



# Student Guide: IND Prompt Effects Summary (National Capital Region)

Material Prepared for DHS FEMA by:  
Lawrence Livermore National Laboratory  
Send Comments and corrections to:  
[brooke2@llnl.gov](mailto:brooke2@llnl.gov)

This work performed under the auspices of the  
U.S. Department of Energy by  
Lawrence Livermore National Laboratory under  
Contract DE-AC52-07NA27344



LLNL-PRES-492023





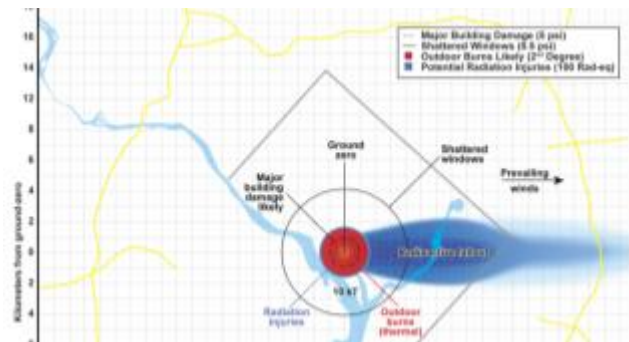
# Student Guide: IND Prompt Effects

## Defining Different Effects

Prompt effects are those effects that radiate outward from the detonation site. They include several effects:

- Light and thermal radiation
- Blast wave and shock effects
- Radiation given off during the criticality and first minute of fission products
- Electro-magnetic pulse.

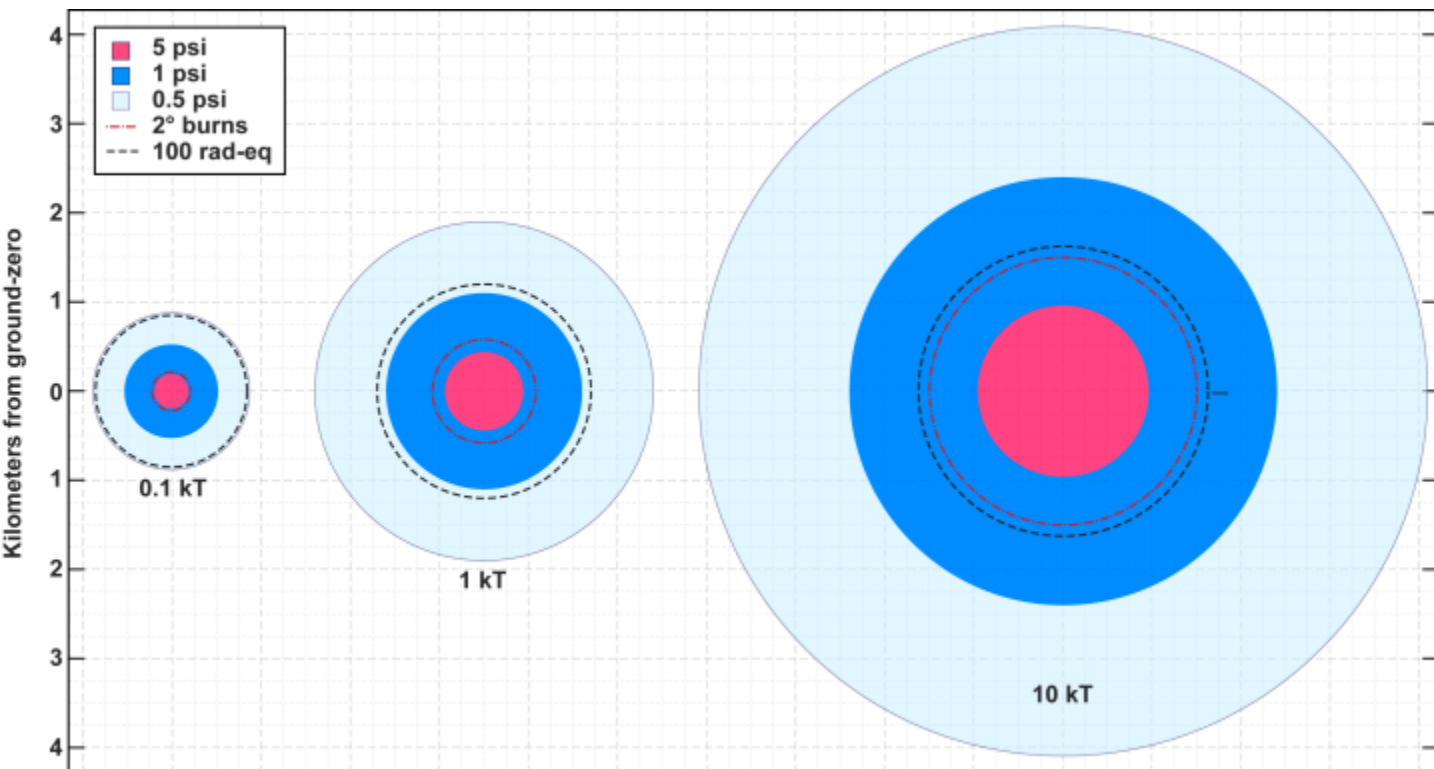
National Planning Scenarios #1 is a 10kT nuclear detonation in downtown D.C.



## Prompt Effects

What's important to remember is that **the magnitude and relative range of these effects change with yield.**

As you can see by the figures presented, the blast effects (the red, blue, and light blue solid colors) and the Thermal Effects (red dashed line) scale together with changing yield, however, prompt radiation effect ranges contract much more slowly with decreasing yield making prompt radiation the more dominant prompt effect at very low yields like 0.01kT. So the effects and the magnitude of those effects depends on the yield size.



# Student Guide: IND Prompt Effects



## NCR Example: Downtown 10kT

- The following slides represent the “prompt effects” in the scenario of a 10kT improvised nuclear device being detonated in downtown Los Angeles.
- There are a few important aspects of a downtown DC detonation that must be recognized.
  - A detonation of an IND would produce a flash of light that is equivalent to a thousand mid-day suns at a mile away
  - A 10kT yield is about equivalent to the explosive power of about 5000 Oklahoma City Truck Bombs
- For the Following Scenario:
  - The detonation took place on ground level at 1600 K St NW
  - The population estimates were based on a typical DC Workday
  - The weather profile was taken from actual weather conditions at noon on Feb 14, 2009
- While this information may seem specific, the information from these slides can be used to help response planning for other Tier 1 cities.



## Accidents and Congestion Caused by Flash blindness

- The bright flash would be able to temporarily 'blind' anyone who sees it, out to ten miles. This blindness may last for several seconds to a couple minutes. Not significant if you are standing on a street corner, but could be a significant issue if you are driving down the freeway.



- It can be expected that most roads within about a six mile range will be snarled with accidents and many injuries would occur.
- The potential for flash blindness would be worse at night time, and could cause accidents much further out.

## Damage Zones

• There are three major blast damage zones defined by the federal Planning Guidance for Response to a Nuclear Detonation that one should be aware of when assessing the best course of action following a nuclear detonation. Those three zones are:

- **Severe damage zone**
- **Moderate damage zone**
- **Light damage zone**

• The zones are defined by the amount of observable damage. To understand the damage zones, the definition of blast effects should be recognized. Blast effects are the damages/injuries done to structures/people following the detonation.

## Severe Damage Zone

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





## Outer Edge of Severe Damage Zone

As an example of types of effects that might be seen in the severe damage zone, the pictures shown below are from a test detonation in the Nevada Desert. They demonstrate the damage done to buildings near the severe damage zone.

If there is 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.

The images below are a good estimate of what might occur on the outer edge of the Severe Damage Zone.

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



Nighttime shot, the only light is from the blast



Thermal pulse ignites paint and wood

Pressure wave destroys house



# Student Guide: IND Prompt Effects

## Underground Infrastructure 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 Laboratories using data from nuclear tests at the Nevada Test Site and extrapolation from earthquake damage of the effects on these systems indicate that:

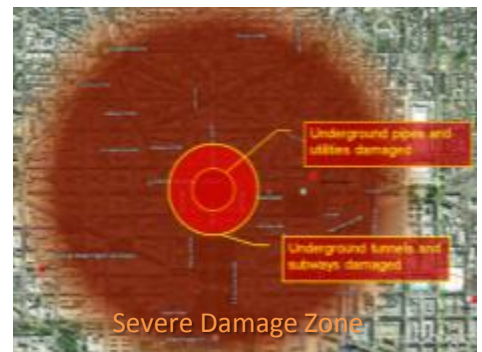
Water, power and Telecommunication conduits may be damaged out to 120 meters from a 10 kT surface detonation.

Larger tunnels, such as subway systems may be damaged out to 250 meters (~ 2 city blocks) from a 10kT.

**Since the Severe Damage Zone extends ~ ½ mile (~800m), this means that the primary underground infrastructure damage is contained by the Severe Damage Zone**



Collapsed tunnel for the Nevada Test Site



### References

- T. N Dey and R. J. Bos, Underground Infrastructure Damage for a Chicago Scenario, LA-UR-11-00566
- Hiroyuki KAMEDA, "ENGINEERING MANAGEMENT OF LIFELINE SYSTEMS UNDER EARTHQUAKE RISK," Proceedings of The 12th World Conference Earthquake Engineering, 2000
- Chapter 8 of **Effects of Nuclear Earth-Penetrator and Other Weapons** Committee on the Effects of Nuclear Earth-Penetrator and Other Weapons, NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMIES, THE NATIONAL ACADEMIES PRESS, Washington, D.C., 2005.



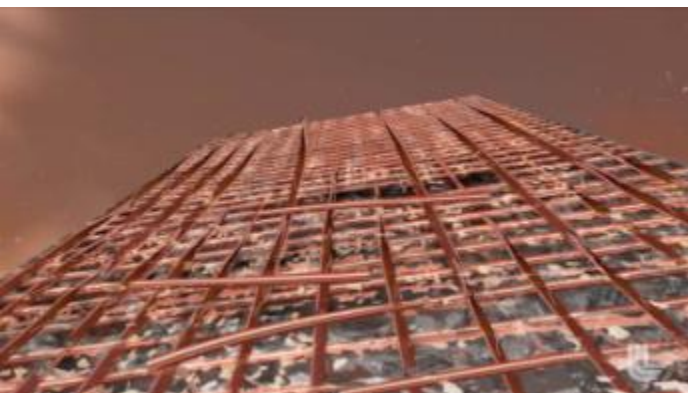
## Moderate Damage Zone

- The orange annular ring demonstrates the moderate damage zone. For a 10kT, it will extend from  $\frac{1}{2}$  a mile to one mile from the detonation site, and this area has the most potential life saving opportunities. However, it will also see significant structural damage and fires.

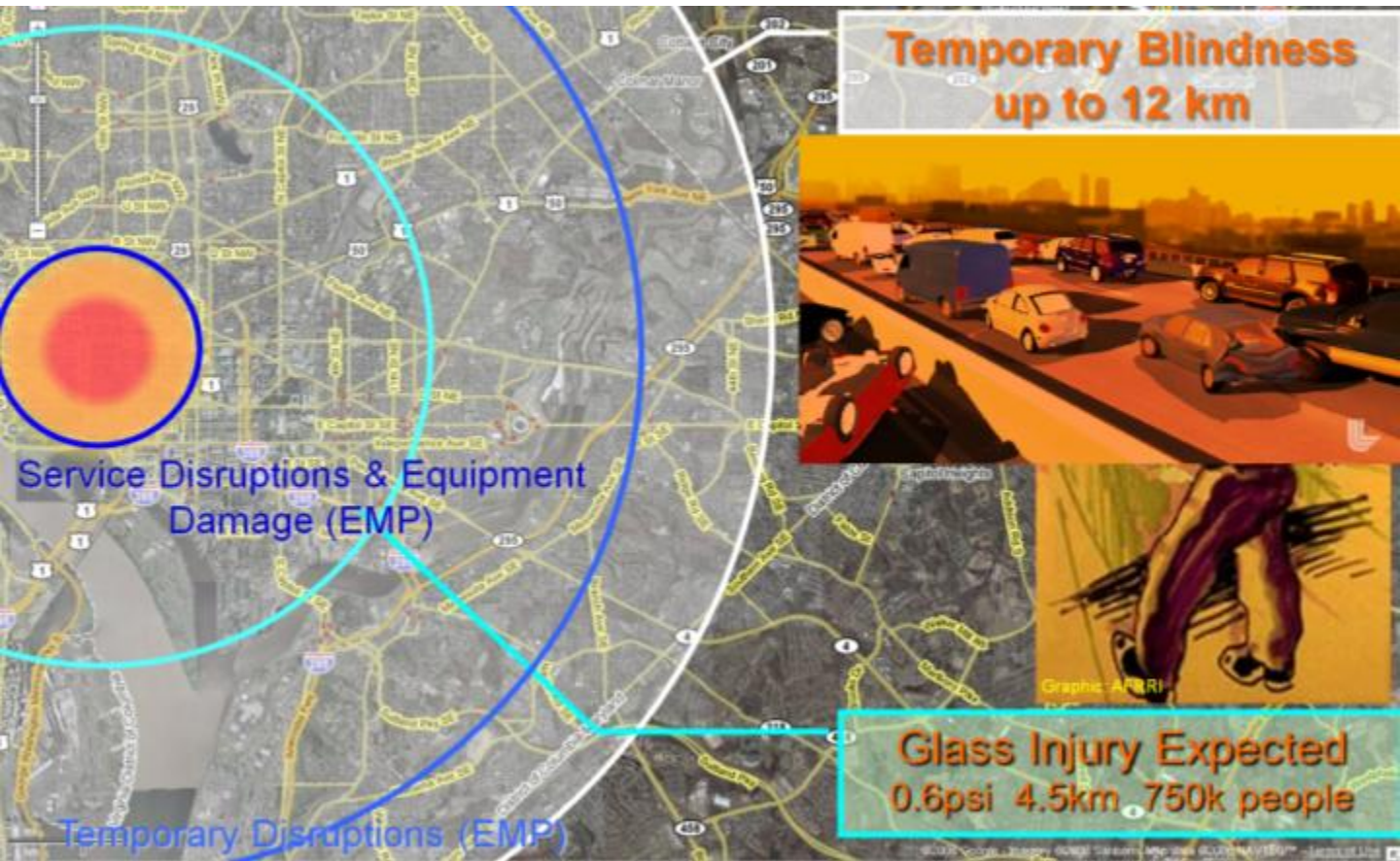


## Outer Edge of Moderate Damage Zone

- The outer edge of the moderate damage zone typically shows building damage consisting of broken glass, and external panel damage, and partial destruction of weaker structures.
- The animation on the PowerPoint depicts the timing and type of effects that might be observed on the outer edge of the moderate damage zone. The bright flash will be followed by a “thump” as the shock is transmitted through the earth. This will be followed in several seconds by the air blast which will severely damage many structures and blow the glass into buildings causing injuries and bringing the facades of many buildings to the ground. This will create rubble and debris in the street which can impede the progress of responders and evacuees.



## Other Long Range Effects



The blue line that appears is where glass is broken with enough force to cause injuries. The D.C. population during the workday in this area is about 750,000 people.

The white area that appears is the area where people outside have the potential to be blinded by the brilliant flash that appears during detonation. This blindness may last for several seconds, or as long as a couple minutes. The potential flash blindness is not expected to be of issue for pedestrians, however, drivers will be unable to see the road or other drivers which could potentially cause additional accidents clogging major thoroughfares. Because of that, we can expect most roads in about a 10km range to 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 will be limited to within a mile. An EMP blast will disrupt most electronics, but cause little direct harm to people. Although a “firestorm” isn’t likely to occur, there will be a large number of small fires that started from the thermal and blast effects (generally around the 1 mile perimeter) which could spread and coalesce if not mitigated.

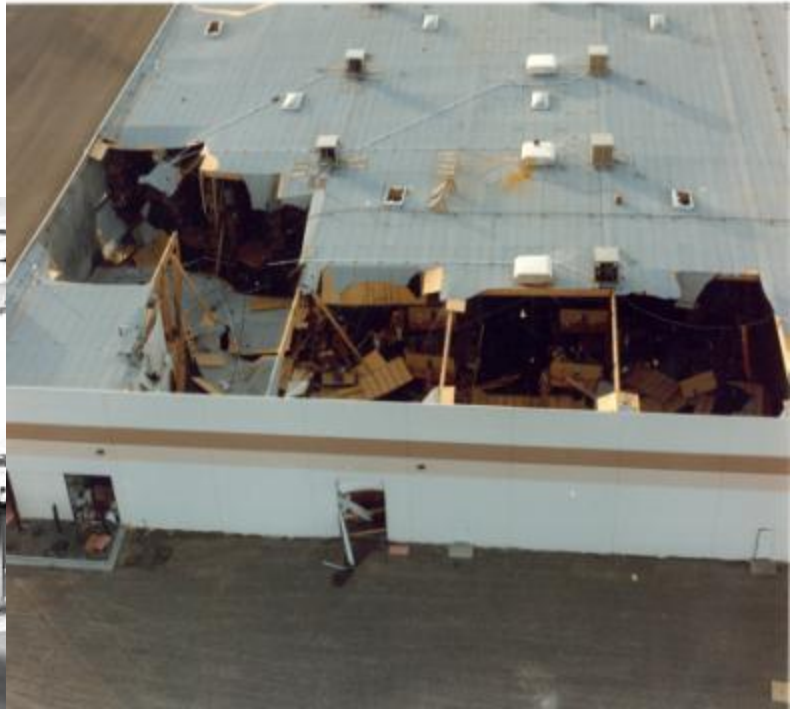
# Student Guide: IND Prompt Effects



## Light Damage Zone

- The last blast zone is the light damage zone. This extends from one to three miles from a 10kT and represents the largest of the three blast zones.
- The majority of 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. The damage in this zone is caused by the “shockwave” following the blast. This is similar to a “sonic boom” and consists of free field overpressure.

- The images presented are from an accidental explosion at a booster rocket manufacturing facility in Henderson Nevada. The explosion was estimated to be the equivalent of about 1kT. The office glass had been blown into the building and the ceiling tiles have caved in. The large flat roof of the warehouse also collapsed.



## Light Damage Zone

Outer boundary may be defined by (mostly minor) glass injuries.

1. Zone extends from ~1 mile up to ~3 miles (10kT Example)
2. Damage NOT caused by dynamic (wind-like) pressure, but the “shockwave” of peak free field overpressure
3. Damage not just to windows, but other larger flat (and weak) features

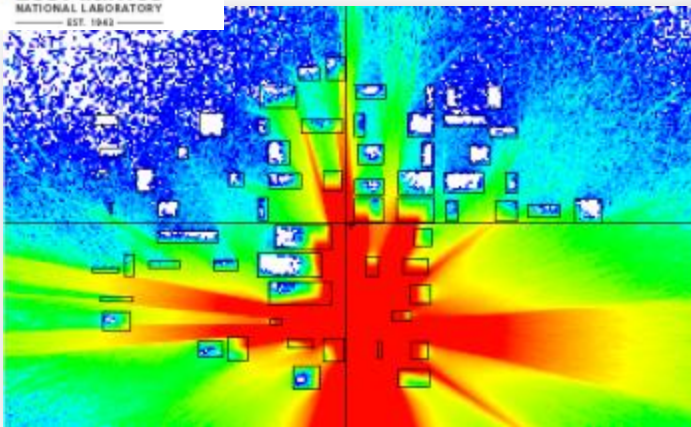
## Other Effects

There are three other effects that should be mentioned. Those three are: Urban Mitigation of Line of Sight Effects, Building Damage is non-linear, and Rubble.

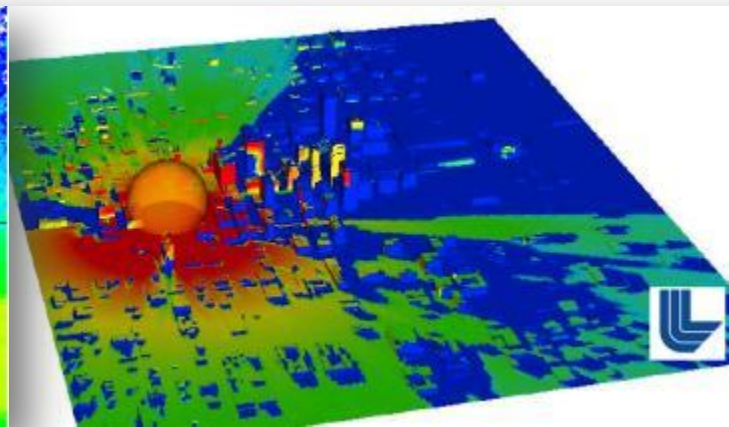
### A) Urban Mitigation of Line of Sight of Sight Effects

- The range of prompt effects mentioned are typically only relevant for an open plane (like the Nevada Desert). The protection afforded by the urban environment can greatly reduce the number of previously calculated burns and radiation exposure that have been cited in many studies.
- These images, which model a ground level, low yield nuclear detonation, demonstrate how some types of radiation and thermal effects are greatly mitigated by the urban environment.
- The blue and green areas on the images represent low (survivable) exposure levels. Without the urban environment, harmful levels of gamma radiation and thermal burns could extend into the moderate damage zone..
- Another key point is that the ranges for these effects are not uniform, and perfect “circles” depicted on earlier slides should be taken as examples of maximum ranges and not an average range.

Los Alamos  
NATIONAL LABORATORY  
EST. 1943



Prompt gamma doses in the urban environment



Prompt thermal exposures in the urban environment

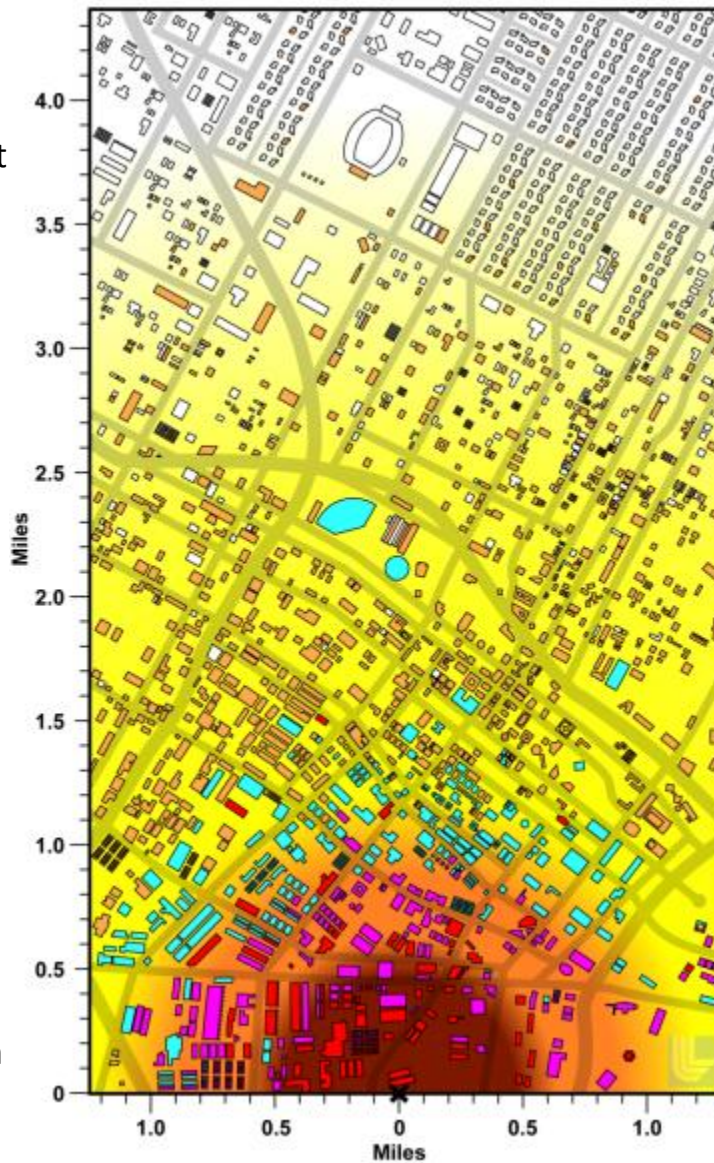
# Student Guide: IND Prompt Effects

## Building Damage is Non-linear

The circles of blast effect can also be misleading. Blast “waves” can be greatly modified as they move through the urban environment. The overpressure can be reflected off of buildings, channeled down streets, and even reflected off of different layers of the atmosphere.

You can see that some building collapse beyond the range predicted by the ideal air blast model because of this phenomenon.

Also, some buildings can survive unscathed fairly close the detonation.



<span style="color: yellow;">■</span>	<b>Light Damage (LD) Zone:</b> Windows broken, mostly minor injuries that are highly survivable even without immediate medical care.
<span style="color: orange;">■</span>	<b>Moderate Damage (MD) Zone:</b> Significant building damage and rubble, downed utility poles, overturned automobiles. Areas, many serious injuries. Early medical assistance can significantly improve number of survivors.
<span style="color: red;">■</span>	<b>Severe Damage (SD) Zone:</b> Most buildings destroyed, hazards and radiation initially prevents entry into the area, the survival likelihoods.
<span style="color: black;">✕</span>	<b>Notional 10KT Detonation</b>

Structural Damage	
<span style="color: red;">◆</span>	Buildings Collapsed
<span style="color: magenta;">◆</span>	Buildings Severe Damage
<span style="color: cyan;">◆</span>	Buildings Moderate Damage
<span style="color: blue;">◆</span>	Shattered Glass Injuries
<span style="color: grey;">◆</span>	Possible Window damage without injury

## Rubble

The damage and collapse of buildings will also create significant amounts of rubble and debris in urban canyons. Often 10s of feet of rubble can be found in urban canyons, which can block urban roadways and limit the movement of evacuees and responders in the moderate damage zone and into the light damage zone.

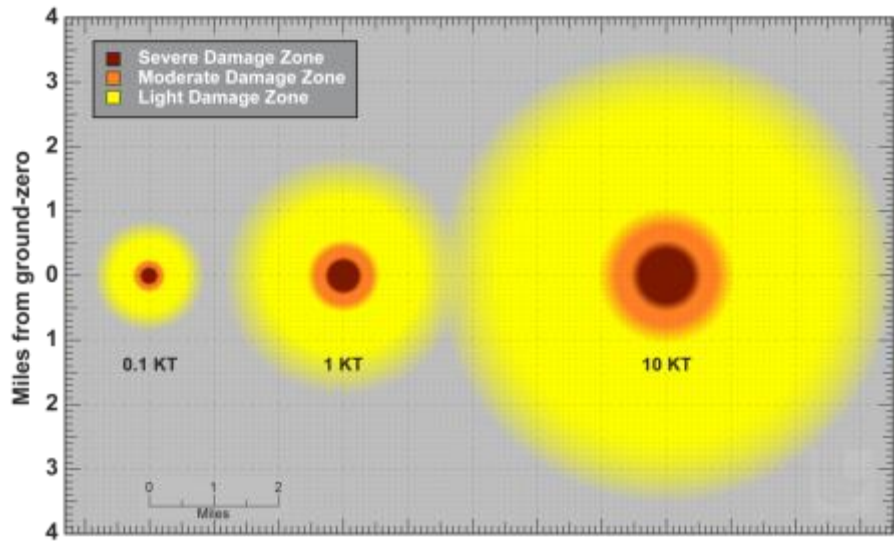


# Student Guide: IND Prompt Effects



## Damage Zone Ranges Change with Yield

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



## Radiation Hazards Take Precedent

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 will apply. These are:

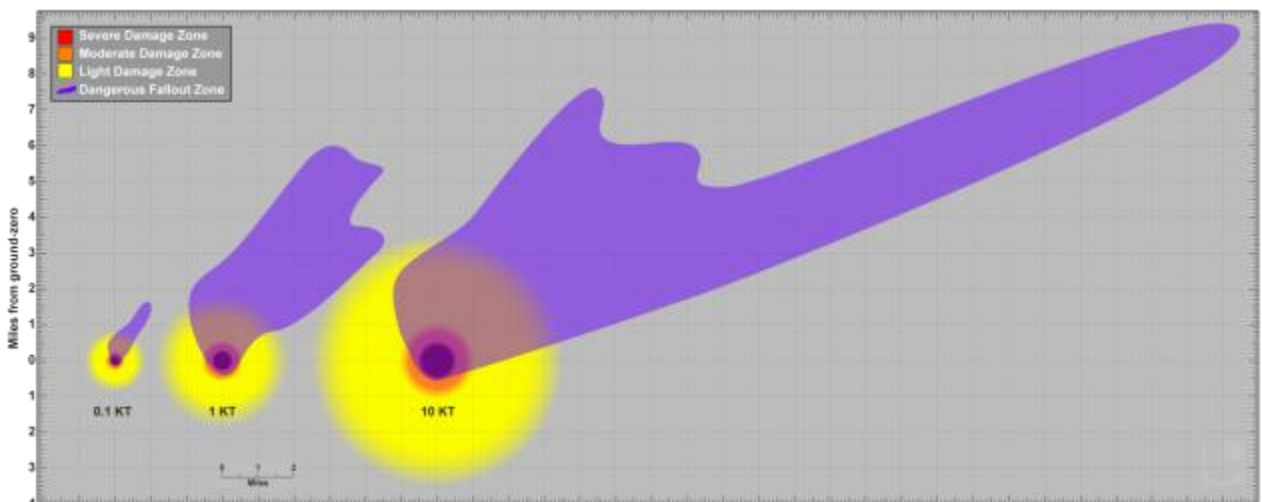
**The dangerous radiation zone from fallout will overlap damage zones**

**When zones overlap, radiation precautions take precedent**

-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 the portions of the damage zones that are outside the 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 dangerous fallout zone.



# Student Guide: IND Prompt Effects

## Zoned Approach to Response

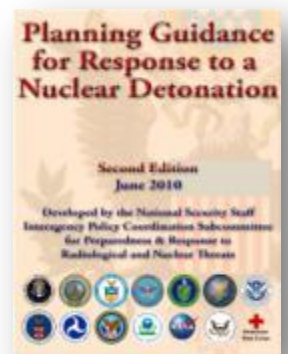


The amount of damage to structures can be used to describe zones for use in response planning. Each zone will have health and survival implications, although not as neatly as arbitrary zone delineations would indicate. The purpose of establishing zones is to help plan response operations and prioritize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

### Light Damage (LD) Zone:

- Damage is caused by shocks, similar to those produced by a thunderclap or a sonic boom, but with much more force. Although some windows may be broken over 10 miles (16 km) away, the injury associated with flying glass will generally occur at overpressures above 0.5 psi. This damage may correspond to a distance of about 3 miles (4.8 km) from ground zero for a 10 KT nuclear explosion. The damage in this area will be highly variable as shock waves rebound multiple times off of buildings, the terrain, and even the atmosphere.
- As a responder moves inward, windows and doors will be blown in and gutters, window shutters, roofs, and lightly constructed buildings will have increasing damage. Litter and rubble will increase moving towards ground zero and there will be increasing numbers of stalled and crashed automobiles that will make emergency vehicle passage difficult.
- Blast overpressures that characterize the LDZ are calculated to be about 0.5 psi at the outer boundary and 2–3 psi at the inner boundary. More significant structural damage to buildings will indicate entry into the moderate damage zone.
- Much of the LDZ may be essentially non-radioactive. However, responders should be prepared to encounter elevated radiation. The most hazardous radiation levels would be associated predominantly with the major path where fallout deposition overlays the 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 depth) in the torso, limbs, and face. Eyes are particularly vulnerable. As responders proceed inward they will begin to observe an increasing frequency and severity of injuries from flying glass and debris, and crush, translation, and tumbling injuries

Excerpts from the Planning Guidance for Response to a Nuclear detonation (June 2010).



# Student Guide: IND Prompt Effects

## Zoned Approach to Response



### Moderate Damage (MD) Zone:

- Responders may expect they are transitioning into the MDZ when building damage becomes substantial. This damage may correspond to a distance of about one mile (1.6 km) from ground zero for a 10 KT nuclear explosion. The determination is made by ground-level and/or overhead imagery.
- Observations in the MDZ include significant structural damage, blown out building interiors, blown down utility lines, overturned automobiles, caved roofs, some collapsed buildings, and fires. Some telephone poles and street light poles will be blown over. In the 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 communication lines are expected and fires will be encountered.
- The MDZ is expected to have the highest proportion of '*survivable victims*' who require medical treatment.
- The MDZ presents significant hazards to response workers, including elevated radiation levels, unstable buildings and other structures, downed power lines, ruptured gas lines, hazardous chemicals, asbestos and other particulates released from damaged buildings, and sharp metal objects and broken glass, for which consideration and planning is needed.

### Severe Damage Zone:

- Few, if any, buildings are expected to be structurally sound or even standing
- Very few people would survive; however, some people protected within stable structures (e.g., subterranean parking garages or subway tunnels) at the time of the explosion may survive the initial blast.
- Very high radiation levels and other hazards are expected in the SDZ, 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 may have a radius on the order of a 0.5 mile (0.8 km) for a 10 KT detonation. Blast overpressure that characterizes the SDZ is 5–8 psi and greater.

Excerpts from the Planning Guidance for  
Response to a Nuclear detonation (June 2010).





# Student Guide: IND Prompt Effects

## Zoned Approach to Response



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

### Light Damage (LD) Zone:

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

### Moderate Damage (MD) Zone:

- Responders may expect they are transitioning into the MDZ when building damage becomes substantial. This damage may correspond to a distance of about one mile (1.6 km) from ground zero for a 10 KT nuclear explosion. The determination is made by ground-level and/or overhead imagery.
- Observations in the MDZ include significant structural damage, blown out building interiors, blown down utility lines, overturned automobiles, caved roofs, some collapsed buildings, and fires. Some telephone poles and street light poles will be blown over. In the 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 communication lines are expected and fires will be encountered.

**With proper response planning, many lives can be saved  
with minimal risk to responders.**





## Conclusion

- **Many existing models will over-predict thermal and prompt radiation effect ranges in the urban environment.**

- Response plans should be developed using more "building aware" modeling.

- **Blast will be a primary injury mechanism and can cause damage and injury several miles from the detonation site.**

- 100,000s casualties can occur from the prompt effects in the first few minutes within a few miles of detonation site.

- Overall number of casualties likely to be reduced by protection from the urban landscape and being within heavy buildings.

- Tertiary effects (building collapse, glass and debris missiles, and flash-blindness accidents) may increase number of casualties.

- **Federal planning guidance has defined several damage zones based on observable effects.**

- Severe Damage – responders should not focus on this area, as radiation levels will be too high and survival is unlikely.

- Moderate Damage – This should take highest priority as there is the highest potential to save lives.

- Light Damage – This is a lower initial priority, as most injuries can be treated with minimal or no medical care.

- **Fallout radiation hazards may exist in some parts of all zones. Safety precautions should be taken within every zone.**

- Responders should be aware that while they should not initially enter areas with dangerous fallout levels, these levels will fall quickly





## 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?

