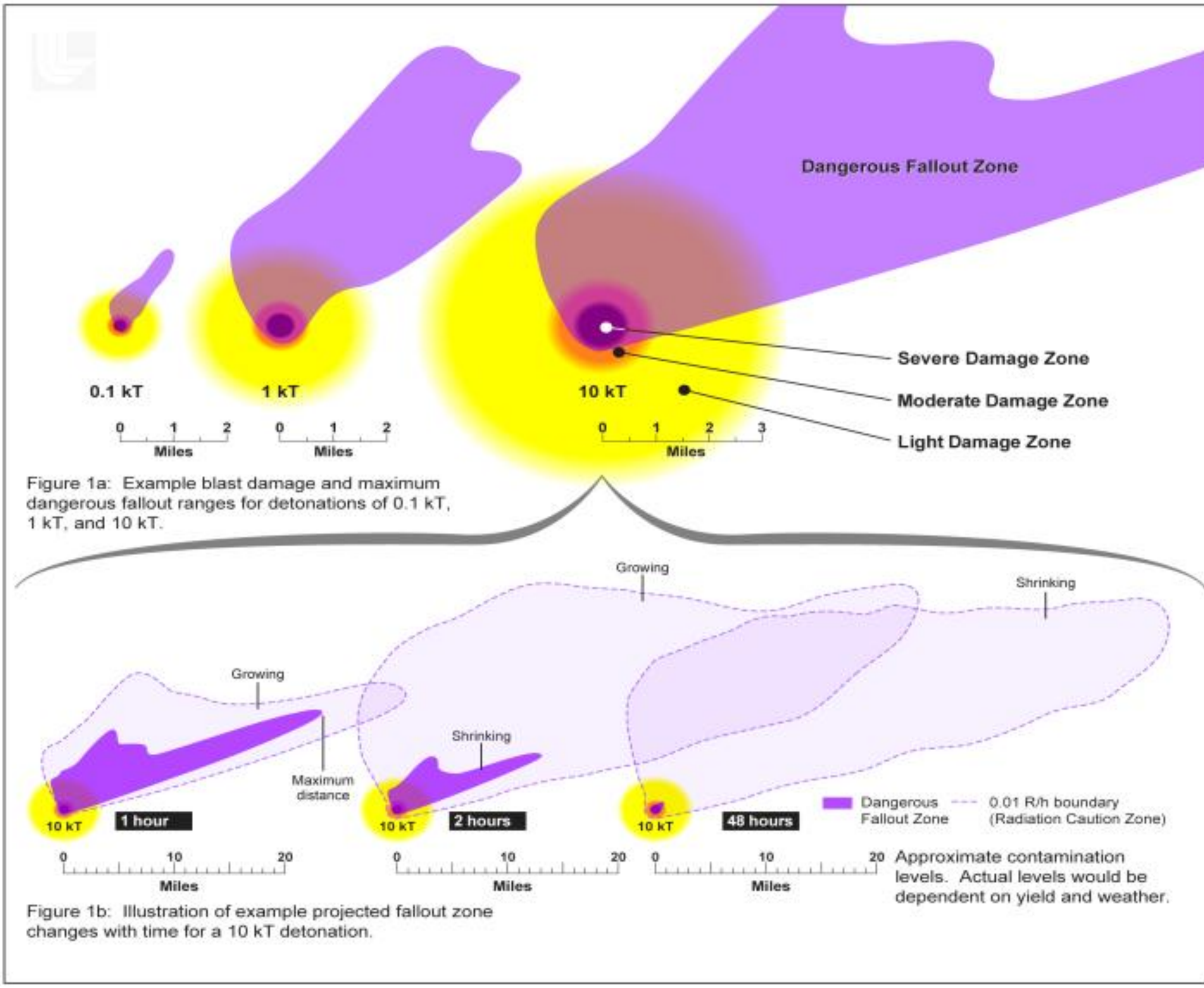

Figure 1a: Example blast damage and maximum dangerous fallout ranges for detonations of 0.1 kT, 1 kT, and 10 kT.

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

Student Guide: IND Fallout Effects (Los Angeles Version)

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FEMA

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National Nuclear Security Administration

This Student Guide is used to accompany the IND Fallout Effects Presentation.

Instructional Goal

By the end of this presentation, you should be aware of the fallout effects that occur after an improvised nuclear device (IND). Fallout effects are those effects that are created when the nuclear detonation creates a large cloud of radioactive dust & water vapor which falls **back to earth contaminating horizontal surfaces.** Dangerous levels of fallout creates visible dust and debris. These particles give off **penetrating radiation** that can injure people (even in cars or inadequate shelter). **Fallout decays rapidly away with time**, and is most dangerous in the first few hours after the detonation. By gaining knowledge about fallout, emergency responders and the general public will be better prepared to deal with the effects caused from fallout. Being prepared and knowledgeable is the difference to saving lives. Knowing what to expect from the fallout effects will give the emergency responders the extra knowledge and time they need to understand what to do quickly and efficiently.

Purpose

The purpose of this presentation is to inform students about the fallout effects from an improvised nuclear device. By the end of this module, students should be able to understand how fallout works and how to remain safe when conducting response efforts in areas where fallout may be present.

Module Objectives

- Define fallout and explain how it is created
- Explain how fallout spreads
- Explain the decay rate of fallout
- Define planning guidance zones

Notes

Note: For this module we will only be discussing fallout effects. Prompt Effects was discussed in a separate module.

Video

- This video gives a quick introduction on how dangerous radiation is formed within a fallout cloud. Fallout begins to form immediately following the 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. The radiation coming from these particles is the dangerous aspect; not breathing it.

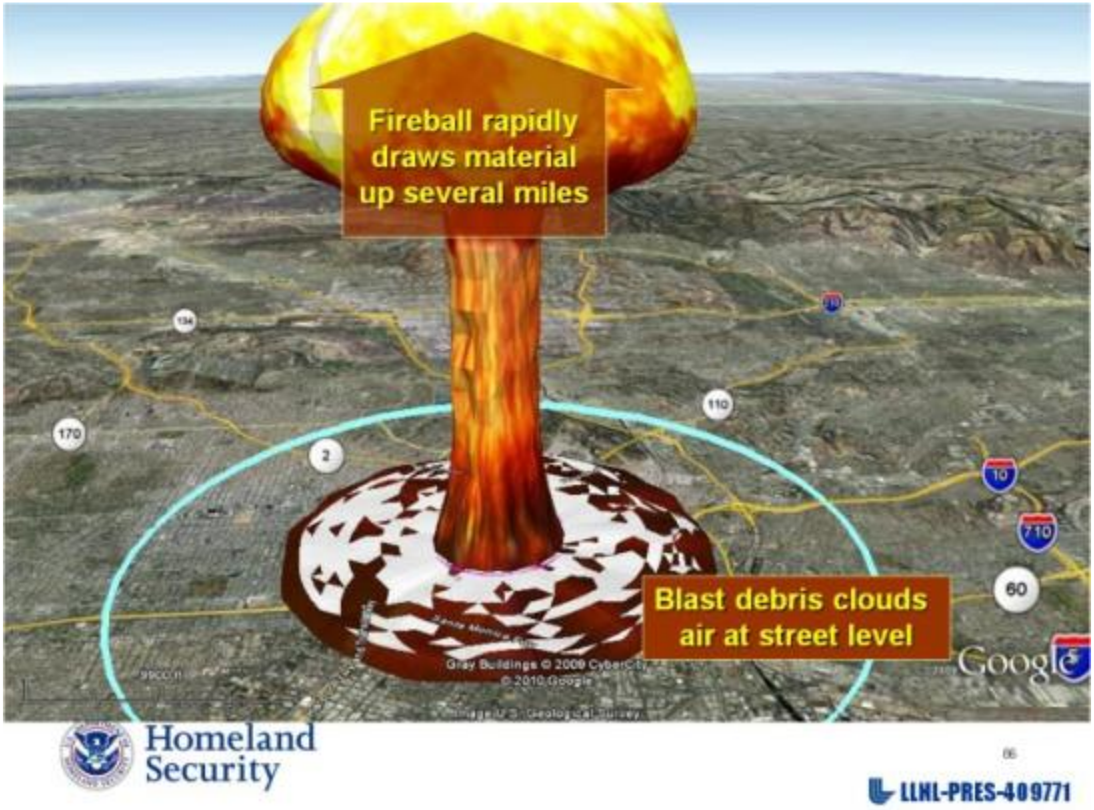
- For a 10kT detonation, Nevada Tests predict the cloud will rise five miles into the upper-atmosphere however more recent models of detonations in built up areas indicated that the fallout cloud may not rise far.

- Larger particles will fallout first, and within several miles of the detonation these may be the size of table salt or sand. The further 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 the explosion is combined with radioactive fission products and drawn upward by the heat of the event. This cloud rapidly climbs through the atmosphere, up to five miles high for a 10kt 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.



- Note: the light blue line represents the outer edge of the light damage zone (3 miles from detonation for a 10 KT).
- The 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 this will create a "mushroom" shaped cloud, however this may not be the case for low yield or non-ideal wind conditions.

Fallout Particles Move Away in Various Directions and Speeds

This image represents how fallout travels over the first few hours of the event given the specific weather pattern analyzed for this event. Depending on weather conditions and wind speed, dangerous fallout particles will move away from the initial blast site in different directions at different speeds. In order to help visualize how the cloud will appear over these first few hours, scientists at the Interagency Modeling and Atmospheric Assessment Center (IMAAC) at Lawrence Livermore National Laboratory created a cloud image represented by the purple balls of the presentation.

As this animation unfolds for the first six hours after a 10KT detonation, you will see two things:

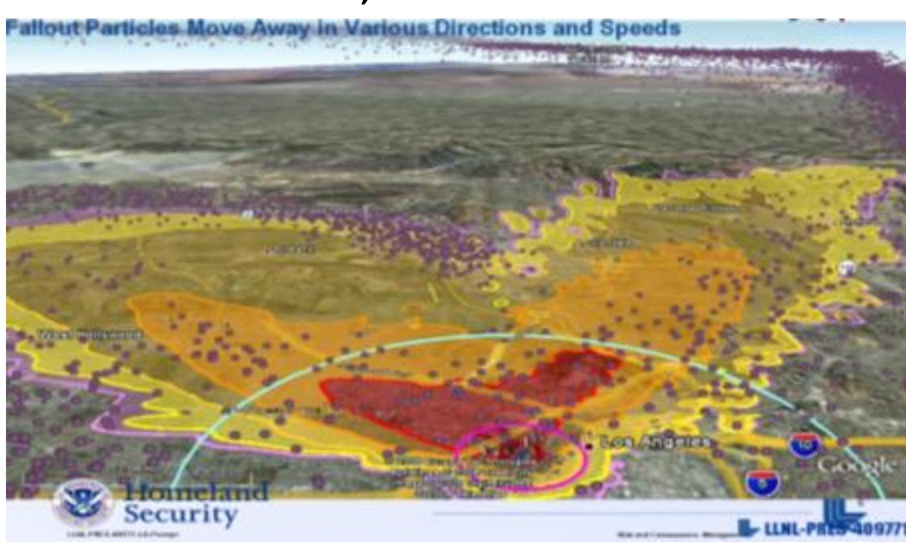
(1) The purple balls demonstrate the fallout cloud movement

(2) The colored contours on the ground represent the different radiation levels being given off by the particles that have fallen on the ground.

Animation of the fallout cloud's initial movement begins.

- The upper atmosphere winds push the top of the cloud off to the northeast while parts of the fallout in the lower atmosphere push it off to the northwest. The different colors represent fallout levels on the ground. After just the first hour, the cloud moves away, but the dangerous radiation remains present on the ground.

View from the South, 15 minutes after detonation

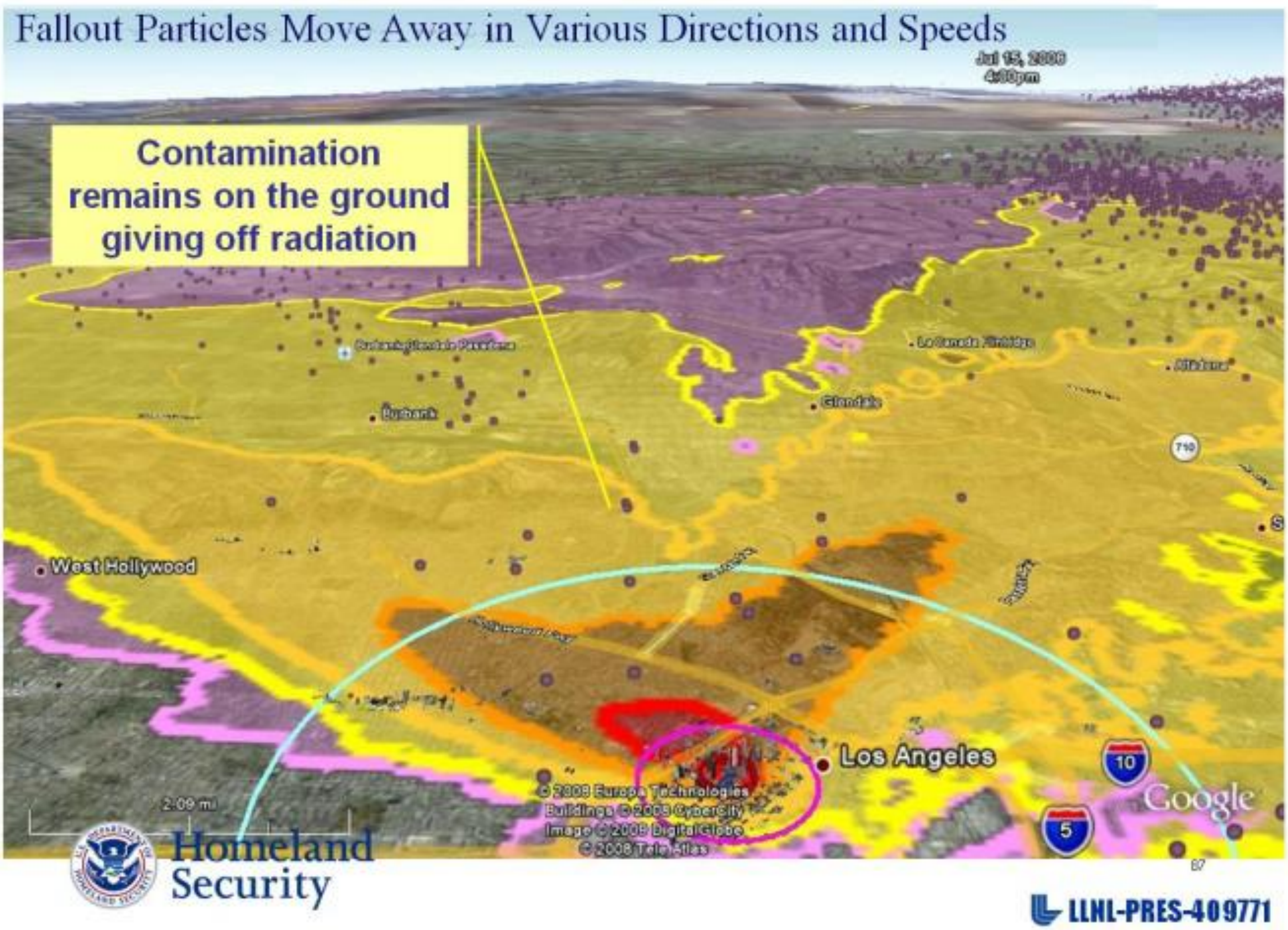


View from the South, ~1 hour after detonation

Fallout Particles Move Away in Various Directions and Speeds

Animation continues, showing the remainder of a six-hour period.

- It is important to remember that even though the fallout cloud has moved downwind after the first few hours, dangerous radiation levels of fallout particles will remain on the ground giving off radiation. Understanding how radiation remains behind following the detonation is a key response issue.



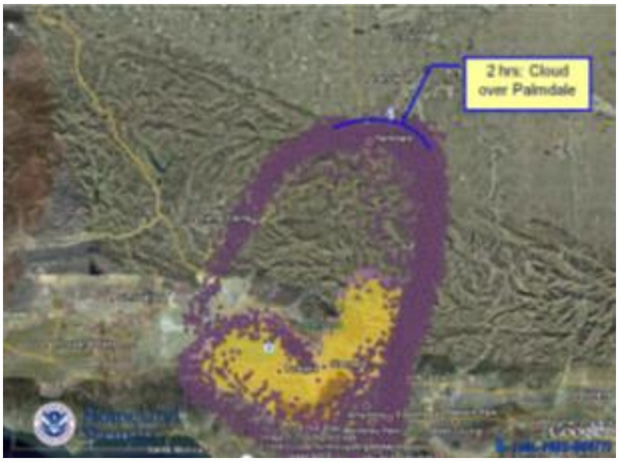
Fallout Cloud: Regional View

The following animations will show how the fallout cloud spreads across a view of LA County.

Note how the radiation level on the ground lag significantly behind the movement of the fallout cloud. This is because the fallout particles have to fall from several miles in the upper atmosphere.

First 45 minutes: LA Basin

- The cloud moves away quickly, but has already deposited dangerous levels of radiation over areas near the detonation site. At 45 minutes the cloud reaches the edge of the LA basin

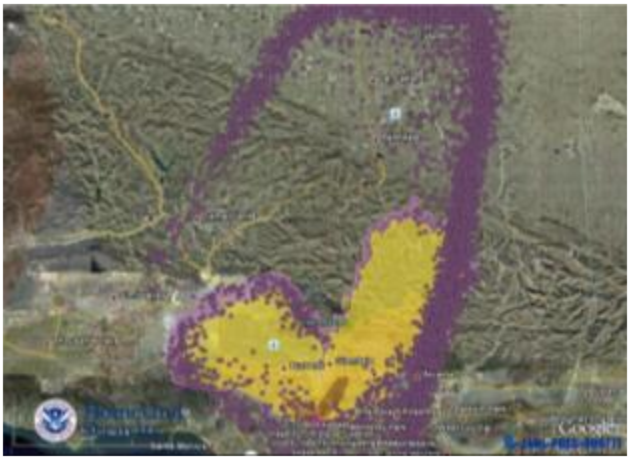


2 hours: over Palmdale

- The cloud continues to move away from the detonation site and continues to deposit some fallout.

Animation continues to show the spread of the fallout cloud

- 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 does decay quickly. This means that as the cloud moves farther away, the radiation levels in areas where the fallout has already been deposited will lessen over time.

DHS and EPA Guidelines on Exposure Levels

• Although there are current guidelines for shelter or evacuation, they were designed for slowly evolving events like a possible nuclear power accident.
These recommendations indicate that you should:

"consider shelter or evacuation when a four day outdoor exposure would exceed one rem, and shelter or evacuation is warranted if expected exposure exceeds five rem."

• Unfortunately it fails to actually tell you which (shelter or evacuation) is the better option, instead stating that you should choose the option that leads to the lowest possible exposure and leaves the evaluation to be performed during the midst of the actual event.

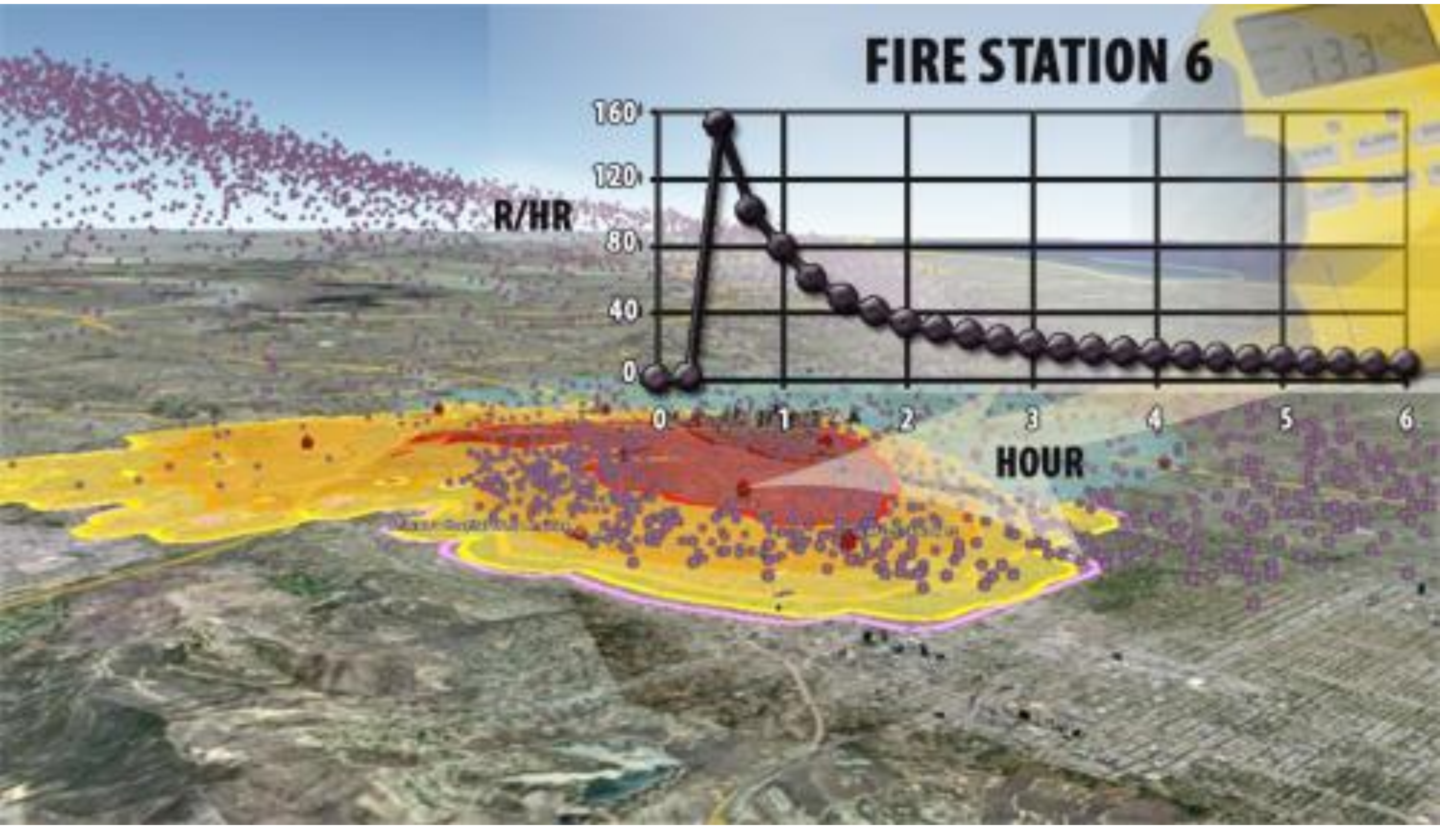
• These figures demonstrate why having response plans ***in advance*** is so crucial to saving lives, as figuring out what is the appropriate action for several million people *after the detonation* is likely to be extremely hard if not impossible.

Dose Rates Decay Quickly

The demonstration of the details of a detonation area must be understood. Simply understanding how fallout works is not enough. It is important to understand what the event will look like from a first person perspective of the event.

The following images represent a "ground level" view of the cloud movement and demonstrate the radiation levels at a particular area.

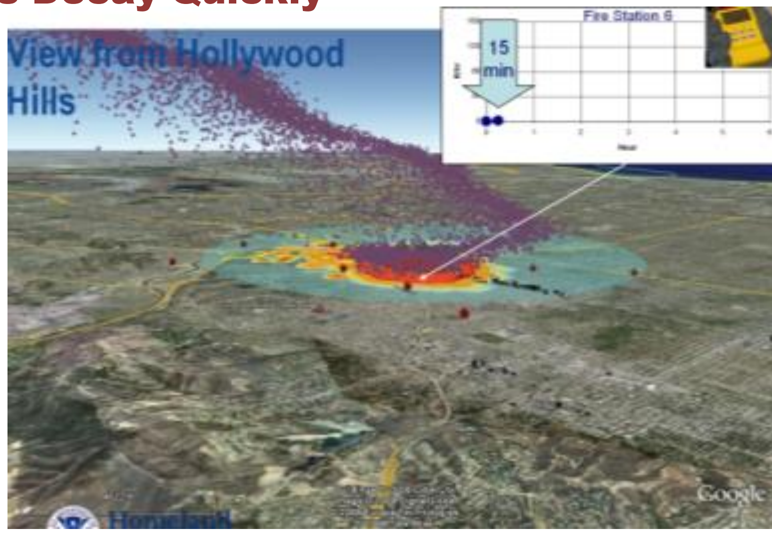
- **Fire stations around detonation site**
  - These red dots represent fire stations outside of the more severe damage zones. These stations have a good chance of surviving the blast, but are in the path of the fallout cloud, and thus susceptible to dangerous radiation levels.
- **Dose rate monitoring for Fire Station 6**
  - This example tracks the outdoor exposure rate at Fire Station Number Six. You don't need to focus on the actual numbers, but, rather, look at the trend of the dose rate.

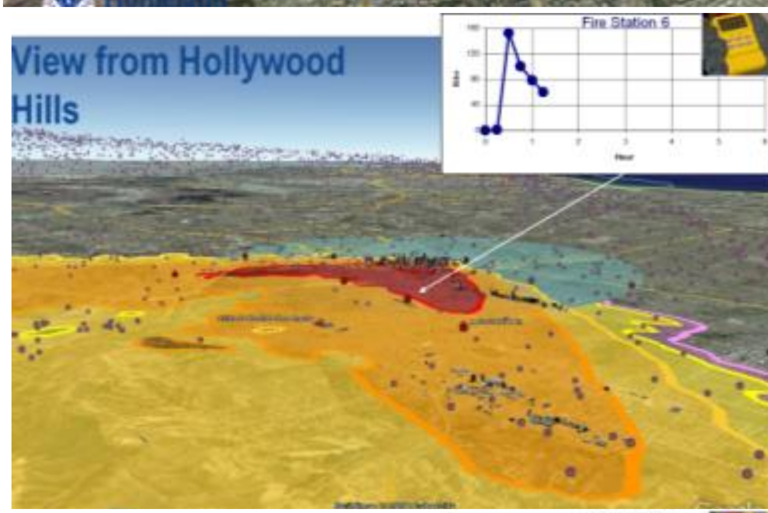


Dose Rates Decay Quickly

•Dose rate in first 15 minutes appears.

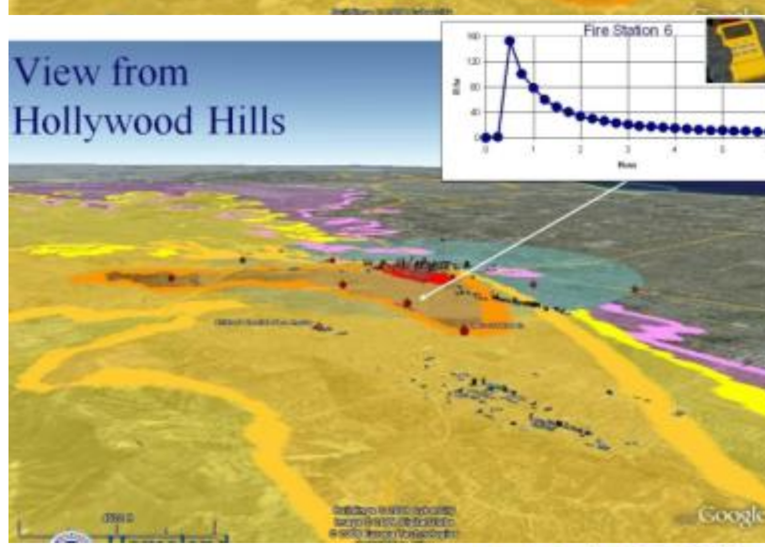
➢The fallout cloud is already overhead, but not enough fallout has reached the ground, so the radiation levels will only be a few rem as the fallout is just starting to accumulate. After 15 minutes dose rates will shoot up to 160 R/hr at the half hour mark. This is over 10 times the 10 R/hr of the Dangerous Fallout Zone.





•Dispersing fallout cloud and different dose rates.

➢While initial dose rates are high, look how fast the rates begin to drop. This is because radiation has an extremely short half-life; it decays very quickly. Over half of the fallout particle energy is given off in the first hour.



Key Fallout Considerations

•Fallout decays rapidly (releasing more than half of its energy in the first hour)

➢The radiation levels are very high initially, but over 50% of the energy is given off in the first hour. Over 80% in the first day.

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

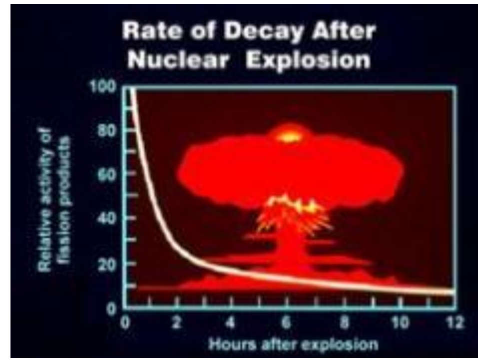
➢The hazard is the penetrating radiation energy given off by the fallout particles. Getting as much distance and mass between you and the particles is the best protection. By remaining indoors and seeking the best possible shelter in their structure, people can dramatically cut down the radiation dose they are exposed to.

•Dangerous levels of fallout are readily visible as they fall

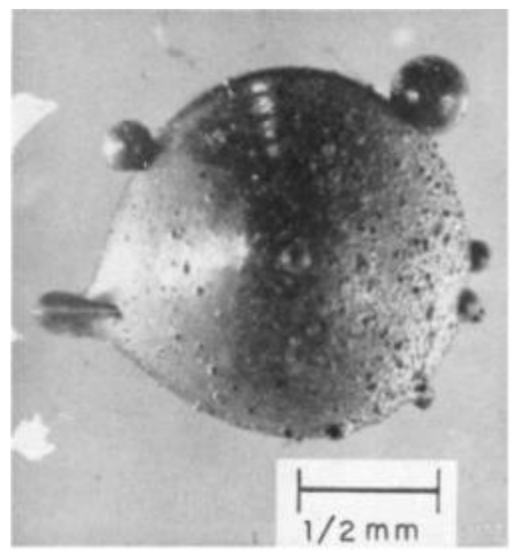
➢Dangerous levels of fallout are not invisible; there will be visible quantities of material raining down, often the size of salt or sand.

•Fallout is not a significant inhalation hazard

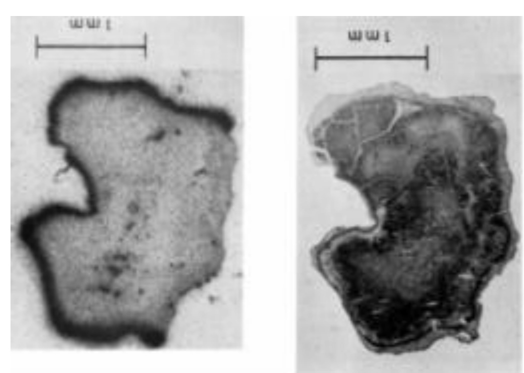
➢Because they are so large, breathing in the particles is not very likely and is a much lower concern than the external exposure from the particles on the ground.



Images courtesy of Armed Forces Radiobiological Research Institute



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

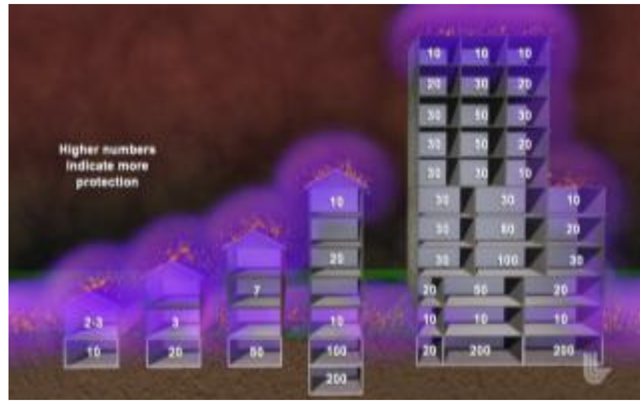


Fallout Images from:
G. R. CROCKER, J. D. O'CONNOR and E. C. FREILING, PHYSICAL AND RADIOCHEMICAL PROPERTIES OF FALLOUT PARTICLES, *Health Physics Pergamon Press, 1966. Vol. 12, pp. 1099-1 104.*

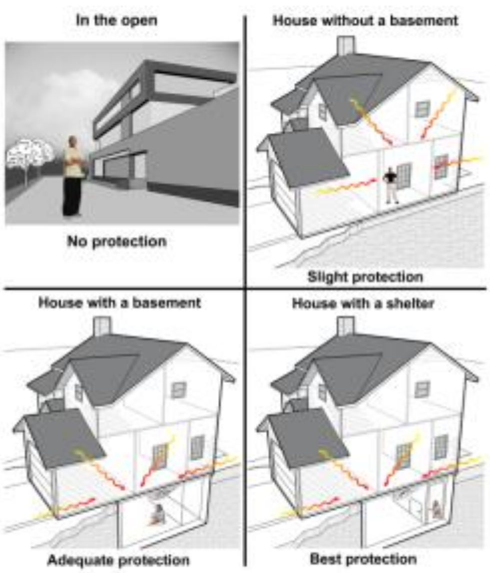
Key Fallout Considerations

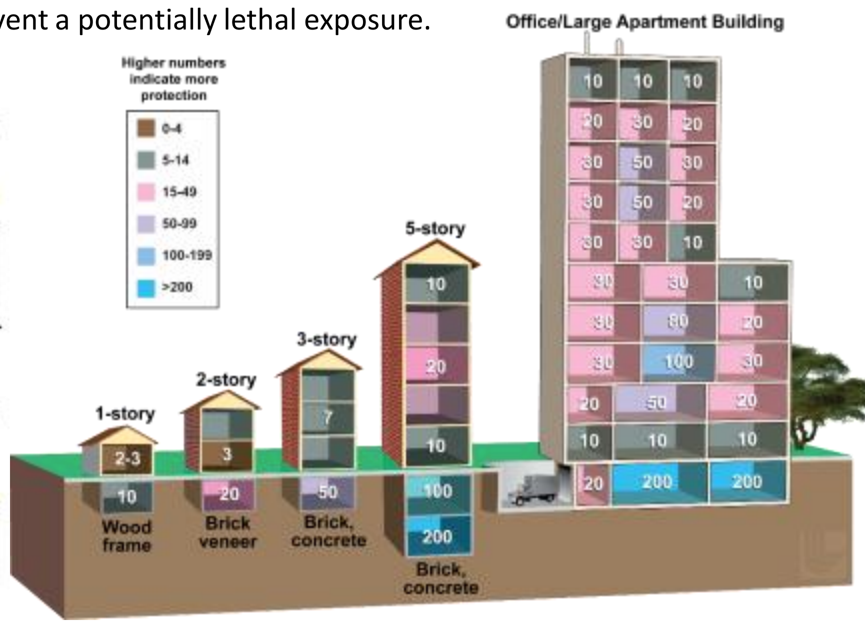
- **Protection factors**

  - As can be seen by this animation, the particles coat the ground and rooftops. The hazard areas are near the places where the fallout accumulates. The 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. This Figure demonstrates presumed protection factors for a variety of buildings and the location within the building. For example, a person top floor or periphery of a ground level of the office building pictured would have a protection factor (PF) of 10 and would receive only 1/10th (or 10%) of the exposure that someone outside would receive. Whereas someone in the core of the building halfway up would have a PF of 100 and receive only receive 1/100th (or 1%) of the outdoor exposure. In fallout areas, knowing locations with adequate protection factors could prevent a potentially lethal exposure.





- **A protection factor of just 10 or higher is considered adequate protection against fallout radiation**. For simple, wood frame houses, just 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.

Dangerous Fallout Zone

More Information on the DFZ
Here is some more crucial information about the DFZ:

- **Bounded by radiation levels of 10R/hr**
  - ➢Determining dose rates early on helps to identify the **perimeters of the DFZ**
- **Could reach 10-20 miles downwind before the decay of the radiation causes this zone to shrink after about 1 hour**

•**Also called:**

- ✓High-Hazard Zone
- ✓ High Radiation Zone

•After establishing the perimeter of the DFZ, everyone should 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.

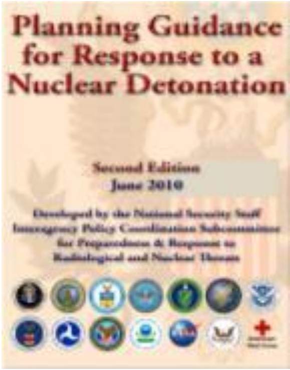
"Identifying the dangerous-radiation zone [exposure rate ≥10 R/h] will have critical implications on response activities in or near fallout areas. The dangerous-radiation zone is an area where large doses could be delivered to emergency responders in a short period of time."

~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)



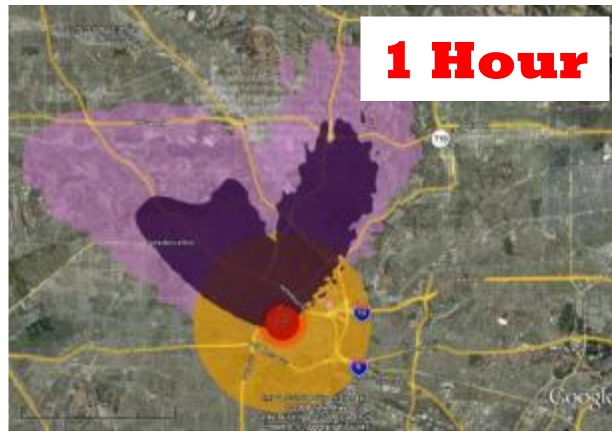
The DFZ Changes Rapidly with Time

- The 'Silver Lining' of radiation is the short half-life; it decays extremely rapidly.

- This animation shows how fallout reaches its peak after about an hour, than begins to recede.

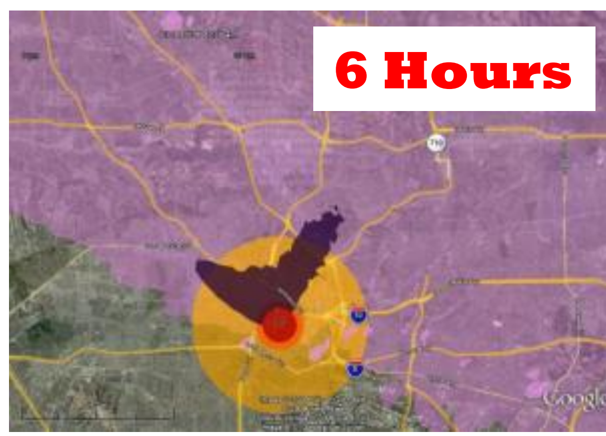
1 Hour

- The (Dark Purple) Dangerous Fallout Zone (DFZ) reaches it's maximum extent. For the LA Example, low speed upper atmosphere winds mean the maximum extent was only ~ 7 miles.



6 hours

- The DFZ has already ~ half its original size.



48 hours

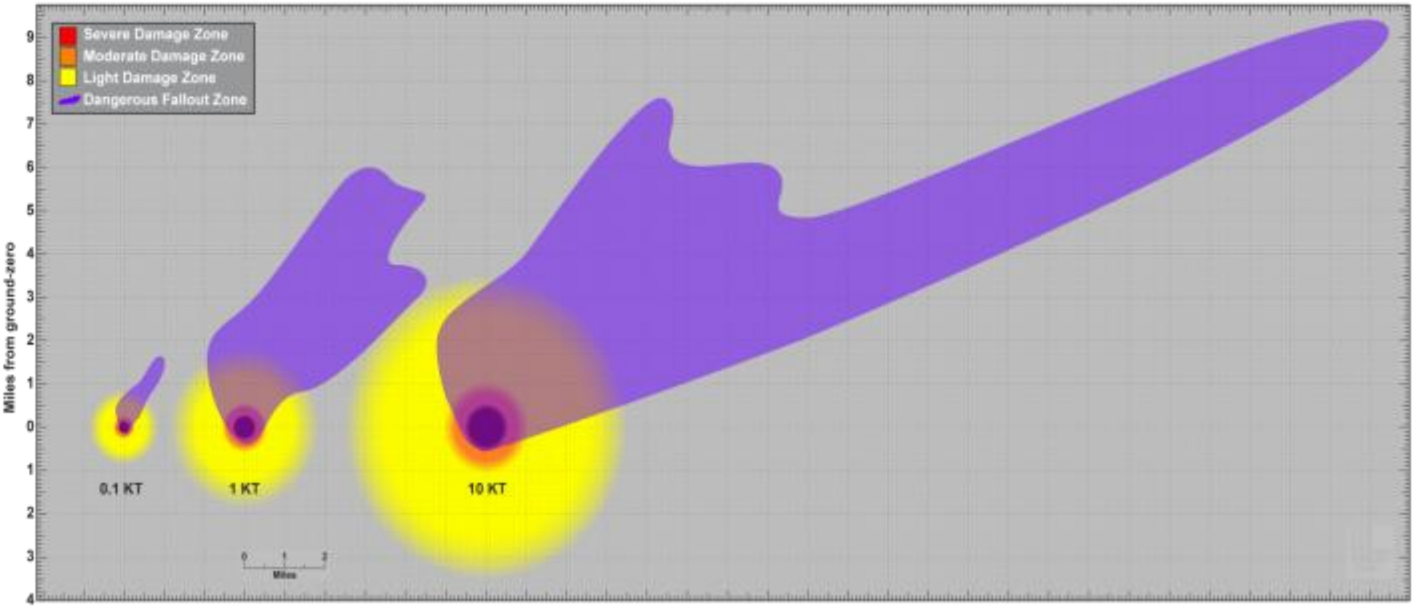
- After 48 hours, nearly all of the light damage zone is safe to enter as the DFZ is only a mile long

Dangerous Fallout Zone
Precautions Take Precedent

This graphic illustrates the maximum extent for several different low yield, ground-level explosions. Note how smaller yields create much smaller DFZs. The timing will also be accelerated and the fallout will reach the maximum extent much quicker.

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:

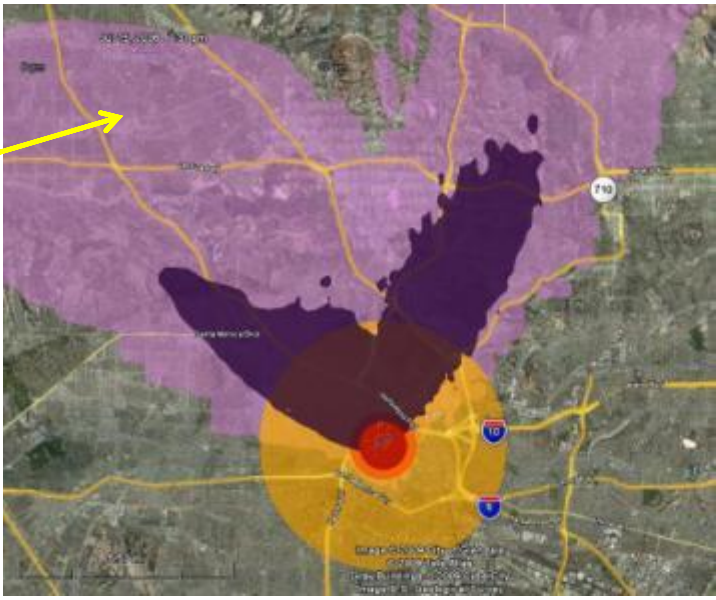
- **The dangerous radiation zone from fallout will overlap damage zones**
- **When zones overlap, radiation precautions take precedent**
  - ➢even if responders know there are victims within the moderate and light damage zones, they should not enter until dangerous radiation levels are no longer present.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



Hot Zone (Bounded by 0.01 R/h)

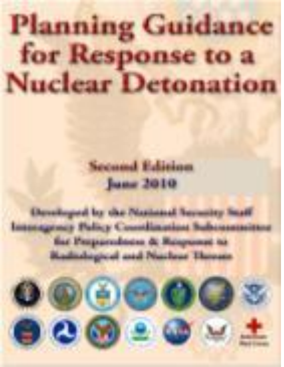
- The 0.01 R/h boundaries, often referred to as the Hot Zone, are areas extending from the DFZ that have radiation levels of 10mR/hr, only 1/1000th of the rate found in the DFZ.
- For a 10 KT detonation, the Hot Zone could extend in a number of directions for 100s of miles, but will reach its full potential after one day.
- Response actions in Hot Zones will **NOT** result in significant exposures of 100 rem and higher.
- Caution should still be taken along the edges of the Hot Zone closest to the DFZ.

Hot Zone (0.01 R/h boundary)



In routine radiation emergency response entering the zone bounded by 0.01 R/h entails donning appropriate personal protective equipment (PPE) and being properly monitored for radiation. For a nuclear detonation, the 0.01 R/h line can reach a maximum extent of several hundred miles within hours of the incident.

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



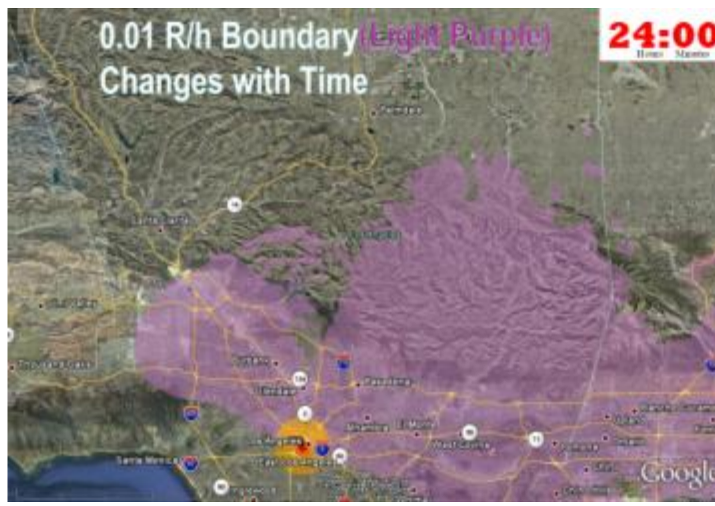
Hot Zone (0.01R/h Boundary) Changes with Time

•Just like the DFZ, the Hot Zone will change with time.

•This animation shows how the Hot Zone reaches its peak after about one day, than begins to recede.

This shows the first six hours after the detonation.

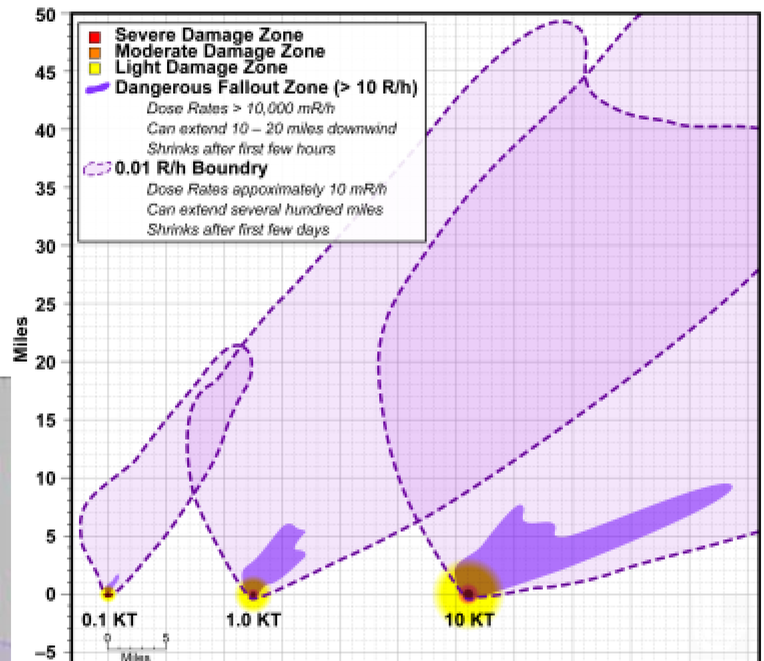
The Hot Zone is already shrinking in size.



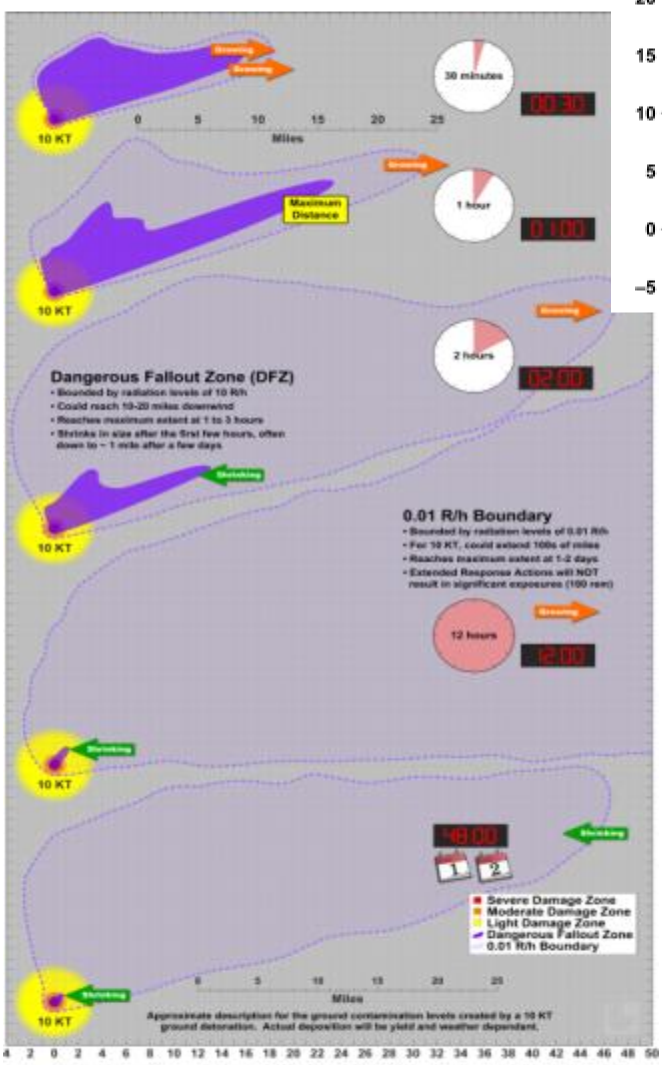
After 48 hours, the Hot Zone is greatly reduced.

0.01R/h Boundary Also Changes with Yield

- This graphic illustrates the maximum extent for several different low-yield, ground level explosions. Note how smaller yields create much smaller Hot Zones. The timing will also be accelerated and the fallout will reach the maximum extent much quicker.



Fallout Zone Timing



The Left Image estimates are based on a 10KT ground level detonation. Smaller yields will result in smaller effected areas and an accelerated timeline.

- In the first hour both the DFZ and the 0.01 R/h bounded areas are growing in size.
- After about an hour, the DFZ reaches its maximum extent while the 0.01 R/h boundary continues to expand as particles fall downwind.
- At a few hours the DFZ is shrinking, although the 0.01 R/h boundary continues to grow
- After about a day a both the DFZ and the 0.01 Boundary are shrinking, the DFZ may only be a mile in length.

Notes

Conclusions

- Fallout radiation hazards may exist ***on some parts*** of the Moderate and Light Damage zones, the safety precautions described in the Fallout section take precedent.

- Although detectable fallout may be found for hundreds of miles, the Dangerous Fallout Zone extends only 10s of miles and shrinks rapidly after the first few hours (for a 10KT)

- The 0.01R/h boundary, called the Hot Line by NCRP, maximizes at potentially several hundred miles after about a day, and then shrinks as well (for a 10KT).

- Although areas outside the DFZ are unlikely to cause radiation sickness, exposure to fallout should be minimized through shelter or evacuation if adequate shelter is unavailable and the evacuation can be completed before the fallout arrives.

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?