical triage with constant consideration of minimizing radiation dose.
- Response within the SDZ should not be attempted until radiation dose rates have dropped substantially in the days following a nuclear detonation, and the MDZ response is significantly advanced. All response missions must be justified to minimize responder risks based on risk–benefit considerations built into worker safety plans.

For more detailed information, read chapter 2A, Zoned Approach to Nuclear Detonation.



Priorities for Immediate Life Safety

The two most important aspects of a successful response effort are: **saving as many lives as possible** and **keeping responders safe.**

Public Protection Strategy

In the event of an IND, saving lives involves a set public protection strategy. To maximize life-saving potential, having everyone in the dangerous fallout zone seek immediate, adequate shelter followed by an informed, phased evacuation are the best courses of action.

Response Strategy

Response personnel need to take several critical steps.

1. Protect response personnel.
2. Support regional situational assessment.
3. Support public safety.

These topics are addressed in more depth later, but a key point is the priority order. An intuitive response might be to try and help nearby victims, but support to regional situation assessment can save far more lives in the long run.

Only emergency personnel can “size up” a scene. A regional size-up is required to define the zones that are critical for immediate action. Just as important is defining low radiation hazard zones and communicating the information to a central location so that outside response elements know where it is safe to initially provide assistance. With such information, the regionally coordinated response has the best potential to save and sustain lives and public safety.

Protecting Response Personnel

Once again, keeping responders safe allows response efforts to continue and as many lives as possible to be saved. Steps to protecting responders include:

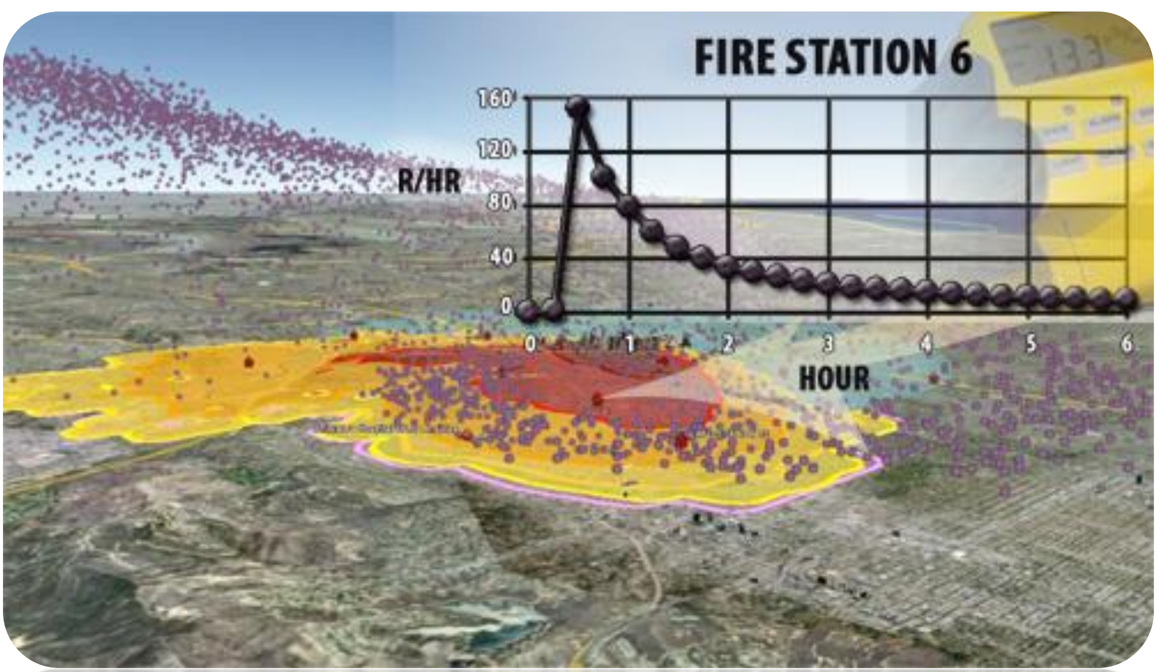
- **Responders without radiation detection instruments must follow the general public protection strategy:**

  ✓ Seek shelter and wait for informed evacuation instructions.

- **Responders with radiation instruments should shelter using radiation detection equipment to monitor shelter conditions:**

  ✓ **Do not exit …**
  Wait until radiation levels are below 10 R/hr, unless there is an immediate risk to safety, such as a fire or building collapse.

  ✓ **Provided outdoor …**
  When outside radiation levels are below 10 R/hr, responders can begin to perform scene assessment for hazards around their shelter.



Responder PPE

Self-contained breathing apparatus (SCBA); respirators; firefighter "turnouts;" and Level A, B, or C Hazmat suits do not protect against the primary hazard, which is the penetrating gamma radiation given off by fallout.

- Radiation/dose monitoring offers primary protection.
- Inhalation and ingestion are secondary concerns compared to external exposure.
- Turnouts and anti-contamination clothing can help ease decontamination after entries, but it cannot delay time-critical, life-saving activities.

Decontamination

Early, gross, dry decontamination, such as the actions used on soldiers who entered fallout-contaminated areas at the Nevada Test Site, is far more effective than delayed, full, wet decontamination used for hazardous chemical spills.

"Reducing the time spent in high dose-rate areas is the greatest protective measure. Bulky isolation suits and elaborate respiratory protection methods may actually increase exposure as they reduce speed, ability to communicate, and worker efficiency."

Key Response Planning Factors for the Aftermath of Nuclear Terrorism

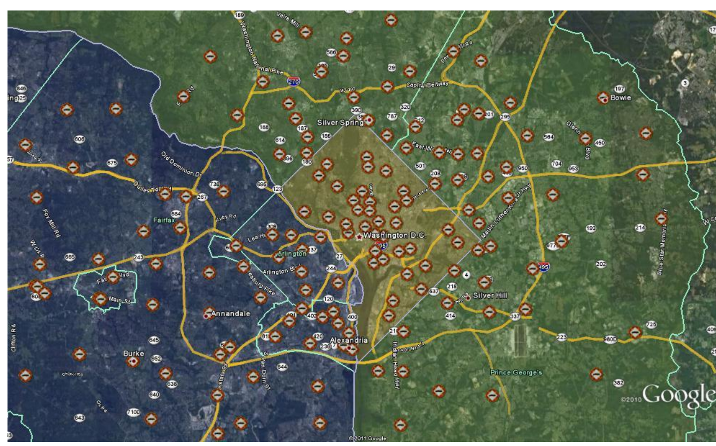
Support Regional Situational Assessment

Coordination can speed response efforts and prevent unnecessary harm. Coordination is aided through regional situation assessment and can be done by:

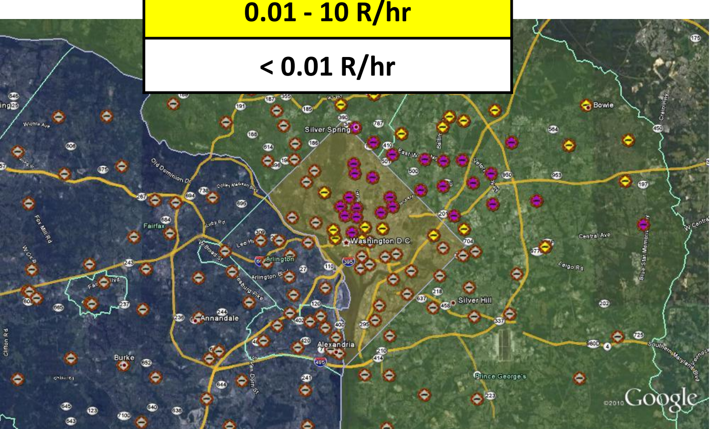
- **Designating a regional situational assessment center** outside the DFZ and away from other hazardous conditions.
- **Establishing communication with responders in the affected area** to provide and collect local hazard information and conditions for responders in all affected areas. Radiation readings from firehouses could inform regional situational assessments.
- **Report radiation levels in the area.** Responders in affected zones should continue to monitor outside dose rates until conditions are safe. Even those in safe areas (areas where radiation levels are below 0.01 R/h or 10 mR/hr) should report dose rates to help determine safe evacuation routes and response staging areas.

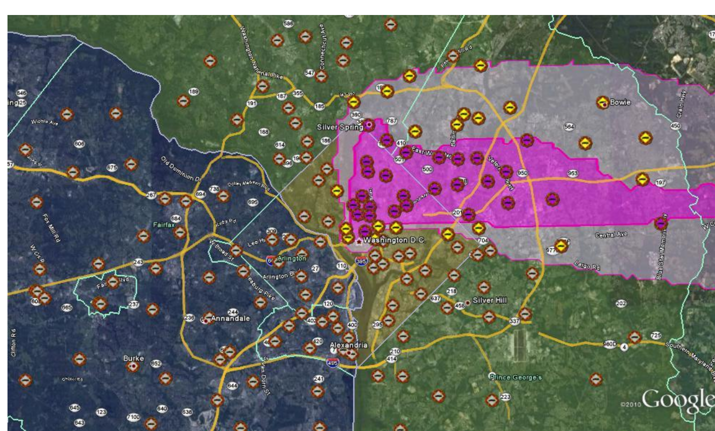
Example

The dots represent fire stations in the National Capital Region. By taking radiation readings at approximately 1 hour after detonation, a pattern can be determined. Even without modeling (shown at bottom, right), fire station measurements alone can successfully identify the DFZ and hot zone.



Radiation Readings at 1hr
> 10 R/hr
0.01 - 10 R/hr
< 0.01 R/hr





Support to Public Safety

Although “shelter-in-place” broadcast messages can begin immediately, most offensive response actions will require knowledge of the hazard zones, particularly the DFZ.

Once the DFZ is established, response actions can commence, such as:

- Establishing reception centers and triage sites for safe staging areas, extracting the injured, and firefighting techniques. Such steps make the best use of response actions.
- Directing response resources to the moderate damage zone to support extraction of the injured.
- Fighting fires and controlling hazards.

Some actions can be performed in the DFZ, but they require so much support that it is not an effective use of limited response resources.

Emergency Alerts

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 surrounding areas, including the most critical region for communications–the dangerous fallout zone.

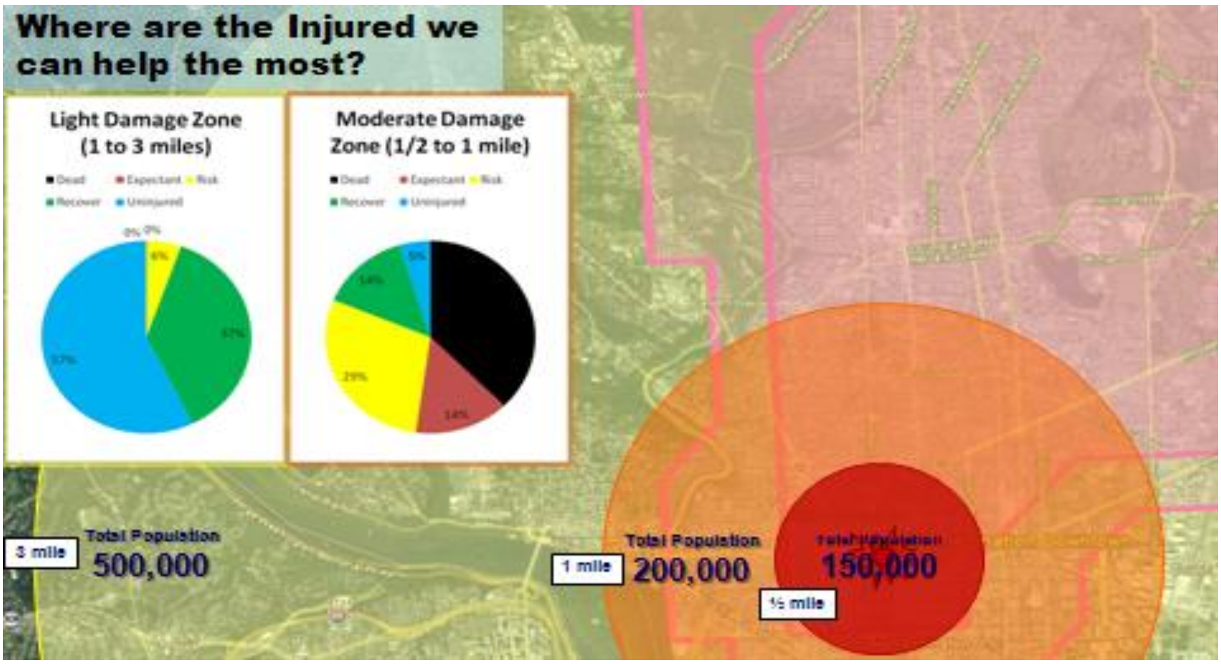
Planners in adjacent communities should collaborate in advance to determine the assets necessary to reestablish communications after a nuclear detonation. They should also identify and remedy gaps in their capabilities.

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.

Offensive Response

In the moderate damage zone (MDZ), the number of initial survivors would outweigh the number of prompt fatalities. About 30% of survivors will have an injury severe enough that they will greatly benefit from medical assistance.

In the light damage zone, most (~60%) of the population will be uninjured. Almost all of the remaining population will have relatively minor injuries (minor crush, glass laceration, and eye injures) and will survive without immediate care.



Initial Priority: MDZ

The MDZ should be the focus of emergency response efforts, with the goal of managing the scene through aggressive rubble removal and site access, fire suppression, and structural and utility stabilization to facilitate expeditious search and rescue and medical triage. Response planners should develop city-specific plans for MDZ response that includes:

- Establishing procedures that maximize rescue operations focused on survivable victims.
- Minimizing the total risk to responders.
- Organizing neighboring response units (and sharing such plans with 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 MDZ should be the focus of early life-saving operations. Early response activities should focus on medical triage with constant consideration of radiation dose minimization.

Offensive Response–continued

Secondary Priority

- Response within the SDZ should not be attempted until radiation dose rates drop substantially in the days following a nuclear detonation, and the MDZ response is well advanced.
- All response missions must be justified to minimize responder risks based on risk-benefit considerations built into worker safety plans.

Evacuation Considerations

Even during the initial and most dangerous phases of response, it is essential to avoid "tunnel vision" regarding the radiation hazard and to focus on all the life safety issues. In particular, it does no good to shelter from radiation if a shelter collapses or is on fire. Be sure that the public knows that other life-threatening hazards can take priority.

After the DFZ is established, evacuation planning can begin:

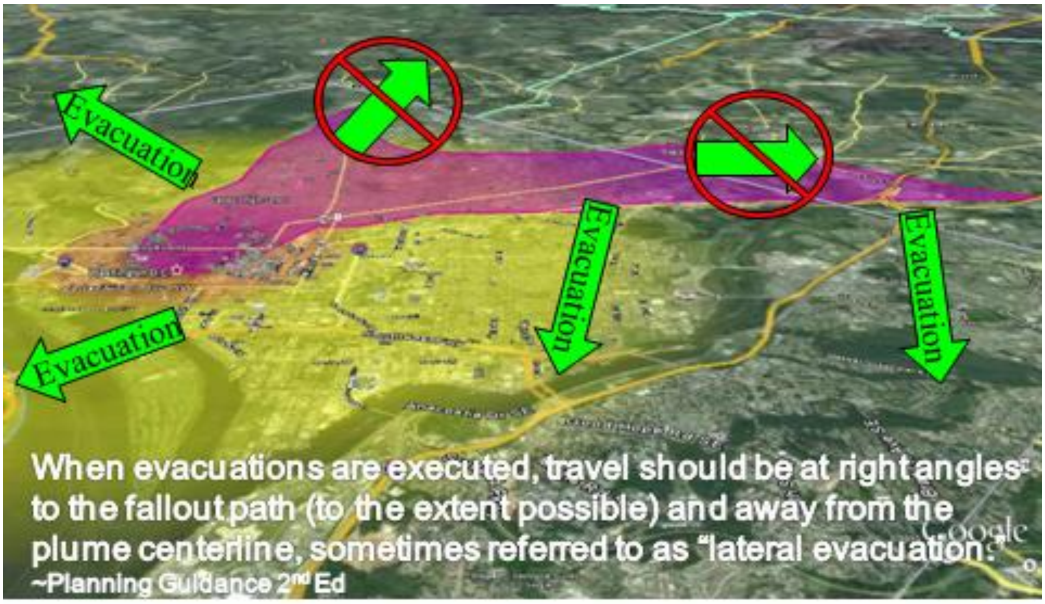
- Evacuation routes should be cleared if possible.
- Routes that take advantage of sheltered passage (subways, underground connectors, through building lobbies) should be used if possible.
- Execution should be phased to reduce time spent transiting through fallout areas.

Evacuation Planning

As stated in the *Planning Guidance*:

- 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."

- For more complex fallout patterns like the one pictured here, ensure that evacuations **do not** move people down the length of the fallout pattern or into another fallout contamination area.



Response Strategies: Conclusions

- **Protect the Response Force**
  - Identify protection strategy.
  - Identify early response priorities.

- **Local Emergency Management:**
  - Establish early public communication.
  - Rapidly identify the hazard zones.
  - Establish coordinated, safe evacuation routes.
  - Identify priority candidates for early shelter departure (i.e., those in inadequate shelters or threatened by other hazards).

- **The first hour is the most critical.**
  - The worst radiation doses will be received within the first hour following detonation of an IND. If everyone seeks immediate, adequate shelter, 100,000s of lives can be saved.

- **100,000s of people can be saved through proper action (both individual and leadership).**
  - If residents know they must seek adequate shelter immediately, many lives will be saved. After the detonation, leadership roles must be quickly established (preferably based on decisions made from prior response planning documents), and decisions about damage zones, the DFZ, and evacuation results must be made quickly.

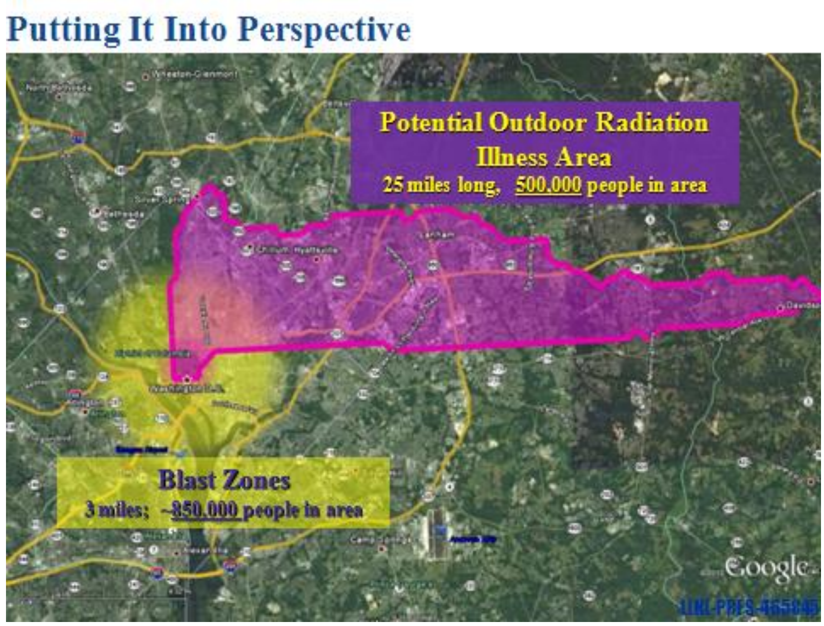
- **Situational awareness and communication will be difficult, but is essential**
  - Communication systems may be down following detonation. It is critical that the systems be quickly reestablished and responders know that the priority is to report radiation readings so that emergency broadcast messages can be made to the public. Everyone in a response capacity must be aware of their surroundings and realize that they may have to wait to initiate response until they are not in danger from radiation.

- **Knowing what to do before the event is critical.**
  - Prior response planning and training for responders and the public are the key to saving many lives after detonation of an IND.

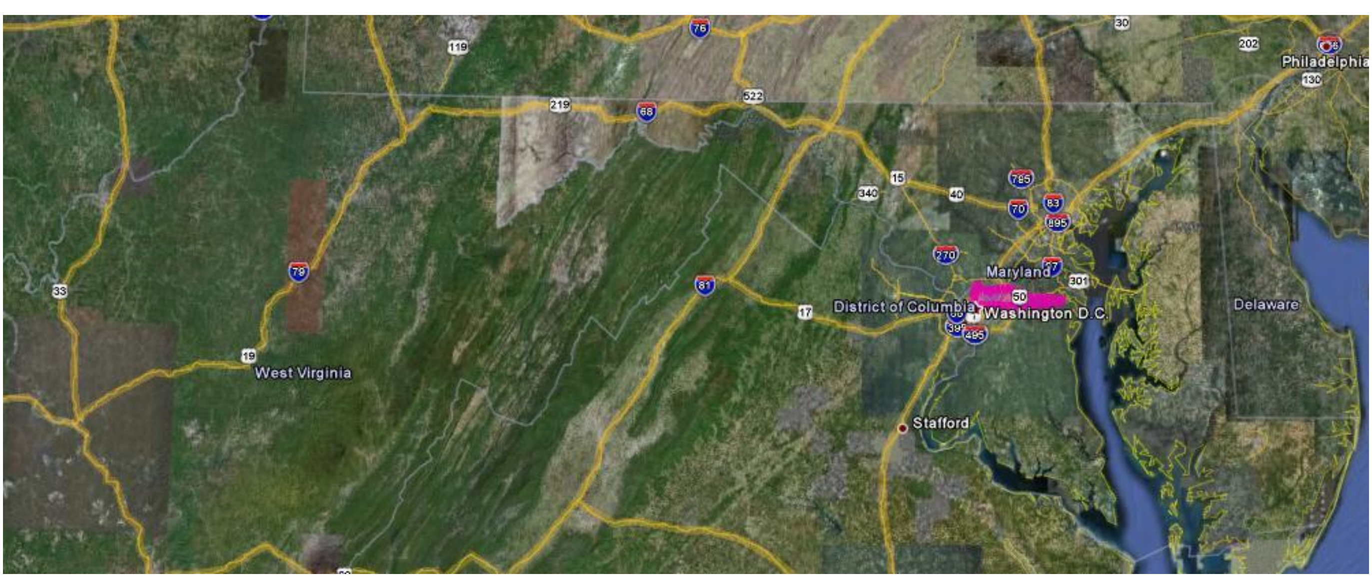
- **Rapid, independent responder actions are also key.**
  - Many responders may not be able to assist initially because of their locations within the DFZ. Other responders must be able to carry out actions when they are temporarily without leadership.

Putting it into Perspective

Review the areas that can lead to acute effects: initial blast zones where there could be injuries from flying glass and debris out to 3 miles, and the dangerous fallout zone, which could extend for 10 to 20 miles.



Looking at the big picture, the areas of potential injury are small compared to area resources. Although impacts will be devastating, the situation is not the “nuclear end-all” many people envision when they think about a nuclear bomb. Many resources in surrounding areas can safely help save and sustain lives if they know what to do!



Check Your Understanding

1. How (that is, by what physical features) can responders recognize the moderate damage zone (MDZ)? The light damage zone (LDZ)?

2. Name two resources for Planning the Response to a Nuclear Detonation?

3. Will dangerous radiation zones from fallout overlap damage zones?

4. What is the most important piece of personal protective equipment?

5. Is Level A Protection required for fallout?

6. What is the most effective decontamination technique for reducing exposure?

7. Which damage zone is the initial priority of Rescue activities?

8. Define “lateral evacuation.”

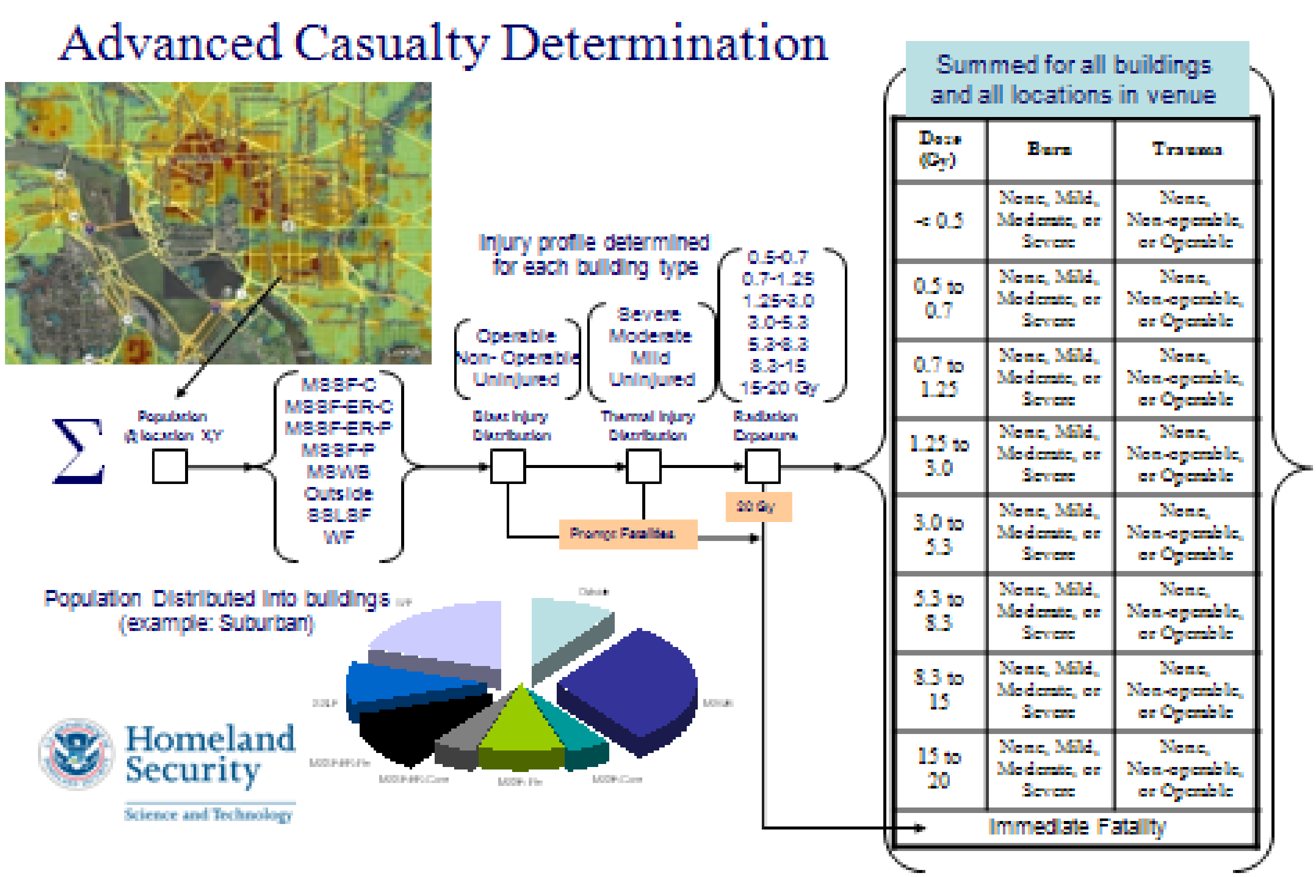
Notes

Advanced Casualty Analysis

DHS Science and Technology
Advanced Casualty Determination

Although blast, thermal, and radiation effects are often considered separately by experts, the consequences they create can affect the same population. To model medical countermeasures, the nature and types of injuries must be known for the affected population.

DHS Science and Technology undertook a detailed, block-by-block, injury analysis as part of an overall risk assessment. The impacts of an IND detonation were evaluated for the affected population by distributing people into likely structures for a detonation occurring during a typical workday. The effects of blast, thermal, and ionizing radiation were then calculated for each structure and population within the structure. Details on the types of injuries were sorted into 97 different casualty codes, which were then summed across all buildings in all locations in the venue.



Blast Effects and Injuries

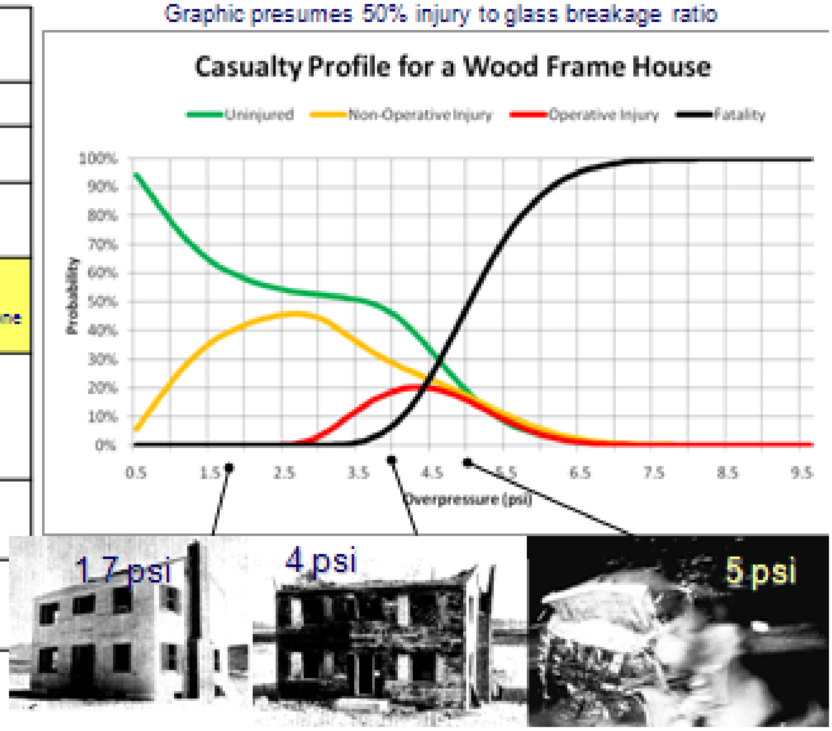
One poorly understood, long-range, prompt effect is glass breakage. Most injuries outside of the Murrah building in the 1995 Oklahoma City bombing were caused by this phenomenon. Extrapolating from recent work on conventional explosives, a 10-kT explosion could break certain types of windows (e.g., large, monolithic, annealed) from more than 8 miles away. We now know that glass can fail catastrophically even at extreme ranges, causing severe injury to those behind it. NATO medical response planning documents[2] 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." Many victims from Nagasaki arriving at field hospitals exhibited glass breakage injuries.

Previous models for human effects from blast stopped at 5 psi (the threshold for eardrum rupture), yet a house at 5 psi can be easily destroyed (see images below). An occupant in a house undergoing the destruction pictured might get more than an eardrum rupture. Advanced modeling now accounts for the collapse, severe damage, or glass breakage to structures and subsequent effects on occupants.

Accounting for Glass and Blast Injuries

Typical Overpressure Damage	
Psi	**Damage**
50	LD_{50} from Lung Damage
15	Lung Damage
5	**Eardrum Rupture** Brick houses destroyed; trucks overturned; telephone poles collapsed
3	Wall of 12-inch concrete shattered; parked aircraft destroyed
2	Aluminum panels ripped off
0.5	Windows shattered

Graphic presumes 50% injury to glass breakage ratio



Safety Solutions, posted 15 October 2005, "Preventing glass from becoming a lethal weapon." www.safetysolutions.net.au, Accessed November 1, 2007.
Applied Research Associates, Inc., 2004, Injury based glass hazard assessment: range-to-effect curves, Sponsored by U.S. Army Technical Center for Explosives Safety, DACA45-02-D-0004.
Akizuki, T., 1981, Nagasaki, 1945. Quartet Books, London, UK.

Burns: Secondary Effects

Although line-of-sight blockages in the modern urban environment will greatly reduce the number of burns from a ground-level nuclear detonation, numerous burns might still occur from secondary effects, such as house and vehicle fires. From information on burns caused by building collapse during earthquakes, an IND could result in 1,700 burn patients.

- 200 with mild burns.
- 650 with moderate burns.
- 900 with severe burns.

(information from Gryphon Scientific)

Radiation Injuries

Radiation exposure can cause acute radiation syndrome (sickness) or complicate other injuries. The table below helps put exposure numbers into perspective (*from NCRP Commentary No. 19 - Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism, 2005*).

TABLE 4.1—*Approximate acute death, acute symptoms, and lifetime fatal cancer risk estimates as a function of whole-body absorbed doses (for adults), for use in decision making after short-term[a] radiation exposure (adapted from AFRRI, 2003; Goans and Wasalenko, 2005; IAEA, 1998; ICRP, 1991; Mettler and Upton, 1995).*

Short-Term Whole-Body Dose [rad (Gy)]	Acute Death[b] from Radiation Without Medical Treatment (%)	Acute Death from Radiation with Medical Treatment (%)	Acute Symptoms (nausea and vomiting within 4 h) (%)	Lifetime Risk of Fatal Cancer Without Radiation Exposure (%)	Excess Lifetime Risk of Fatal Cancer Due to Short-Term Radiation Exposure[c] (%)
1 (0.01)	0	0	0	24	0.08
10 (0.1)	0	0	0	24	0.8
50 (0.5)	0	0	0	24	4
100 (1)	<5	0	5 – 30	24	8
150 (1.5)	<5	<5	40	24	12
200 (2)	5	<5	60	24	16
300 (3)	30 – 50	15 – 30	75	24	24[d]
600 (6)	95 – 100	50	100	24	>40[d]
1,000 (10)	100	>90	100	24	>50[d]

[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.

[c]Most cancers are not likely to occur until several decades after exposure; although leukemia has a shorter latency period (<5 y).

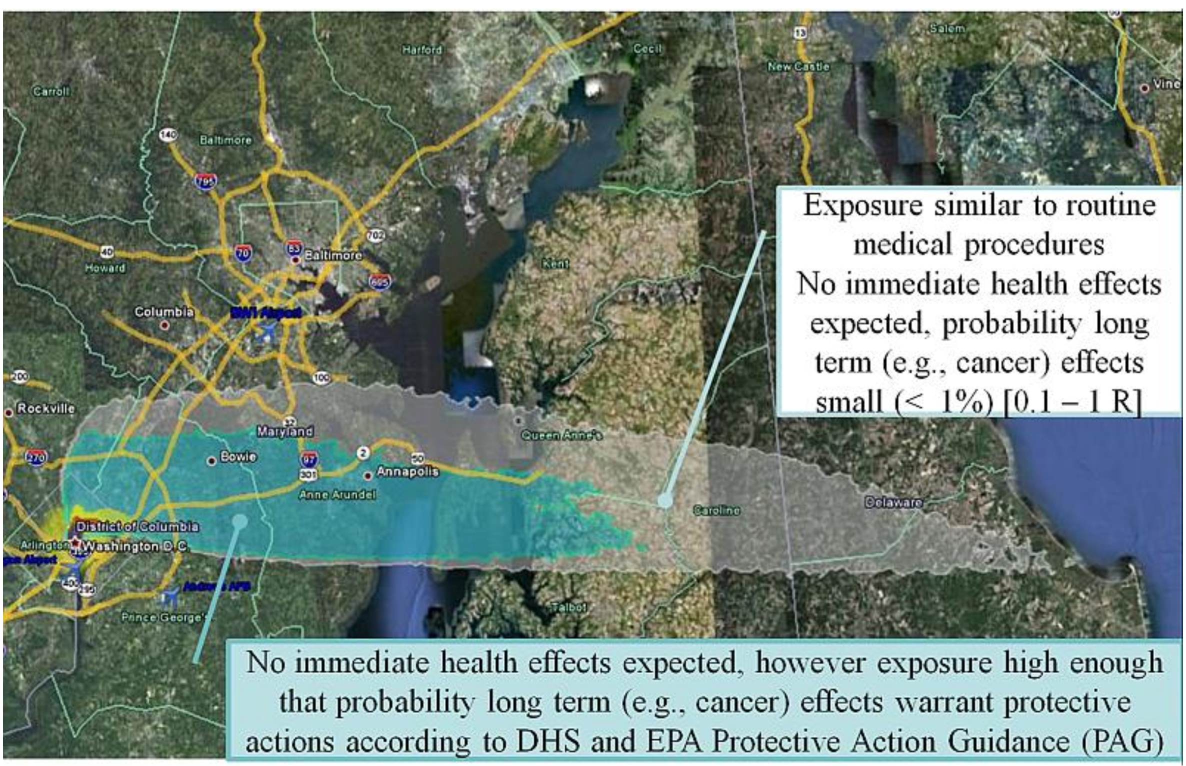
[d]Applies to those individuals that survive ARS.

Potential Fallout Exposure (First 2 Hours, Outdoors)

Long-Range Potential Health Effects

In this illustration, the whitened areas represent radiation-exposure levels that are less than Environmental Protection Agency (EPA) and DHS recommendations for shelter or evacuation (1 rem in 4 days), and the exposures would be similar to those expected from routine medical procedures. No immediate health effects would be expected, and the probability of long-term (e.g., cancer) effects is small (<1%). Even so, protective measures to reduce exposure will likely be performed as good ALARA practice (as low as reasonable achievable).

In the light-blue areas, no immediate health effects are expected; however, exposures would be high enough (1 to 100 rem) that the probability of long-term (e.g., cancer) effects warrants protective actions according to DHS and EPA Protective Action Guidance.



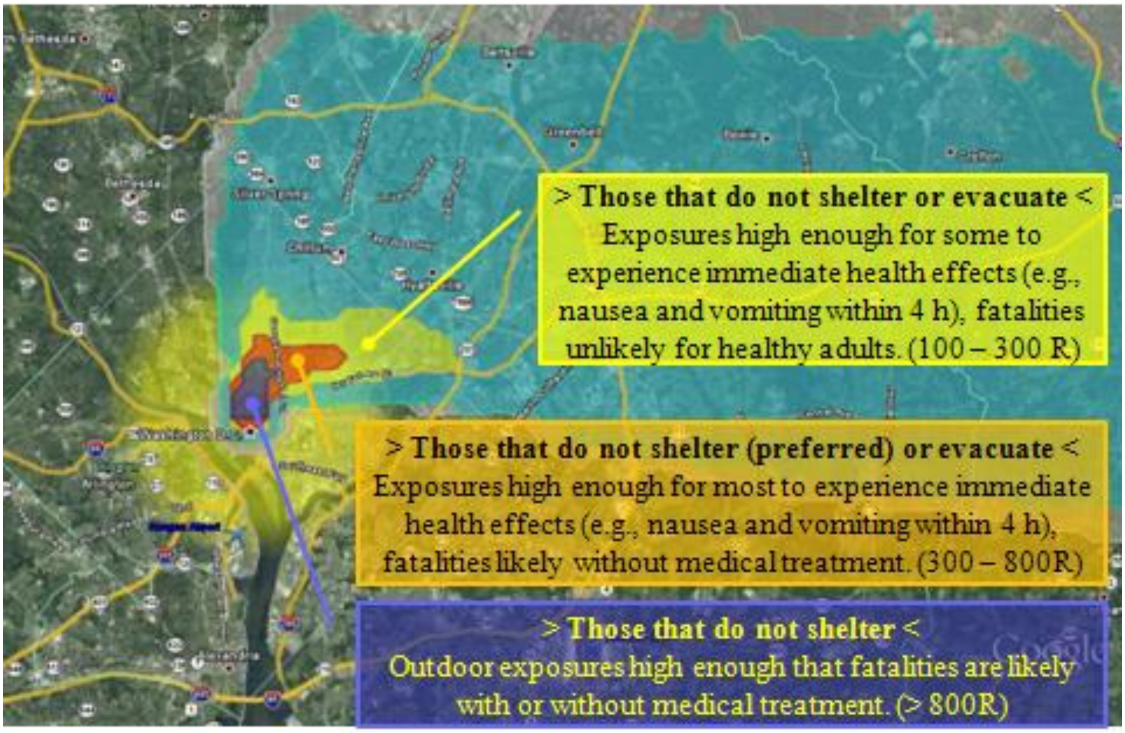
Potential Fallout Exposure (First 2 Hours Outdoors)– continued

Close-In Exposure Concerns

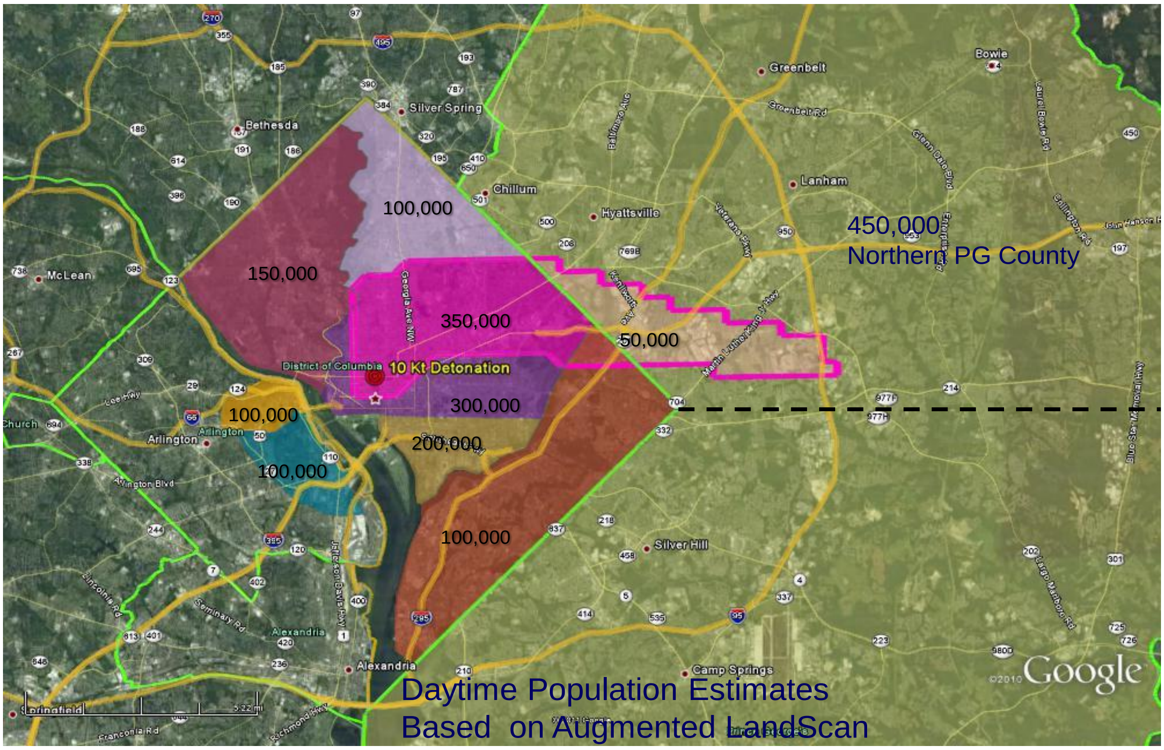
Within 10 to 20 miles of the detonation, exposures from fallout would be great enough to cause near-term (within hours) symptoms, such as nausea and vomiting. The irregular area in yellow (extending north and east of the orange area) represents an outdoor exposure of 100 to 300 R. This area is about 6 miles long, and exposures would have occurred early (within the first hours of fallout arrival), so evacuation would not be easy.

For those who do not shelter (the preferred action) or evacuate the orange area, exposures (300 to 800 R) are great enough for most to experience immediate health effects (e.g., nausea and vomiting within 4 hours). Fatalities are likely without medical treatment.

For those who do not shelter in the dark blue area, outdoor exposures (>800 R) are great enough that fatalities are likely with or without medical treatment. Evacuation is not an option here because fallout would arrive too quickly (~10 minutes) to evacuate.



Daytime Population in Potential Injury Areas



In key areas of the NCR nuclear scenario, the population is distributed as follows:

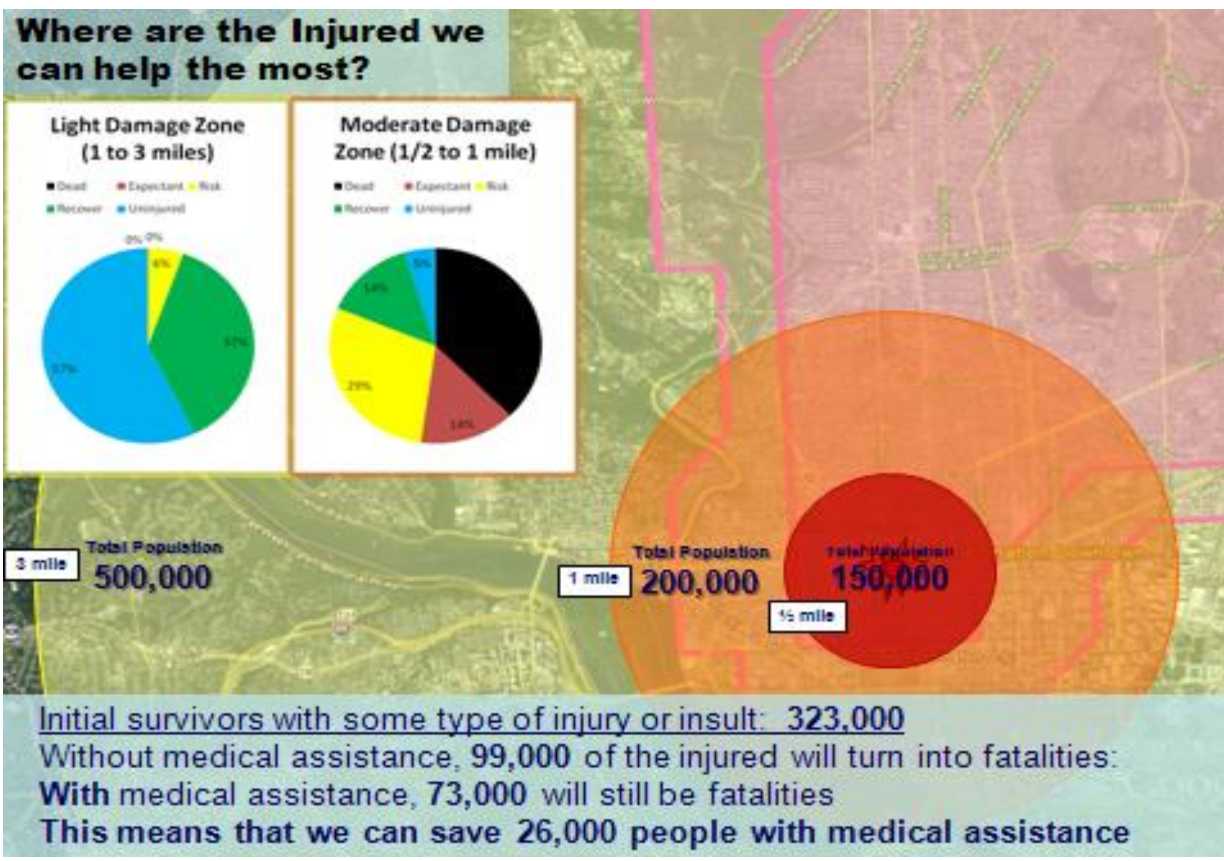
- The dangerous fallout zone has ~400,000 people.
- The light damage zone (1 to 3 miles) has ~500,000 people.
- The moderate damage zone (0.5 to 1 mile) has ~200,000.
- The severe damage zone (< 0.8 km) has ~150,000 people.

What Medical Assistance Can Offer

Although there were survivors directly under the Hiroshima detonation, the severe damage zone is not expected to have a significant fraction of survivors. However, in the moderate damage zone, the number of initial survivors outweighs the number of prompt fatalities. About 30% of the those survivors would have a severe enough injury that they would greatly benefit from medical assistance.

In the light damage zone, most (~60%) of the population would remain uninjured. Almost all of the remaining population would have relatively minor injuries (minor crush, glass laceration, and eye injures) and would survive without immediate care.

- Initial survivors with some type of injury or insult: **323,000.**
- Without medical assistance, **99,000** of the injured will turn into fatalities.
- With medical assistance, **73,000** will still be fatalities.
- **This means that we can save 26,000 people with medical assistance.**



NCR Injury Categories That Could Most Benefit from Medical Assistance

In analyzing the principal injury categories, three injury types comprise the largest number of victims who represent the largest life-sustaining categories.

Low exposure (<125 R), mild trauma = 175,000 people.
~4,000 of the ~5,000 potential fatalities can be saved with medical care.

In general, these individuals are located upwind of fallout but in the light or moderate damage zones (LDZ and MDZ). In the case of the NCR February 14 scenario, this means South and West DC and Virginia. Because the injury of concern is trauma, prompt medical support (in less than 12 hours) will be most effective. The number of potential mortalities is only 3% of the overall population in this category, so separating and saving the ones on a mortality trajectory may be difficult.

Moderate exposure (125 to 300 R), with and without mild trauma = 60,000 people.
~10,000 of the ~15,000 potential fatalities can be saved with medical care.

This category offers the greatest life-saving potential. Survivors will come from downwind areas in the dangerous fallout zone (DFZ), or often in the light damage zone (LDZ). Radiation levels are high enough to complicate an injury or recovery, but not so high as to be acutely life threatening. Because the primary mortality mechanism is complications (i.e., immune suppression) from acute radiation syndrome (ARS), medical care can be applied throughout the ARS stages to improve prognosis, even as delayed as weeks later. However, early intervention, especially with anti-neutropenics, can greatly improve outcomes.

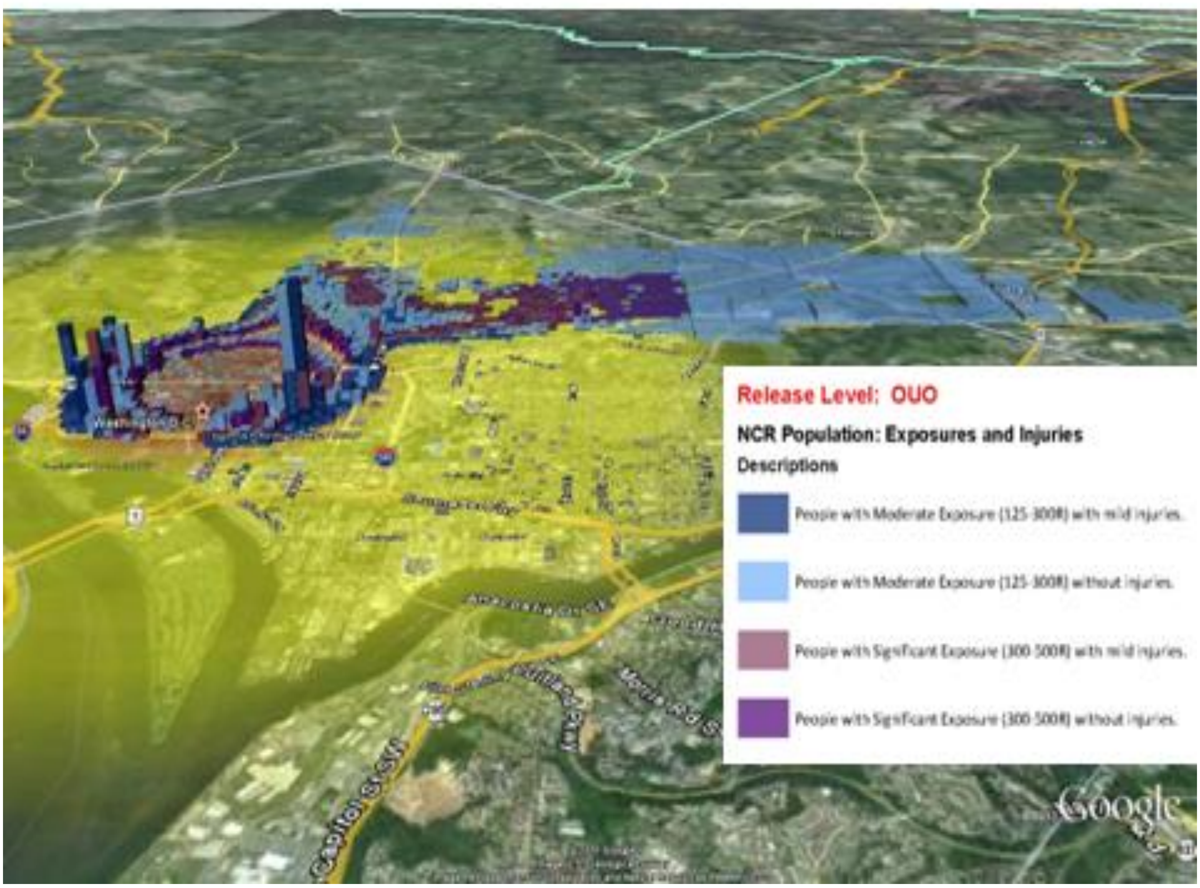
Significant exposure (300 to 530 R), with and without mild trauma = 33,000 people.
~10,000 of the ~25,000 potential fatalities can be saved with medical care.

These candidates come from areas where the DFZ overlaps the LDZ and MDZ.
Although this category has the potential for considerable life saving, the individuals will require sooner (less than 3 days) and more intensive care than those with less severe exposures, as described above. Even with advanced medical care, ~50% will perish.

Injury Categories That Could Most Benefit from Medical Assistance

This illustration is another way of showing where individuals with moderate (blue) and significant (purple) exposure would be located in the NCR scenario. **Projections assume 2 hours of outdoor fallout exposure**, much of which could be mitigated through the practice of shelter-in-place.

The height of each bar represents the number of injured at a given location. Such information reinforces the importance of rescue operations in the moderate damage zone.



Check Your Understanding

1. What type of human injury is likely to predominate following a 10-kT nuclear detonation?

2. What level of radiation exposure is high enough for most people to experience immediate health effects, such as nausea and vomiting within 4 hours?

3. As an aggregate, How many lives in the NCR could likely be saved through medical countermeasures after a 10-kT nuclear detonation if all the injured received timely care?

4. Which categories of injury (low, moderate, or significant) offers the greatest life-saving potential? In what blast zone would these people likely be located?

Notes