Nuclear Detonations - Consequences, Preparedness, and Response

Presented by:

United States Environmental Protection Agency

and

The Palladino Company, Inc.

Developed for:

United States Environmental Protection Agency, Region 9

Emergency Response Program

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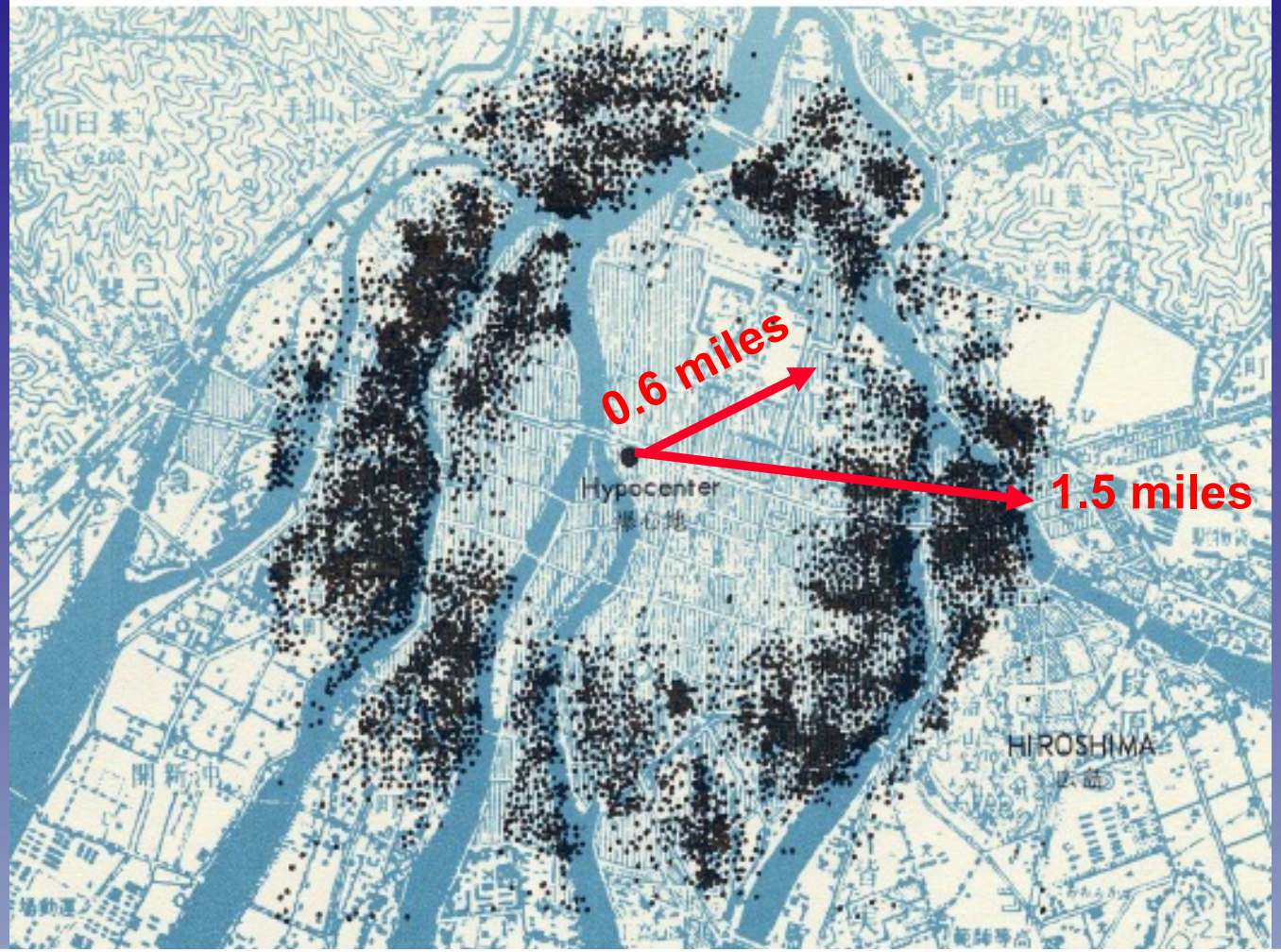
  Dade Moeller and Associates

How to Survive a Nuclear Detonation


FANDANGO
MOVIECLIPS

Hiroshima Injured Survivors

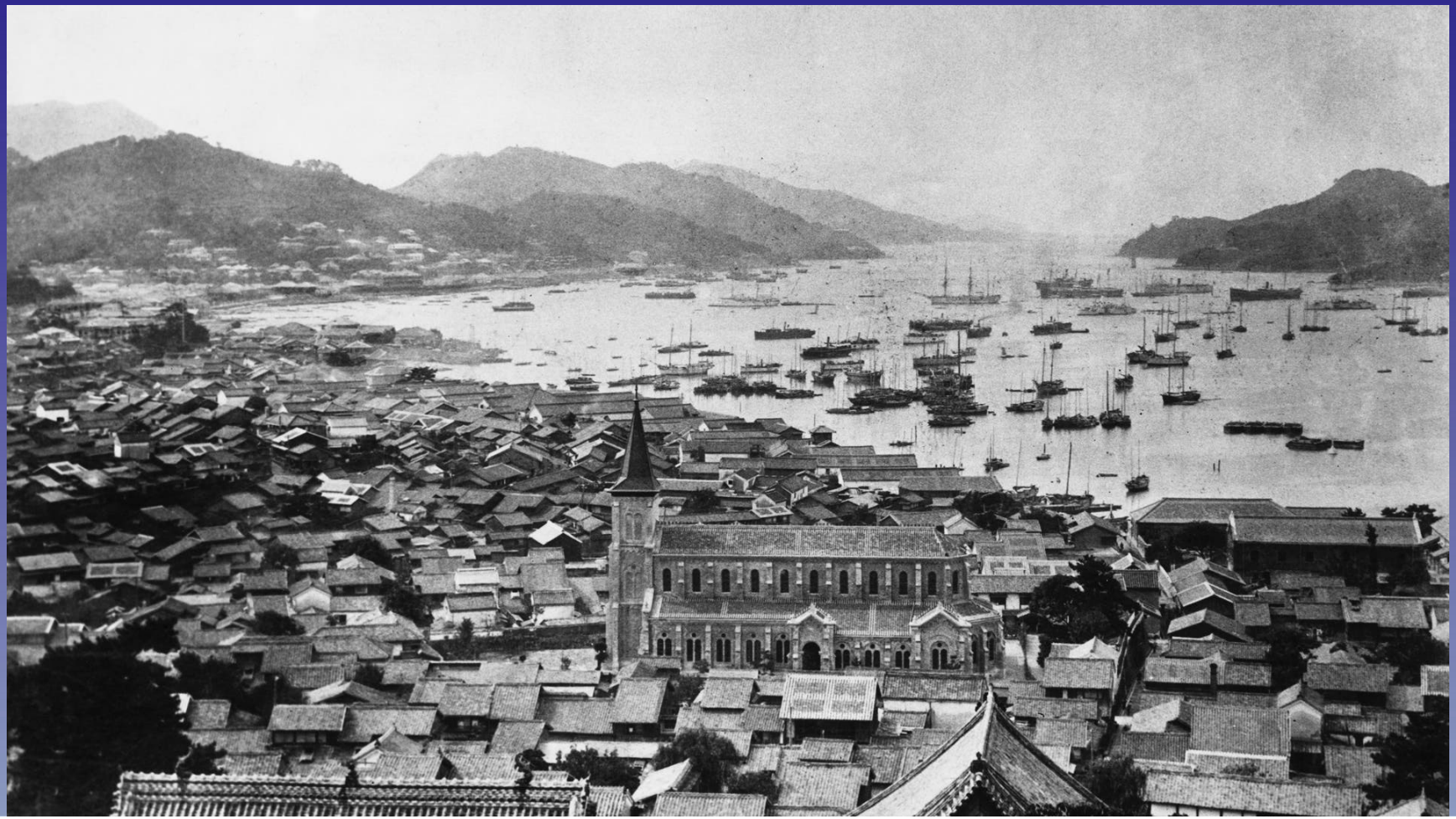


Hiroshima Pre-Detonation

Hiroshima Post-Detonation

Hiroshima Post-Recovery

Nagasaki Pre-Detonation



Nagasaki Post Detonation

Nagasaki Post-Recovery

Course Agenda

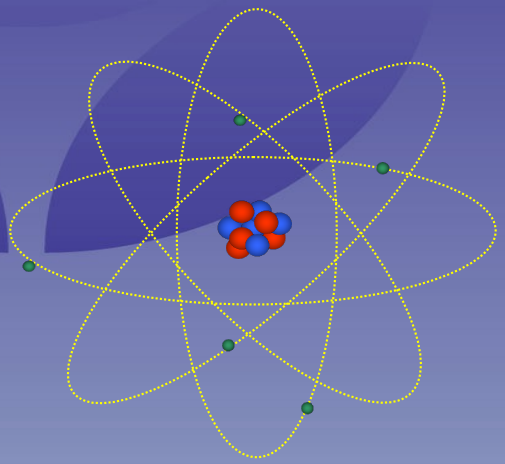
- Quick Radiation Review
- Basics of Nuclear Weapons
- Consequences
- Response
- Preparedness

Course Goals

- Reduce misconceptions of nuclear detonation consequences
- Provide awareness of nuclear detonation preparedness and response
- Increase public awareness and education

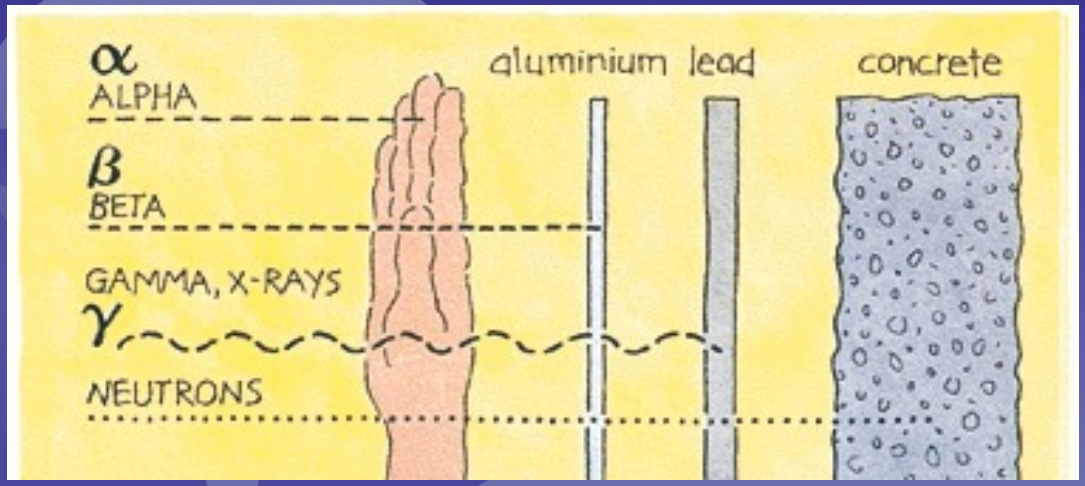
Quick Review

But I ALREADY know it all!



Types of Nuclear Radiation

- Alpha Particles
- Beta Particles
- Gamma Rays
- Neutrons



Units

- Important!!
- Primary cause of miscommunication in radiation response
- Conventional and System International (SI) are very different

Counts Per Minute (cpm)

- **Counts per minute (cpm)** is a relative measurement to compare to background or a predefined action level
- cpm ≠ activity
- cpm ≠ exposure
- cpm ≠ dose

Roentgen (R)

- **Roentgen** (ran-'kin) - ionization of air by gamma radiation

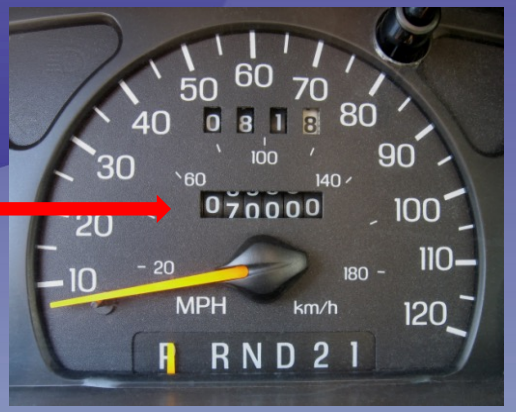
- Exposure rate is like a speedometer
- Rate of exposure
  - **microRoentgen per hour (μR/hr)**
  - **milliRoentgen per hour (mR/hr)**

- Roentgen ≠ radiation dose to people

Roentgen Equivalent Man (rem)

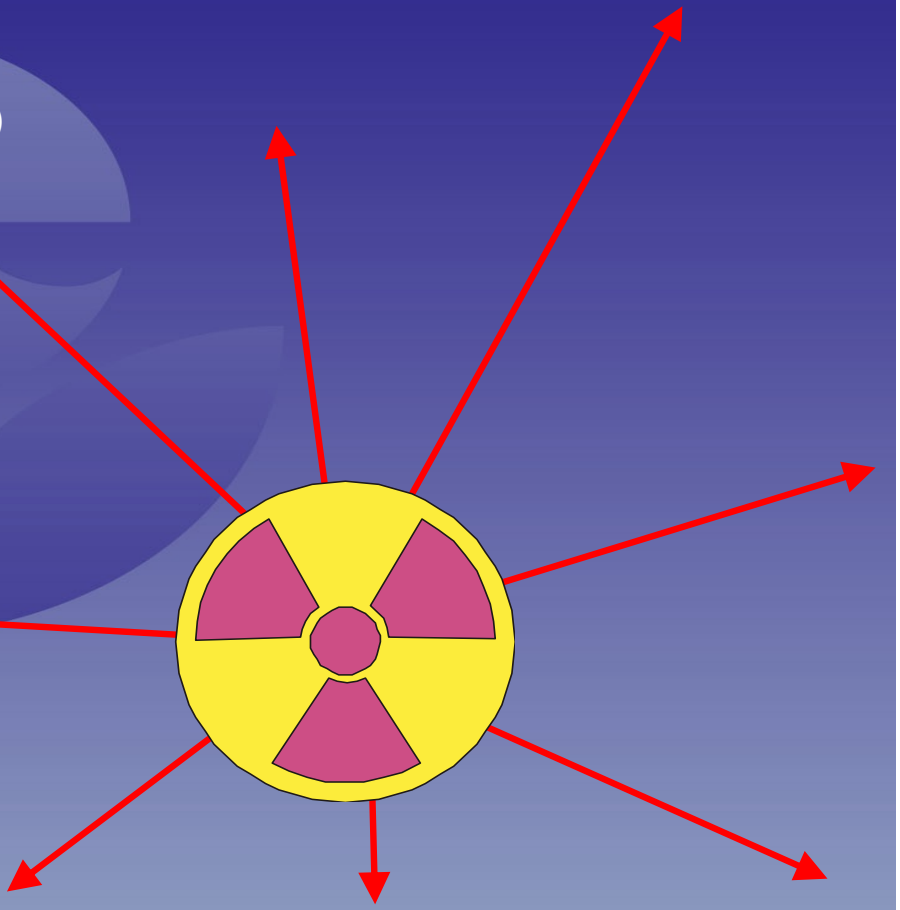
- Rem = amount of damage (dose) to human tissue
  - 1 R ≈ 1 rem (gamma or beta only)
  - 1 R ≈ 20 rem (alpha **internal exposure**)

- 1 rem = 0.01 **Sievert (Sv)** - International units
  - 100 rem = 1 Sv
  - 100 mrem = 1 mSv
- Rem is like an odometer

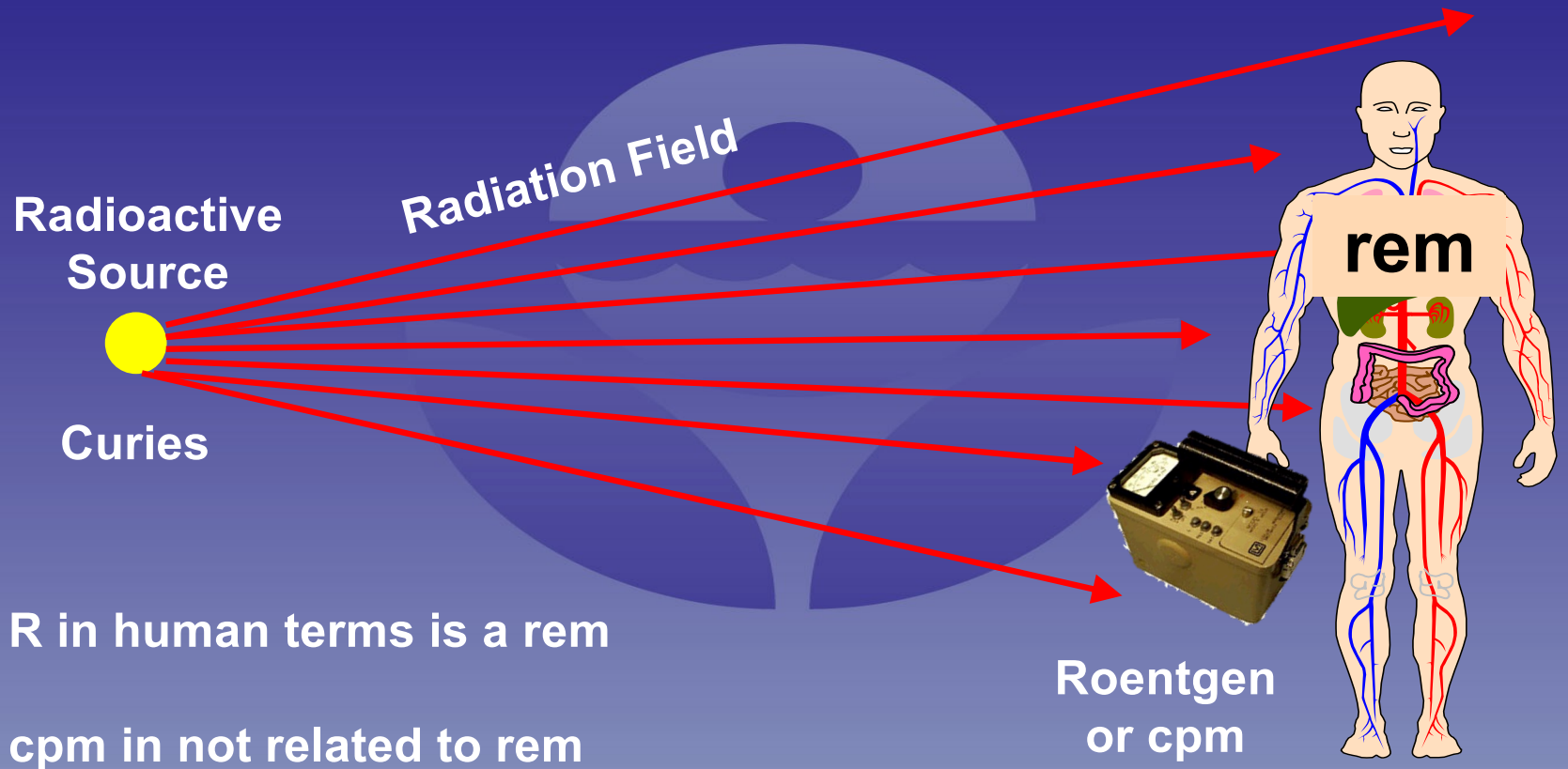


Activity

- **Curies (Ci)** = radioactivity of material
  - 1 Ci = 37 billion disintegrations per second (dps)
- **Becquerel (Bq)** is international unit
  - 1 Bq = 1 dps
  - 1 Ci = 37 billion Bq



Measurement Illustrated

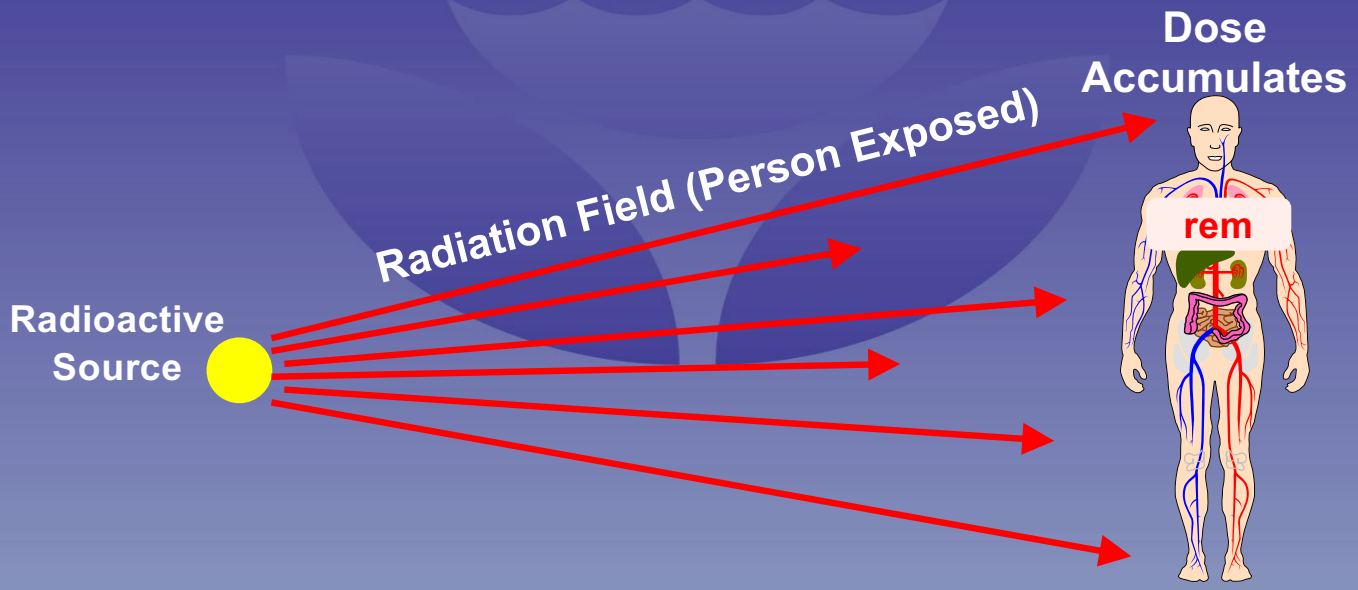


R in human terms is a rem

cpm in not related to rem

Exposure and Dose

- Exposure = radiation interacting with your body
- Dose = damage to your tissue from exposure over time



Units Mnemonic

μR = OK

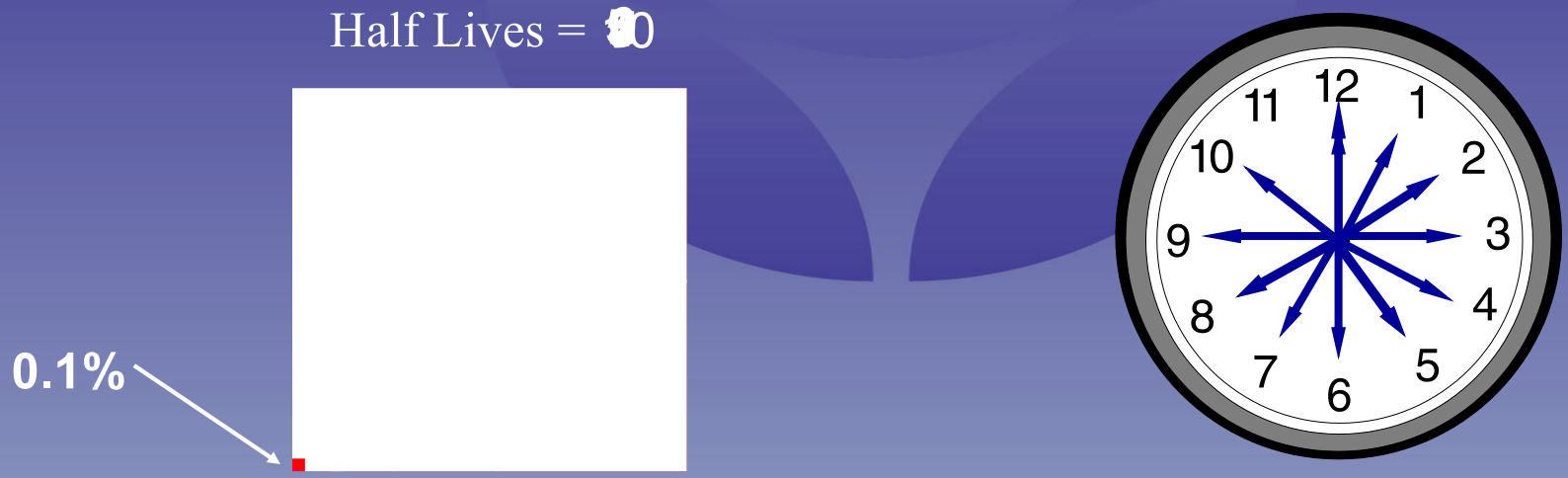
mR = Maybe

R = Rethink

RUN!

Half-Life ($T_{1/2}$)

- **Half-Life ($T_{1/2}$)** = time for radioactivity to decrease in half
- 7 to 10 half-lives until near background
- Example: half-life = 1 hour

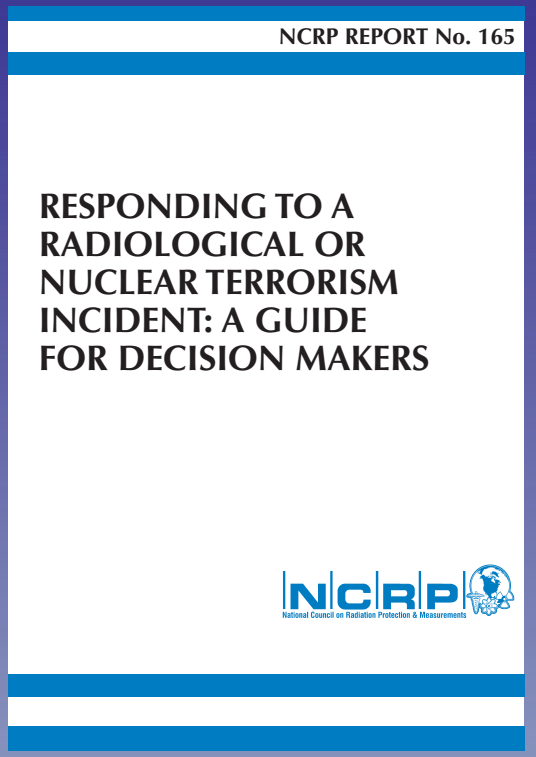


Action Levels

- Occupational whole body dose limit = 5 rem/yr
- Emergency worker whole body dose limits (EPA-recommendation)
  - 5 rem = All activities
  - 10 rem = Protecting valuable property
  - 25 rem = Lifesaving or protection of large populations
  - >25 rem = Lifesaving or protection of large populations on voluntary basis only
- Hot zone = 2 mR/hr (typically)
- Contamination = Twice background (typically)

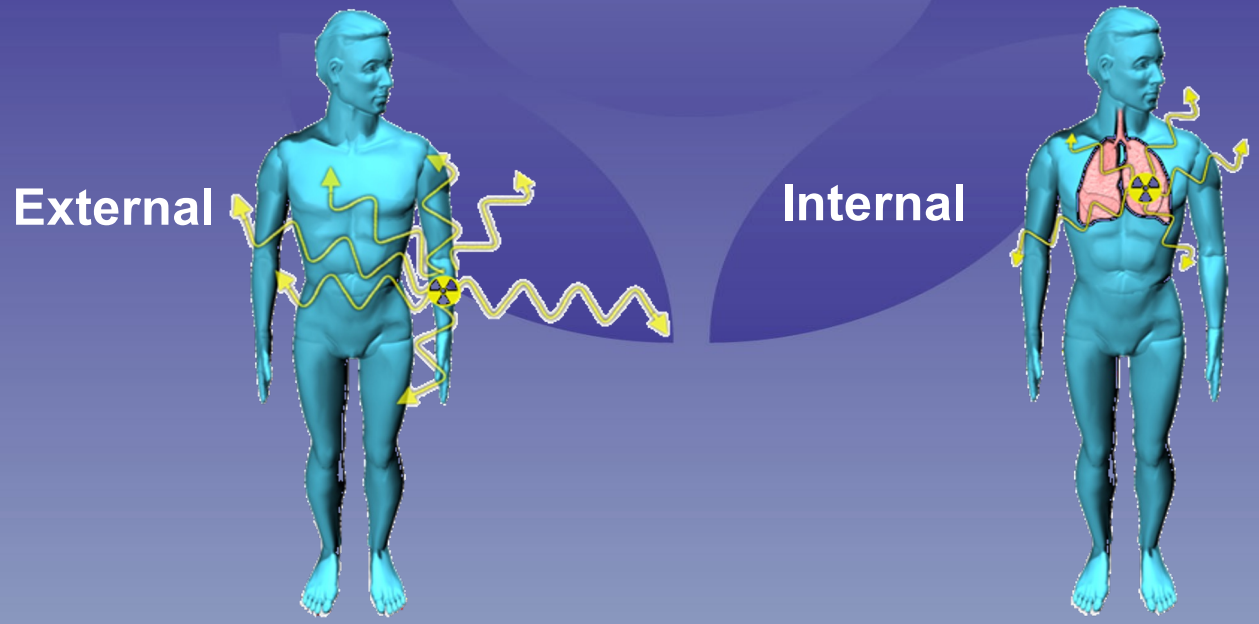
NCRP Action Levels

- National Council on Radiation Protection & Measurements (NCRP)
- Recommends hot zone limits:
  - Exposure rate: 10 mR/hr gamma
  - Surface contamination
    - 60,000 dpm/cm^2 beta/gamma (~180,000 cpm pancake probe)
    - 6,000 dpm/cm^2 alpha (~18,000 cpm with alpha probe)
    - dpm = disintegrations per minute
- Recommends dose limit: 50 rem
- Recommends dangerous radiation zone: 10 R/hr



Exposure Misconception

- You <u>cannot</u> become radioactive if exposed to radiation!
- You are contaminated if a radioactive material is *<u>on</u>* (external) or *<u>in</u>* (internal) your body



Examples of PPE

Instruments

Gamma detector (exposure rate) →

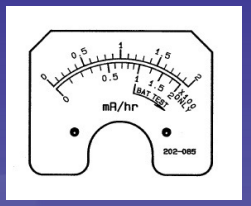
← **Real time dosimeter (dose)**

Decontamination (cpm) →

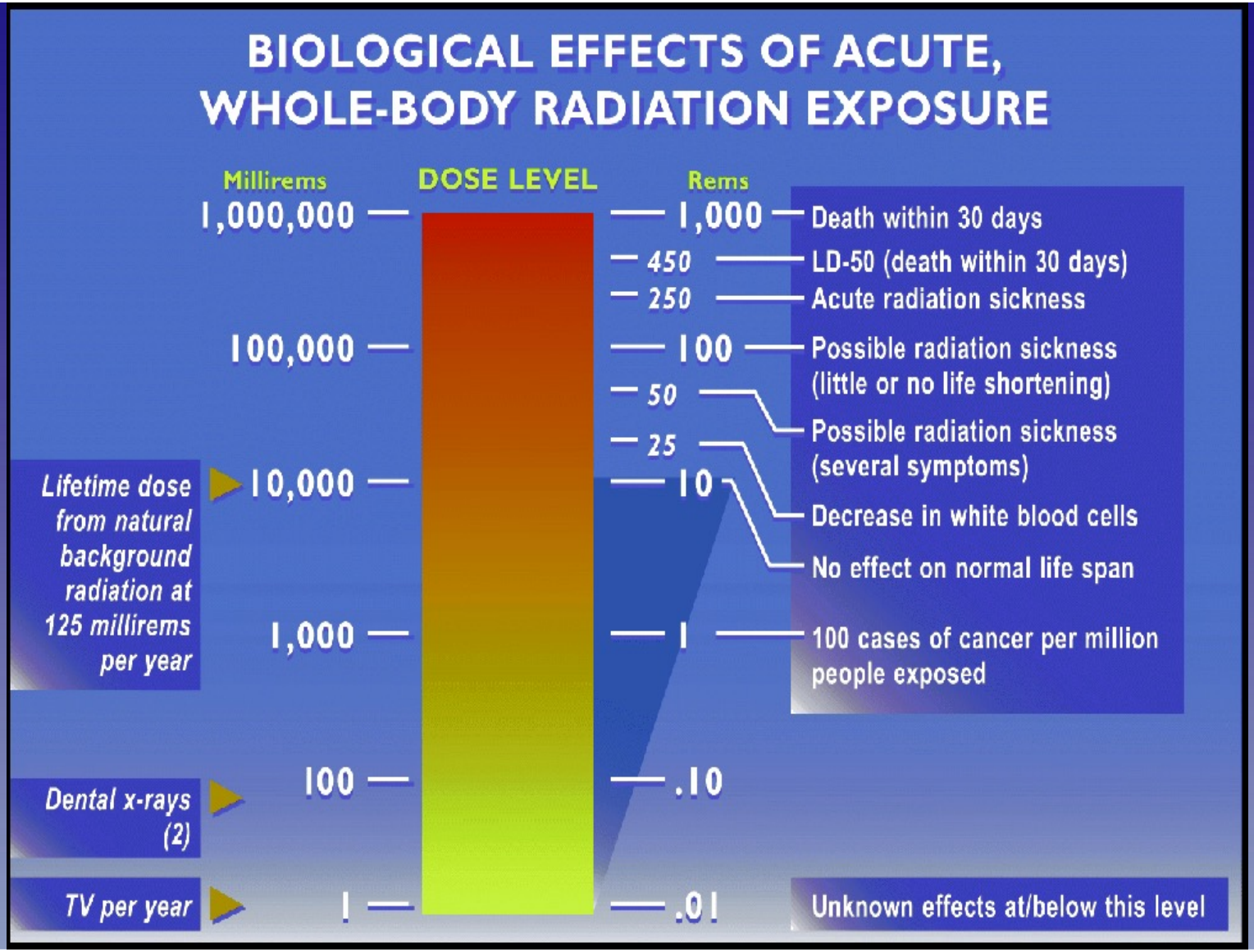
Instrument Readings

- Understand the reading on your instruments

- Units
  - µR/hr = microRoentgen per hour
  - mR/hr = milliRoentgen per hour
  - µR = microRoentgen
  - mR = milliRoentgen
  - cpm = counts per minute
  - c/m = counts per minute
  - kc/m = kilocounts per minutes or thousand counts per minute (1000 times the reading)



Chernobyl Firefighter Injury

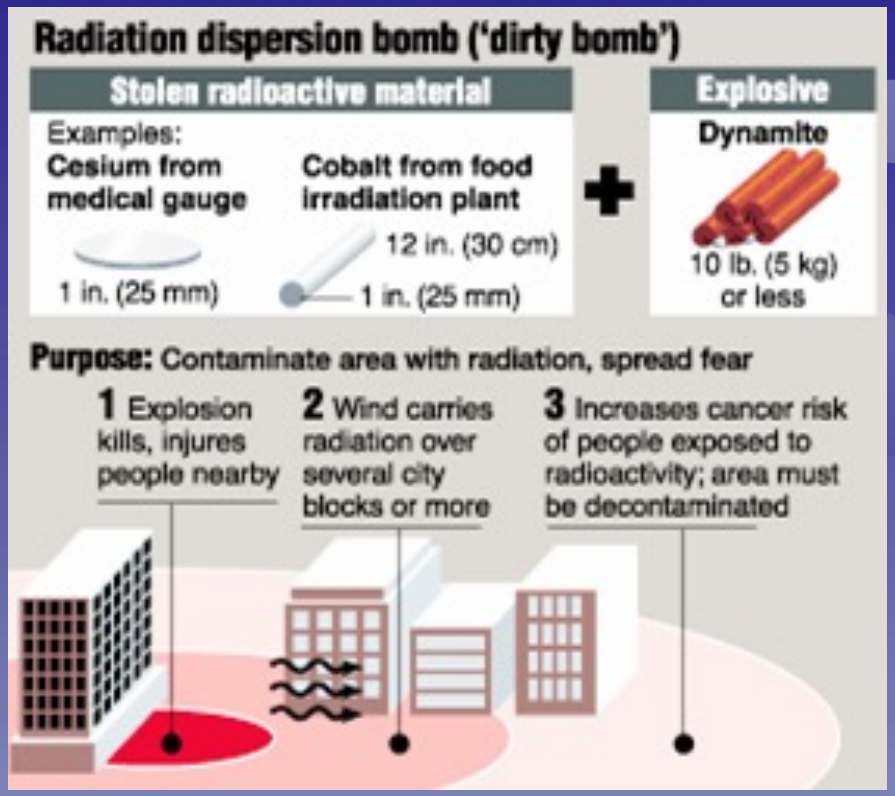

BIOLOGICAL EFFECTS OF ACUTE, WHOLE-BODY RADIATION EXPOSURE
Millirems
DOSE LEVEL
Rems
1,000,000
1,000
Death within 30 days
450
LD-50 (death within 30 days)
250
Acute radiation sickness
100,000
100
Possible radiation sickness (little or no life shortening)
50
Possible radiation sickness (several symptoms)
25
Decrease in white blood cells
Lifetime dose from natural background radiation at 125 millirems per year
10,000
10
No effect on normal life span
1,000
1
100 cases of cancer per million people exposed
100
.10
Dental x-rays (2)
TV per year
1
.01
Unknown effects at/below this level

Gamma Radiation Dose Rate (Rate/hour)	Stay Time to Receive This Radiation Dose				
	1 rem	5 rem	10 rem	25 rem	50 rem
1 mR/hour	6 weeks	30 weeks	13 months	2.8 years	5.5 years
5 mR/hour	200 hours	6 weeks	12 weeks	30 weeks	1 year
100 mR/hour	10 hours	50 hours	100 hours	250 hours	3 weeks
1 R/hour	1 hour	5 hours	10 hours	25 hours	50 hours
10 R/hour	6 minutes	30 minutes	1 hour	2.5 hours	5 hours
100 R/hour	36 seconds	3 minutes	6 minutes	15 minutes	30 minutes
200 R/hour	18 seconds	1.5 minutes	3 minutes	7.5 minutes	15 minutes
500 R/hour	7 seconds	36 seconds	72 seconds	3 minutes	6 minutes

Questions?

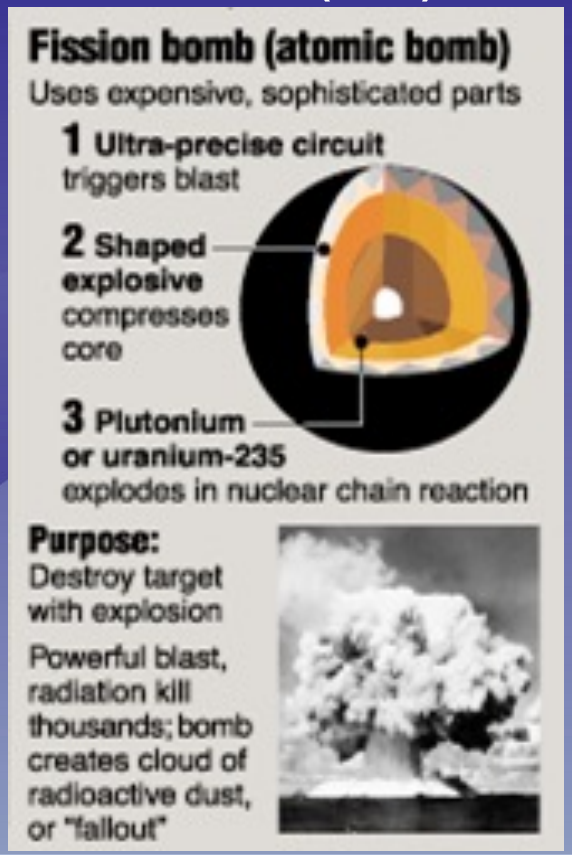
Basics of Nuclear Weapons

RDD versus IND



Radiological Dispersal Device (RDD)

Improvised Nuclear Device (IND)



RDD versus IND Effects

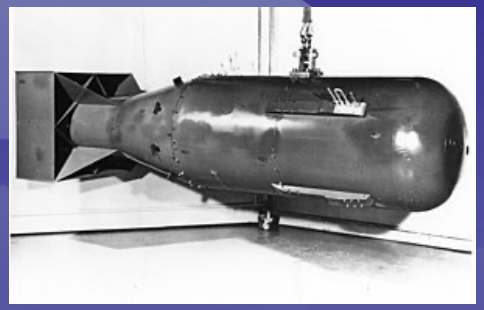
Characteristic	Sr-90 RDD	10kT IND
Activity (Ci)	~ 30,000 max	~ 300 billion
Yield (TNT)	Pounds to tons	kilotons
Affected area (km^2)	1 to 10	1,000s
Lethal Radiation Doses	Few to 100s	1,000s
Contamination	Significant	Lethal
Control	Local	Regional
Response Entry	PPE	Dose constrained

Nuclear Detonation Response Overview

https://www.youtube.com/watch?v=EueJrCJ0CcU

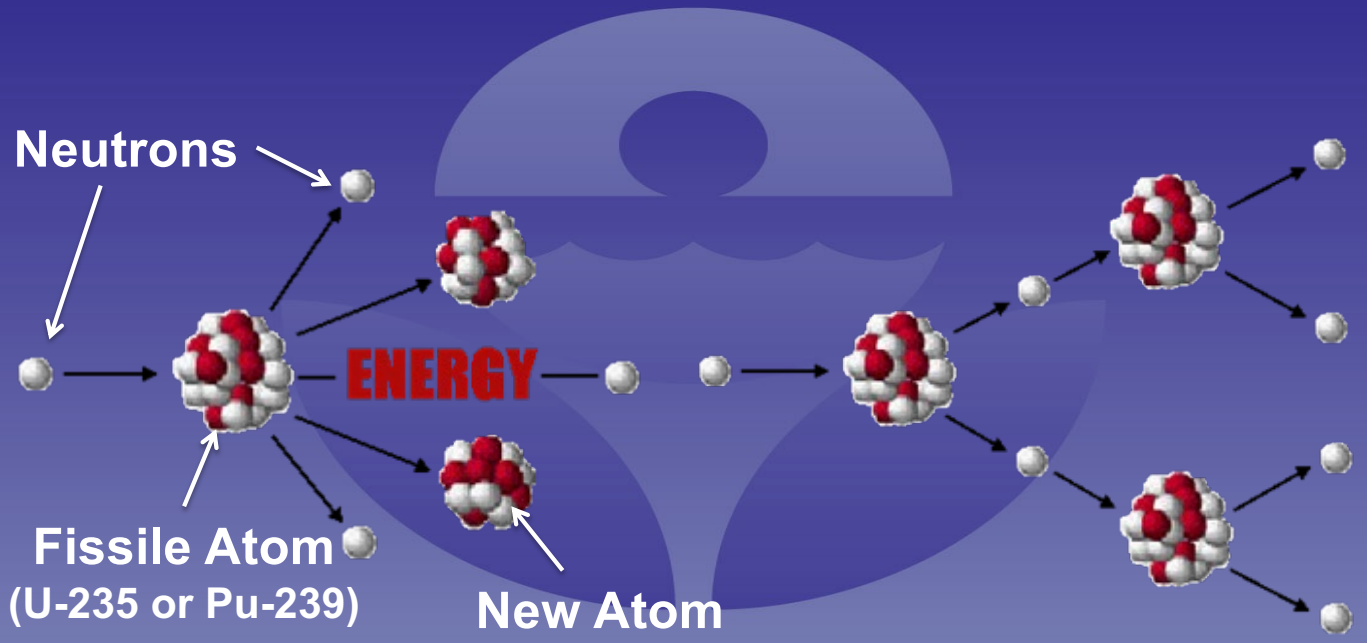
Types of Nuclear Weapons

- Fission (Uranium-235 or Plutonium-239)
  - Gun
  - Implosion



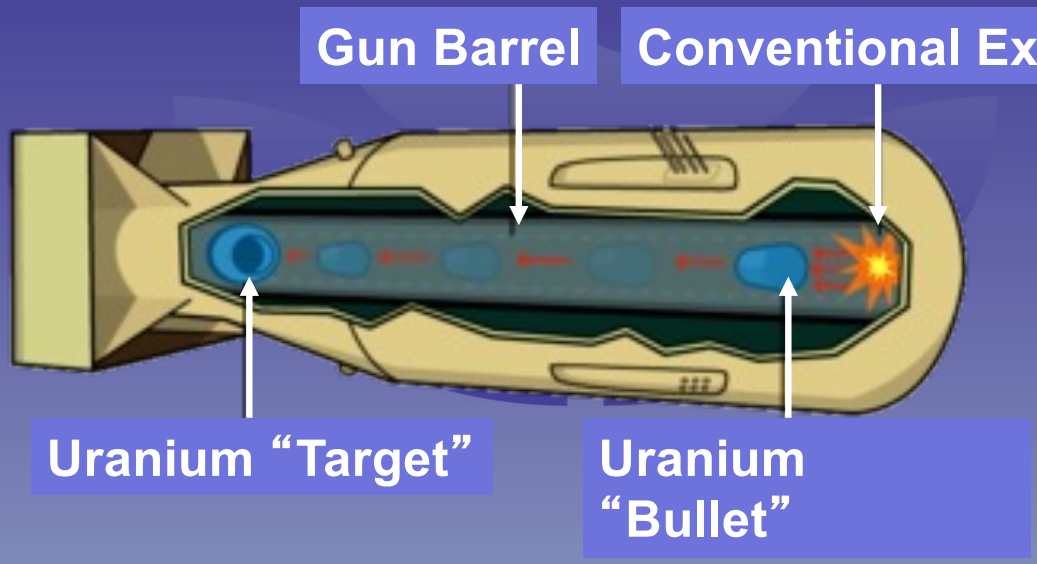
- Fusion (Thermonuclear)
  - Hydrogen

Nuclear Fission



Fission Gun Type

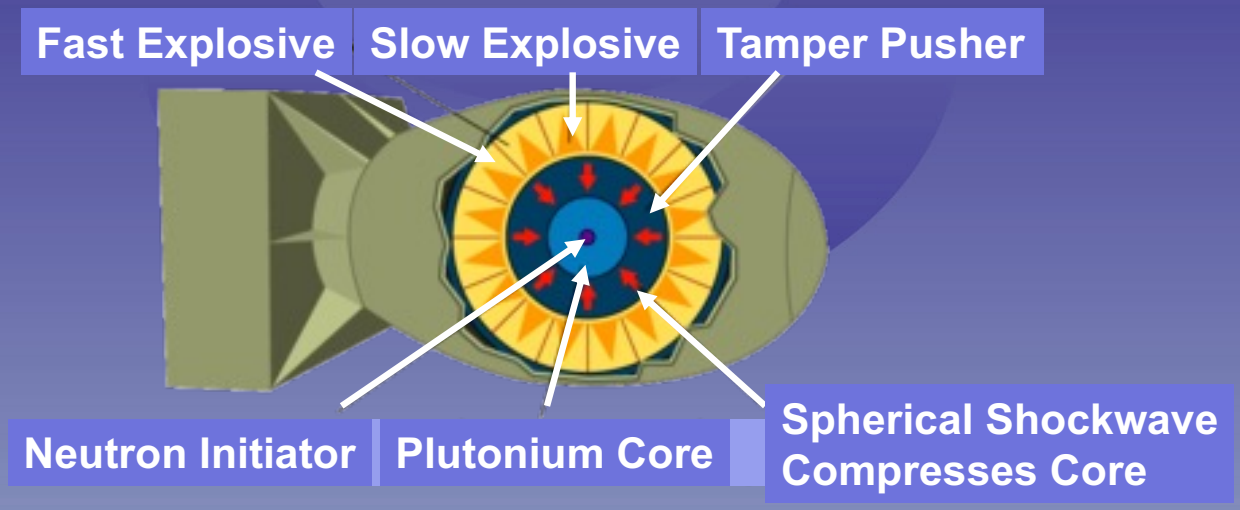
- Two subcritical pieces are quickly forced together
- Critical mass reached with instantaneous explosion



Little Boy (Hiroshima)

Fission Implosion Type

- Subcritical material quickly compressed by explosives
- Critical mass achieved with instantaneous explosion



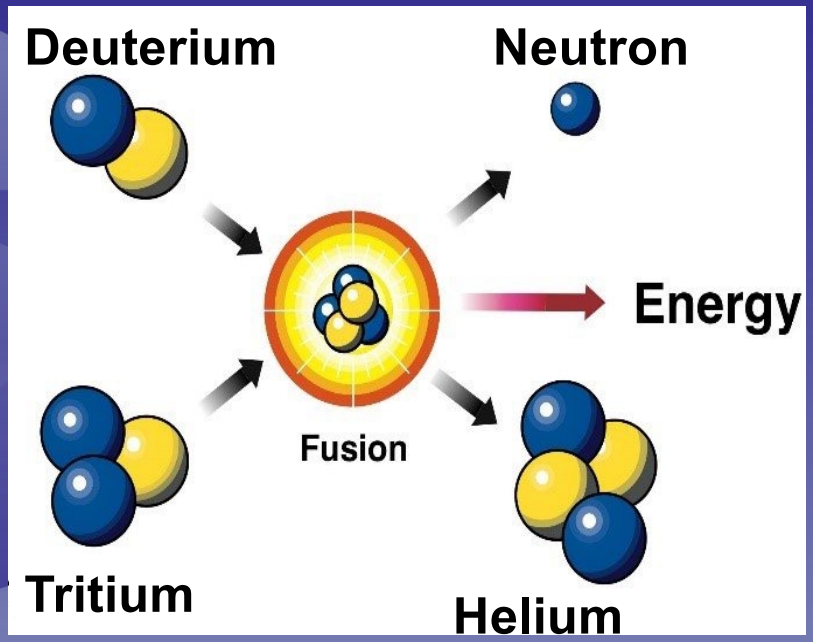
Fat Man (Nagasaki)

Suitcase Nuclear Bomb

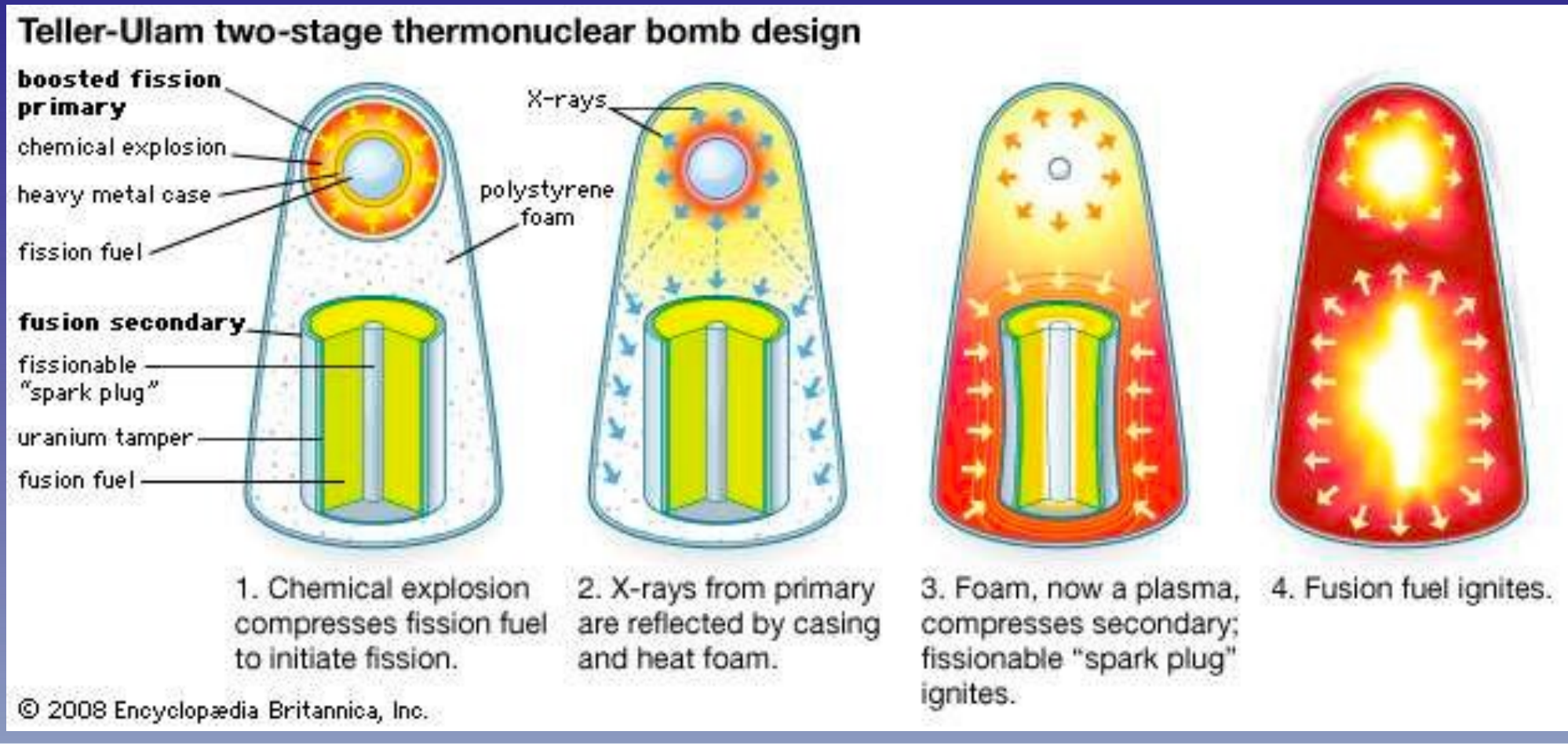
Mock-up of a hypothetical "suitcase" nuclear bomb, made by Congressional staffer Peter Pry; a 105 mm artillery shell device packaged in a large briefcase.

Nuclear Fusion

- Combination of hydrogen isotopes
  - Deuterium (H^2)
  - Tritium (H^3)
- Initiated by a fission reaction to obtain temperature in the **millions** of degrees
- Called a thermonuclear explosion
- Yields over Mega Tons (MT) are possible
  - 1 pound of deuterium yields 26,000 tons of TNT



Thermonuclear Bomb



Performance

- Energy is released
  - 1 pound of U-235 or Pu-239 yields 8,000 tons of TNT
- Fizzle – a “dud”
  - Sub-yield explosion
  - More contamination and fallout
  - Less explosive force, thermal output, fission products, and neutrons
- Yield does not substantially affect response

Performance

Performance

- Energy is released
  - 1 pound of U-235 or Pu-239 yields 8,000 tons of TNT
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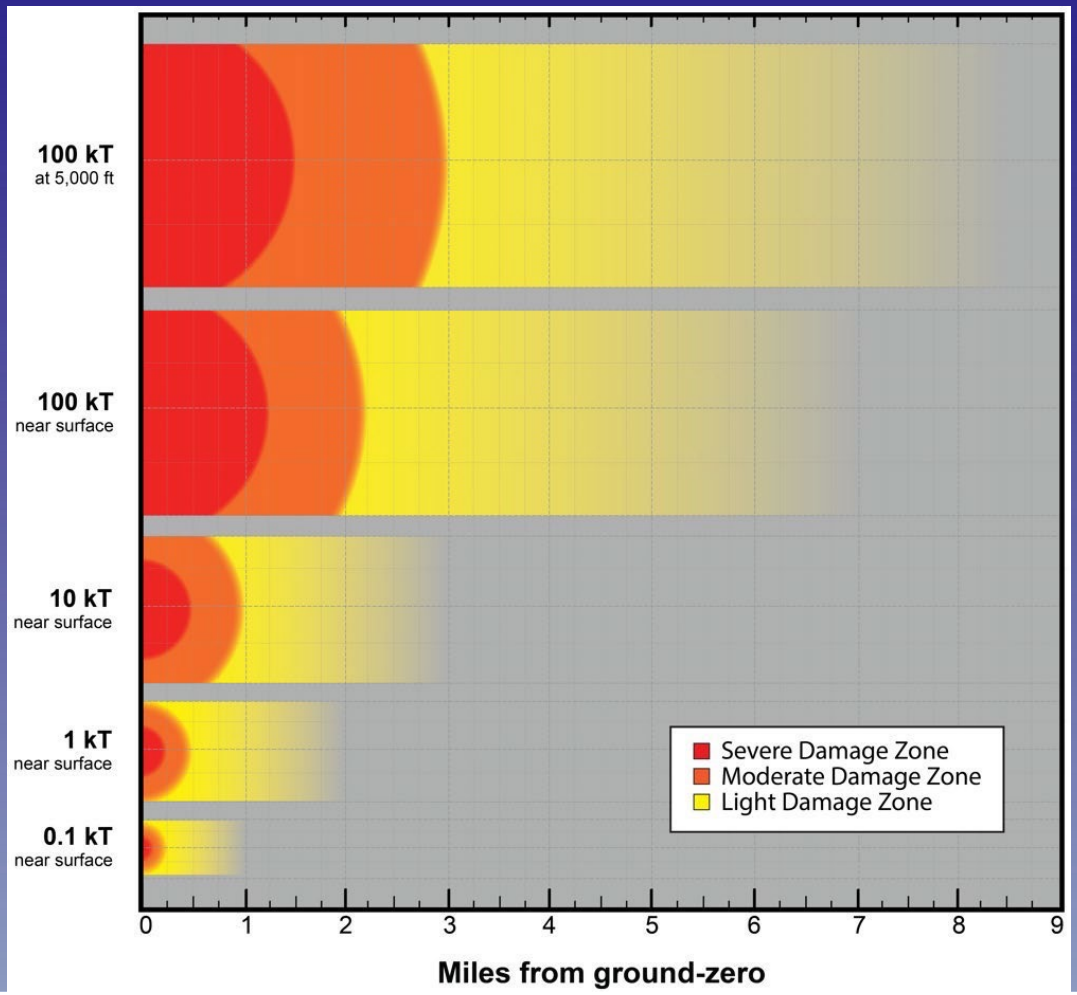
Yield

- 1,000 tons of TNT = 1 kiloton (kT)
- 1,000,000 tons of TNT = 1 megaton (MT)
- 2 tons of TNT – Oklahoma City bomb (non-nuclear)
- 0.1 to 10 kT – Possible terrorist IND (likely)
- 20 kT – Hiroshima and Nagasaki
- 50 MT – Tsar Bomba (Russian)
- 0.1 kT to 50 MT – Military range

Yield and Ground versus Air Burst

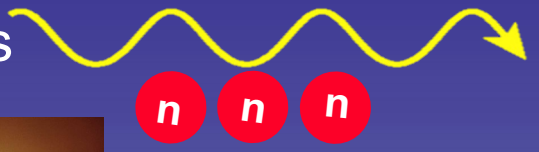


Detonation Effects

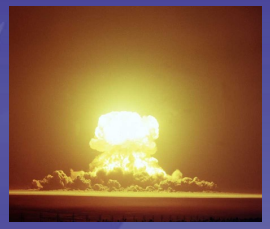
Primary Characteristics

- Electromagnetic Pulse (EMP)

- Prompt nuclear radiation – gamma, X-rays, neutrons



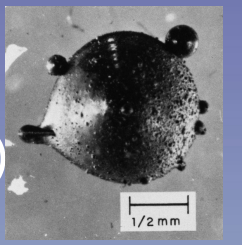
- Thermal radiation and fireball (light and heat)



- Blast/Shock wave

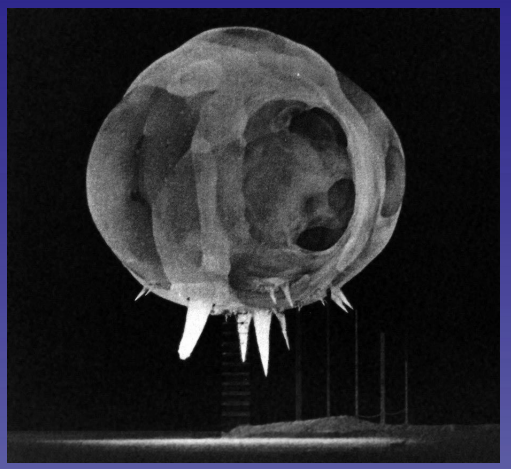
- Mushroom Cloud (may not see if ground detonation)

- Residual nuclear radiation – fallout and induced (neutron activation)

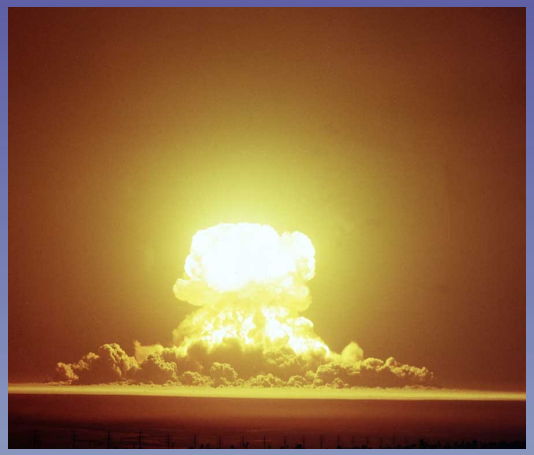


Progression of a Fission Detonation

1. Less than a millionth of a second of detonation
   - Temperature is several tens of millions of degrees
   - Pressure is over million times atmospheric pressure
   - Releases large amounts of energy as X-rays



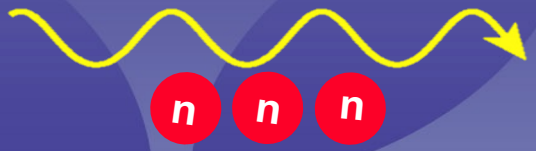
2. Formation of a hot and luminous fireball
   - Light seen from many miles away
   - Expands rapidly rising above the ground surface
   - All materials including soil, buildings, etc. are vaporized



Progression of a Fission Detonation

3. Thermal radiation created – visible and
   - Causes skin burns
   - Causes fires in flammable materials

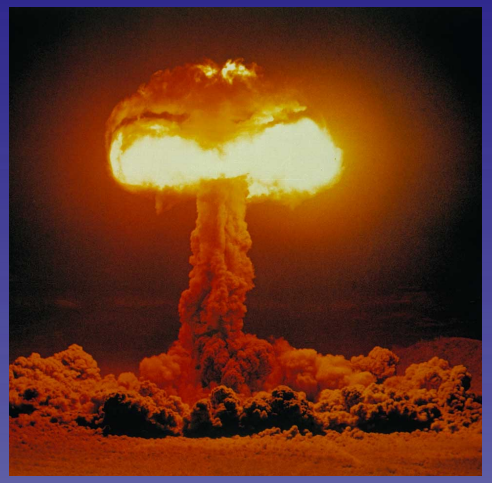
4. Prompt nuclear radiation created within first minut
   - Gamma and neutrons



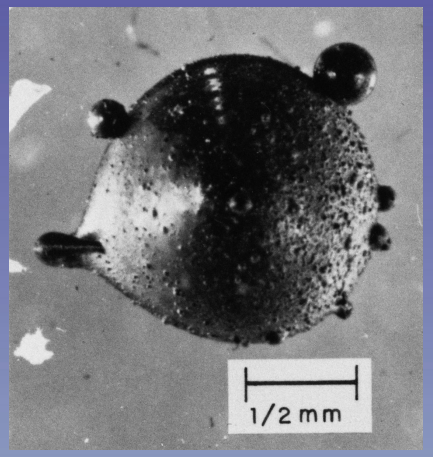
5. Blast/shock wave moves faster than speed of sound
   - High pressure shock front with wind over 100 mph
   - Partial vacuum forms behind shock front

Progression of a Fission Detonation

6. Formation of a mushroom cloud
   - Expands rapidly rising at about 200 mph
   - Vapor cloud forms from water, debris and soil
   - Cloud would reach about 30,000 feet

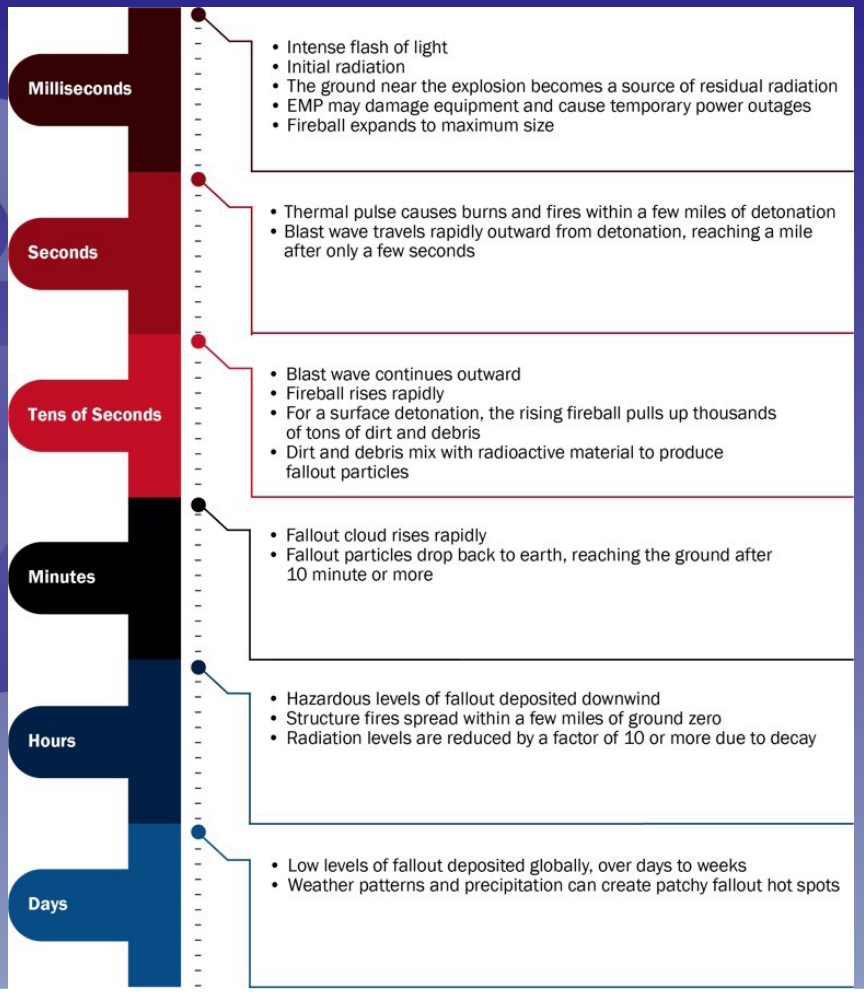


7. As fireball cools, contaminated particulate and water droplets fall to ground surface (ground burst produces much more fallout than air burst)

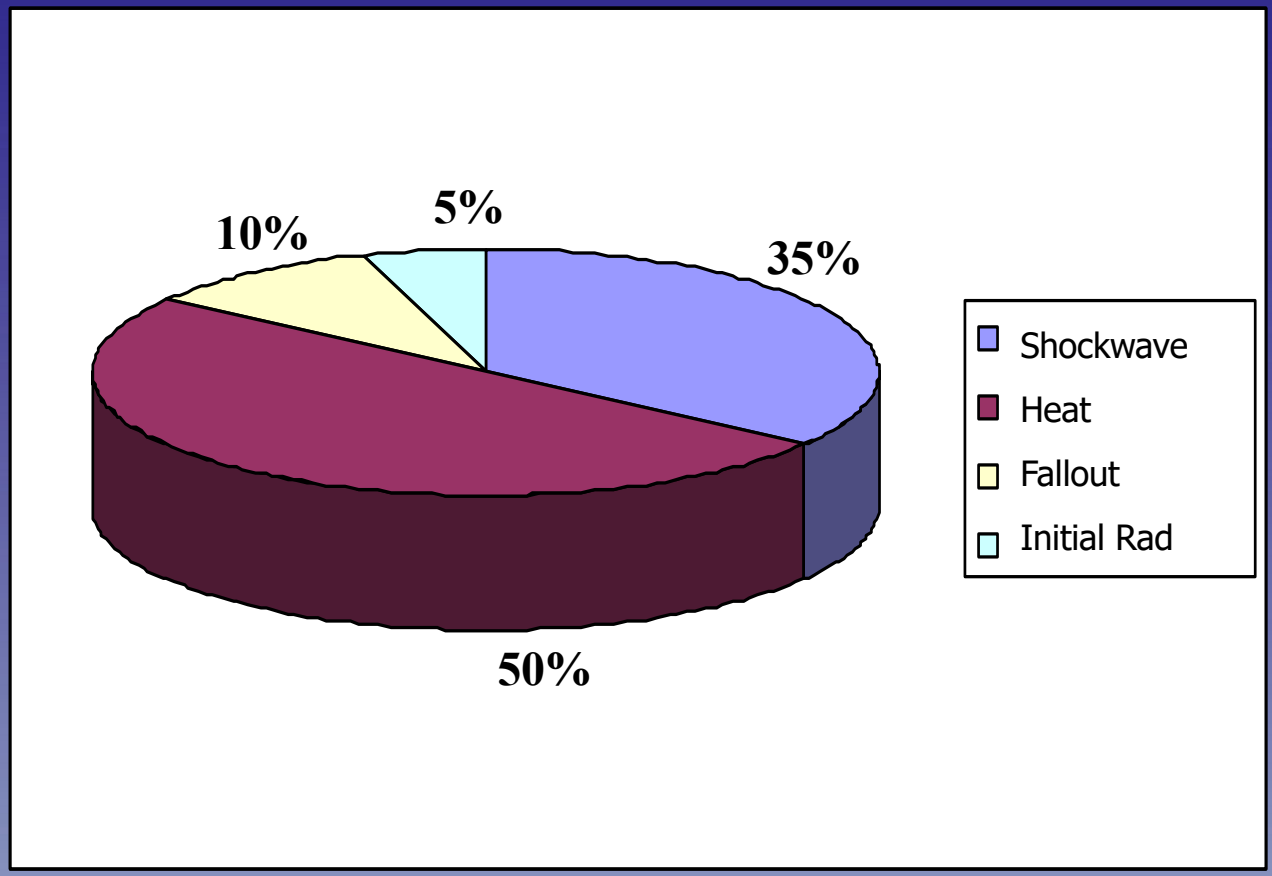


Timeline

- See page 24 of Planning Guidance for Response to a Nuclear Detonation, 3rd edition which has details from milliseconds to days.



Energy Distribution



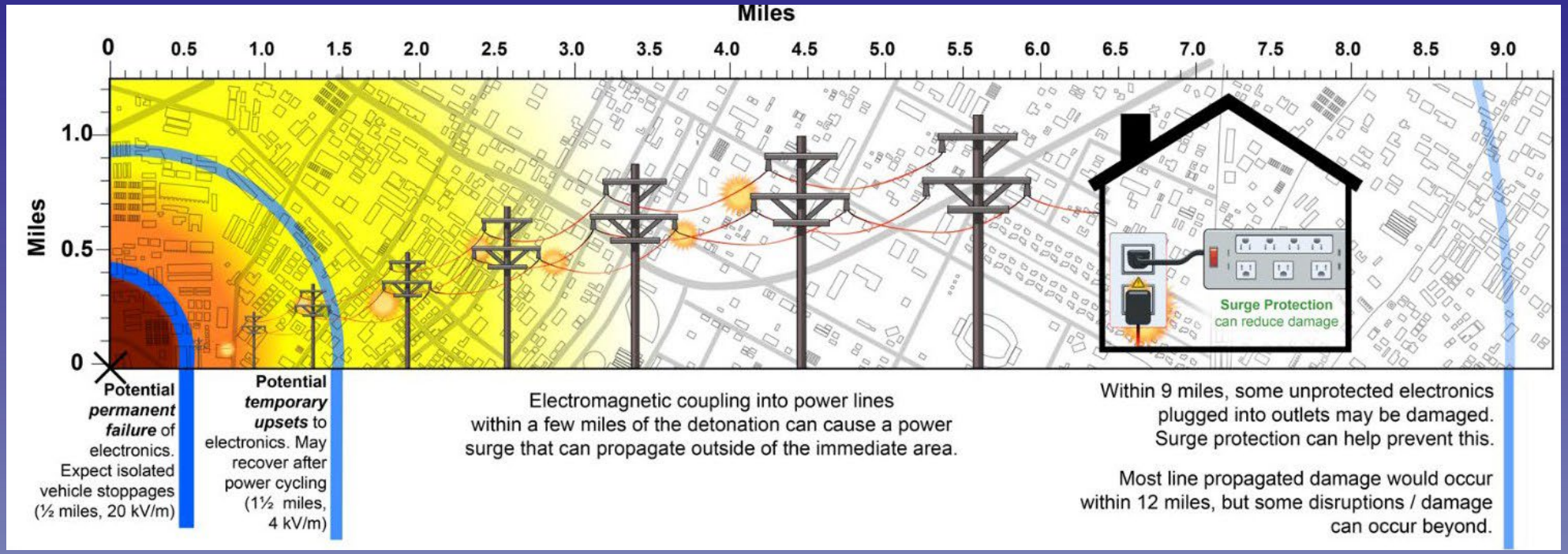
EMP Effects

- Opportunistic – affects unprotected electronics
- More sophisticated technology is more likely to fail
- Shielding of electronics is most important
- Unknown what electronics will work after EMP
- One time occurrence after detonation
- Distance from EMP affects impact

EMP Impacts

- Airplanes
- Vehicles
- Radios
- Computers
- Anything with a microchip

EMP Propagation



Heat and Light

- Heat
  - Several tens of millions of degrees
  - Relatively localized
  - Instantaneous vaporization near ground zero
- Light
  - Initial flash causes temporary (seconds to minutes) or permanent blindness
  - Light can be seen for 10s of miles away
  - Nighttime flash has greater impact at further away

Fire

- Intense heat can cause fires before the blast wave
- After blast wave, fires can continue
- Fires caused most of the destruction at Hiroshima but not at Nagasaki (due to hilly terrain)

Blast Wave

- Highly destructive with positive and negative shock wave

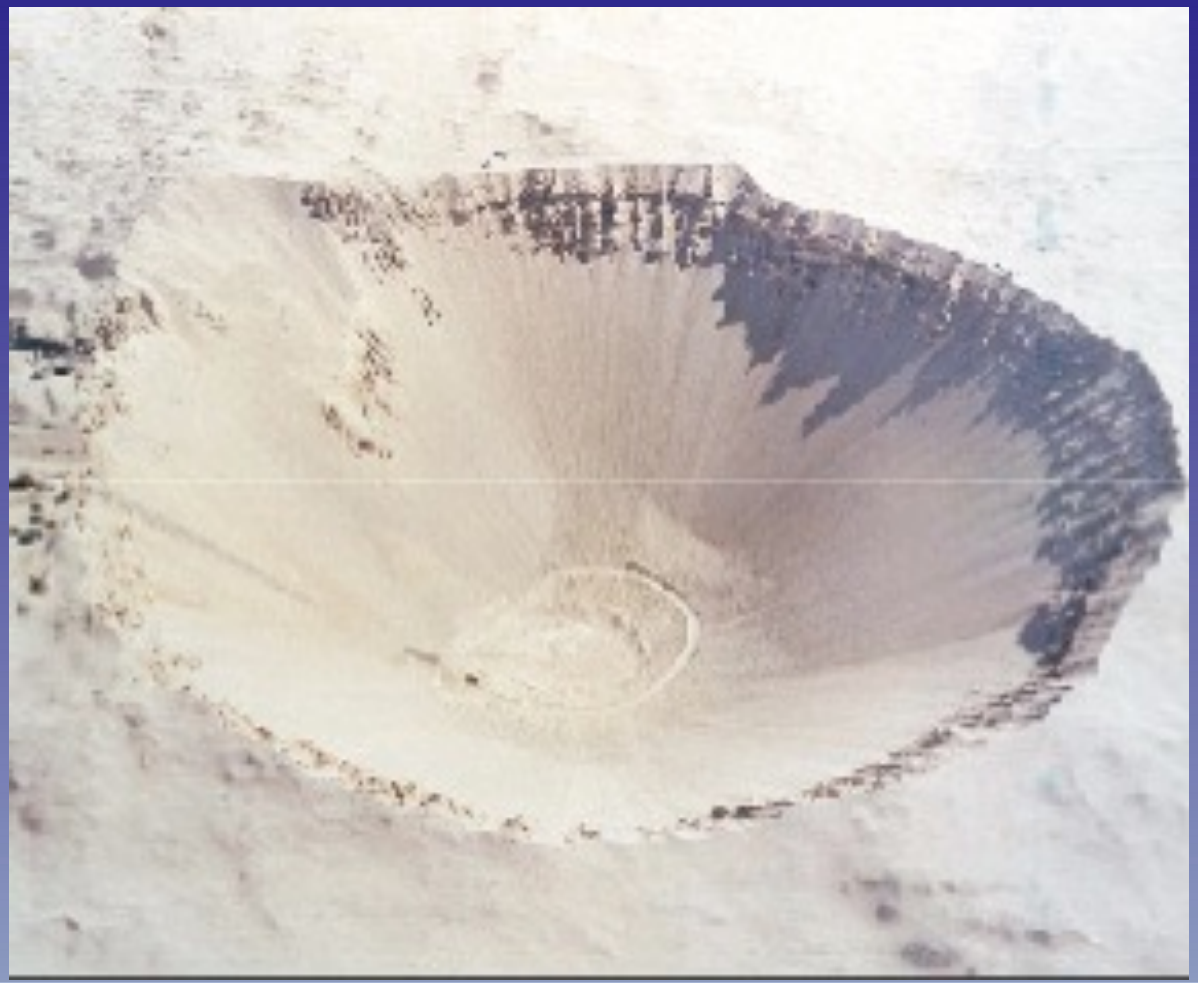
Estimated Impacts

Bomb Size TNT Equivalent	Radius of Total Destruction	Radius of 400 rem Mid-Lethal Dose (LD 50/60)	Radius of Moderate Thermal Skin Burns
20 Kiloton	0.6 Miles	0.8 Miles	1.9 Miles
1 Megaton	2.0 Miles	1.4 Miles	6.5 Miles
10 Megaton	5.0 Miles	2.0 Miles	10.0 Miles

Blast Damage

- Wall of highly compressed air
- Causes majority of deaths and injuries
- Indirect blast effects on infrastructure
  - Damaged buildings and structures
  - Downed power and phone lines
  - Leaking gas lines
  - Broken water mains
  - Weakened bridges and tunnels

Sedan Crater

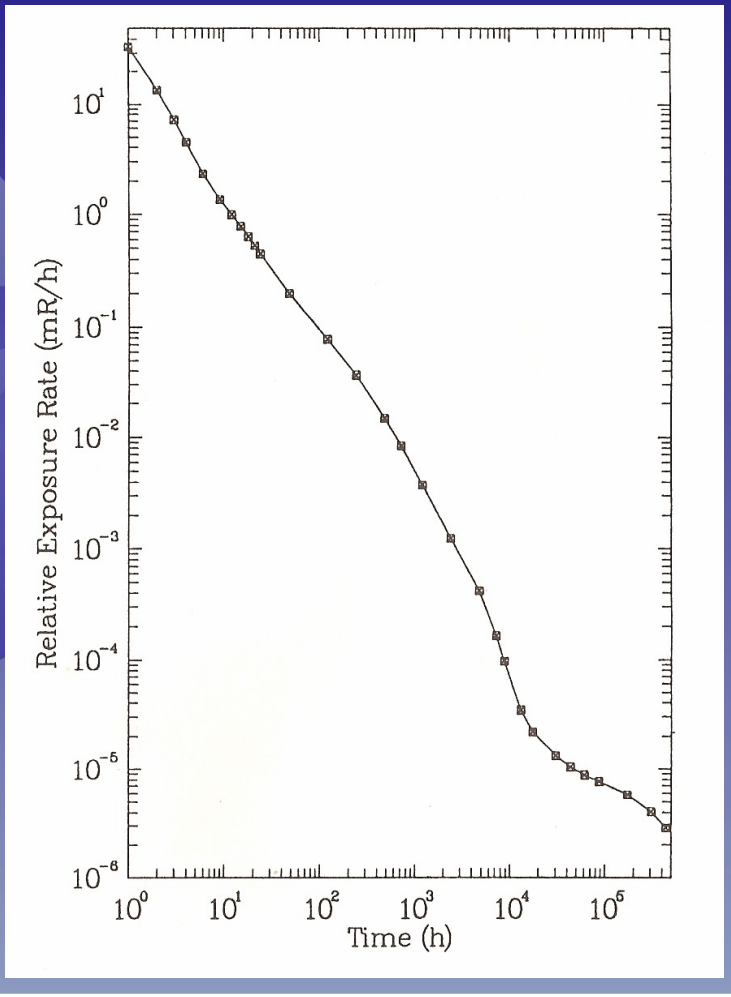


Nuclear Radiation

- Initial burst of ionizing radiation
- Residual radiation
  - “Activated” objects
  - Fallout
  - Radioactive decay

Fallout Decay

- Fission products
- Activation products
- Unspent fuel
- Exposure rate decreases quickly
- Every 7-fold increase in time = 10-fold decrease in exposure rate



Rule of Seven

Initial Radiation Dose Rates Remaining

Time	Percent	Example
0 hours	100%	1000 R/hr
7 hours	10%	100 R/hr
49 hours (2 days)	1%	10 R/hr
343 hours (14 days)	0.1%	1 R/hr

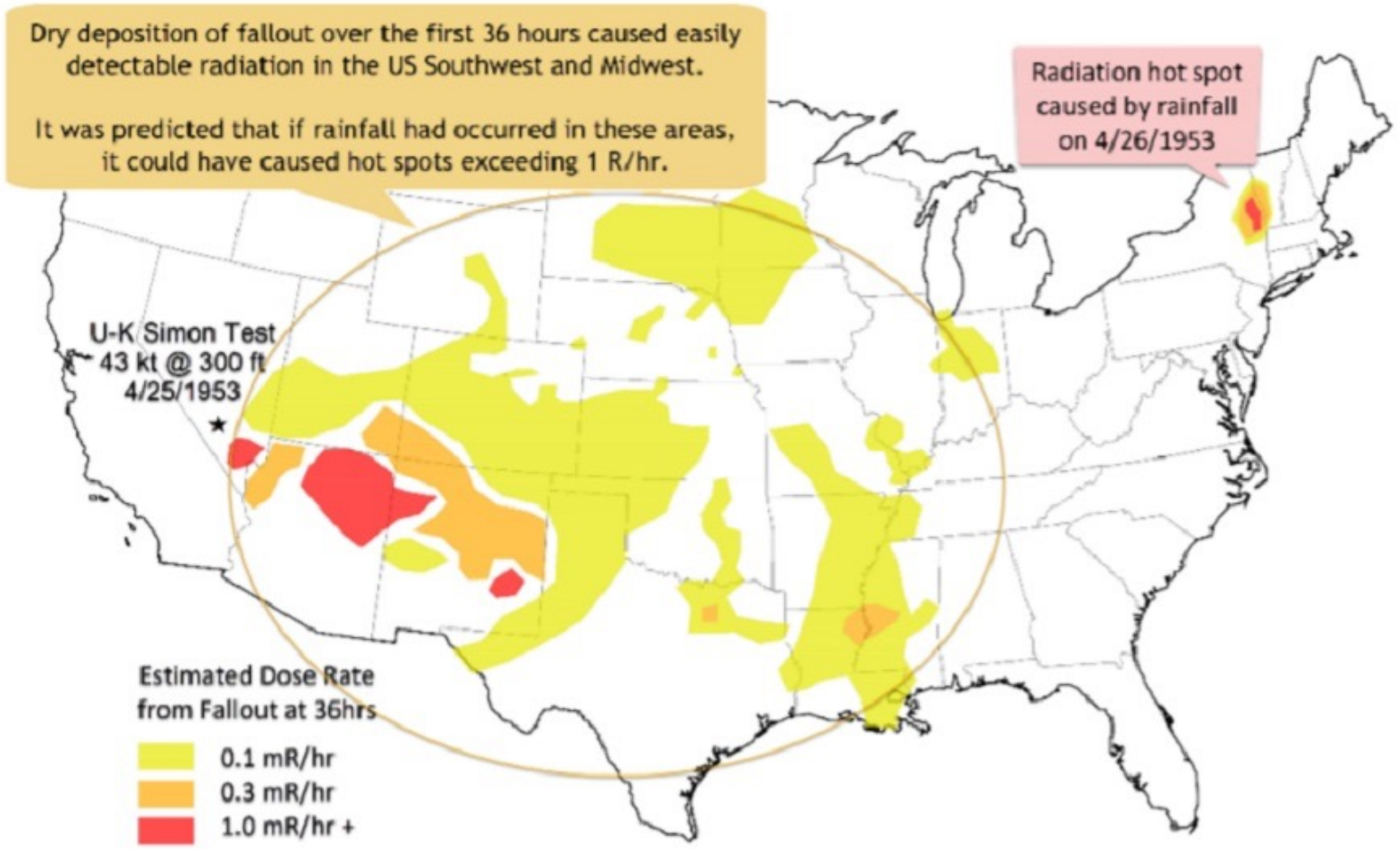


Figure 17: Estimated gamma dose rate above background levels, if measured 1 m above ground at H+36 hours following one particular U.S. historical nuclear test (Upshot-Knothole Simon on 4/25/1953; 43 kT detonation on a 300-foot tower). Median dose rate estimated by county, from measured fallout activity interpolated across counties (derived from NCI, 1997).

Factors Affecting Effects

- Design type – assume gun type
- Yield – assume 10 kT (although consideration for higher yield by state sponsored bomb)
- Target – assume major city
- Atmospheric conditions – rainy versus dry

Ground Burst Implications

- Concentrated blast damage with crater
- Dose range lower than air burst
- More fallout than air burst (maybe no mushroom cloud)
- Less EMP than air burst
- More subsurface damage than air burst

Atmospheric Conditions

- Fallout based on weather
  - Wind speed and direction
  - Temperature and humidity
  - Rain
- Rain knocks down fallout and contaminated rain can cause severe skin burns
- Weather does not dramatically change response

Ground Burst

- Crater diameter = about 130 feet x $(kT)^{1/3}$
  - 1 kT = 130 feet
  - 10 kT = 280 feet
- Crater depth = about 30 feet x $(kT)^{1/3}$
  - 1 kT = 30 feet
  - 10 kT = 65 feet
- Underground effects are similar to an earthquake

Ground Burst

- Ground surface materials are vaporized and sucked up into the fireball forming a radioactive cloud

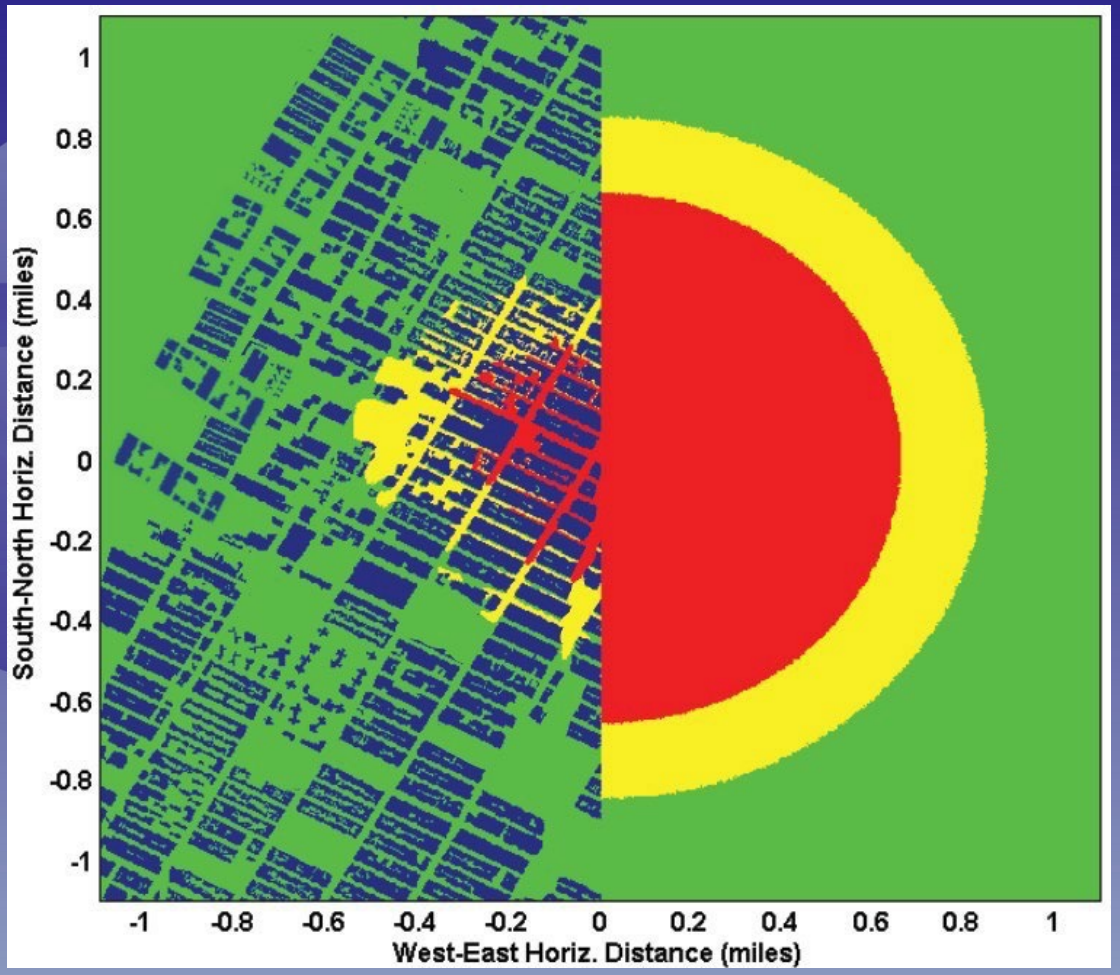
- More fallout created than air burst
  - Mostly non-respirable particulate (falls to ground quickly)
  - High exposure rate to skin
  - Ingestion hazard
  - Fires and fizzle can create respirable particulate (plutonium)

Urban Affects on Radiation

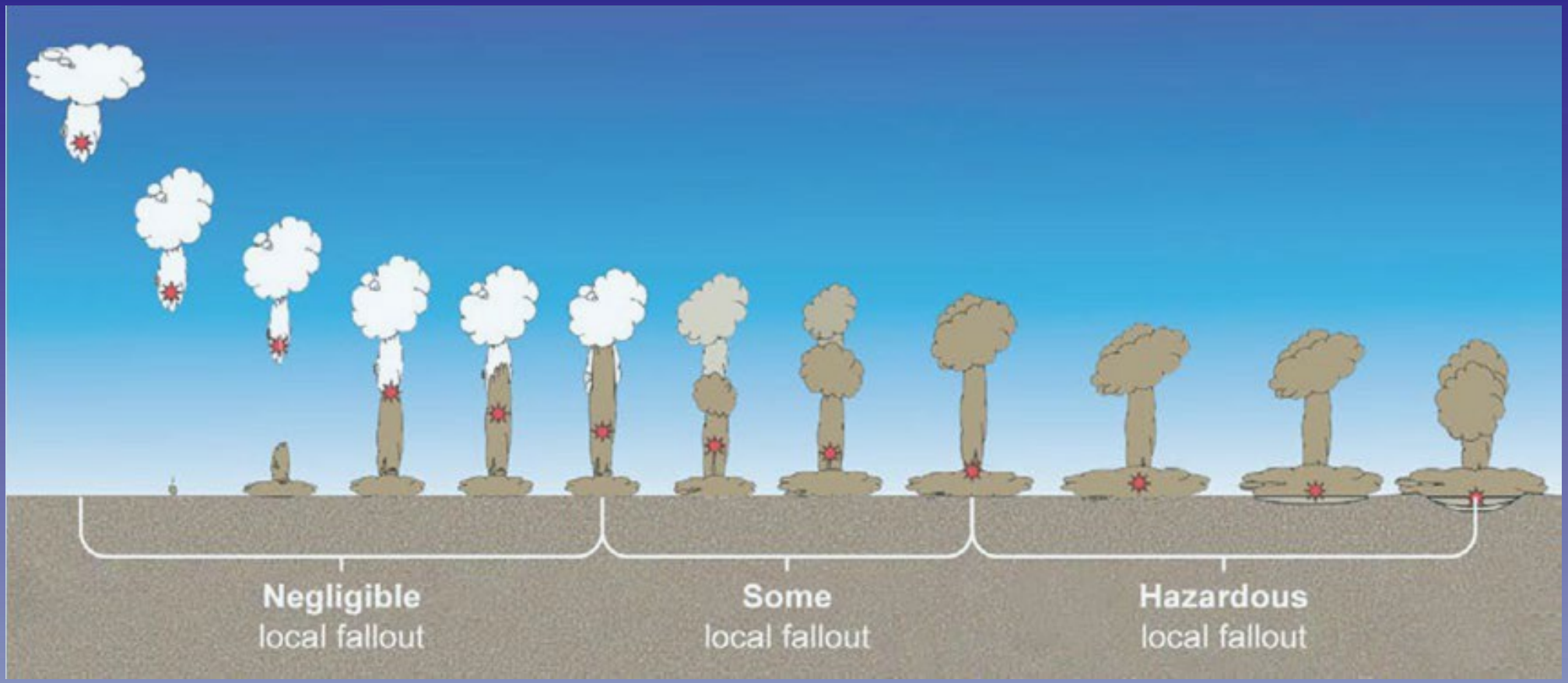
Red >800 rem (lethal)

Yellow >100 < 800 rem

Green <100 rem



Height of Burst versus Fallout

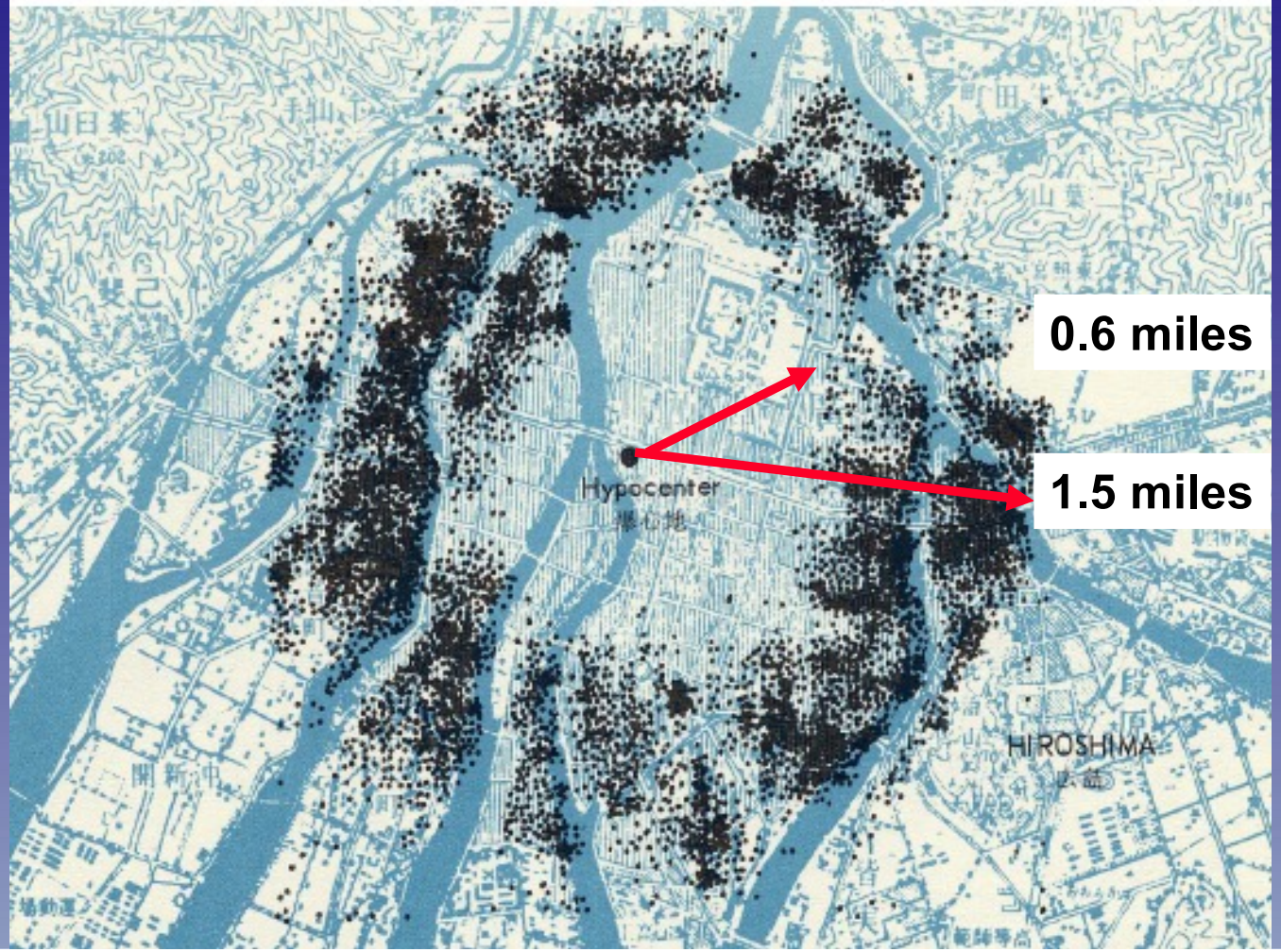


Consequences

Hiroshima

- 70,000 to 130,000 fatalities – mostly from blast & heat
- 20 kT yield (now considered a "Tactical Nuke")
- Airburst
  - Little fallout
  - Radiation injuries from prompt gamma/neutrons
  - Thyroid cancer and leukemia long term effects

Hiroshima Injured Survivors



Effects on Structures

- Surveys of Hiroshima and Nagasaki and tests performed at the Nevada Test Site provide for generalized destruction data
- Small masonry buildings engulfed in blast wave collapsed
- Light structures/residences totally destroyed by blast/fire
- Steel industrial buildings lost roofing/siding with twisted frames
- Strong reinforced concrete structures and smokestacks ***survived***

Effects on Structures

- Buildings leaned away from ground zero
- Telephone poles snapped off at ground level
- Gas containers ruptured and collapsed
- Further away from ground zero appeared sound but structures still damaged and gutted by fire
- Flying objects caused secondary damage

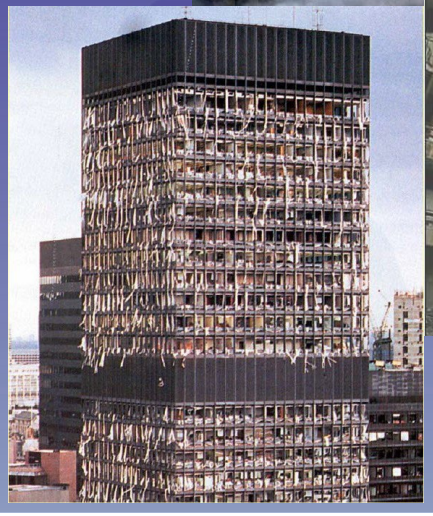
Effects Video

Disclaimer

- Modeling predictions in this presentation are limited by the accuracy of input data and the model algorithm
- Modeling is better at predicting effects on structures than on people
- Actual results are dependent on *many* variables
- Examples are illustrative purposes

Damage Zones

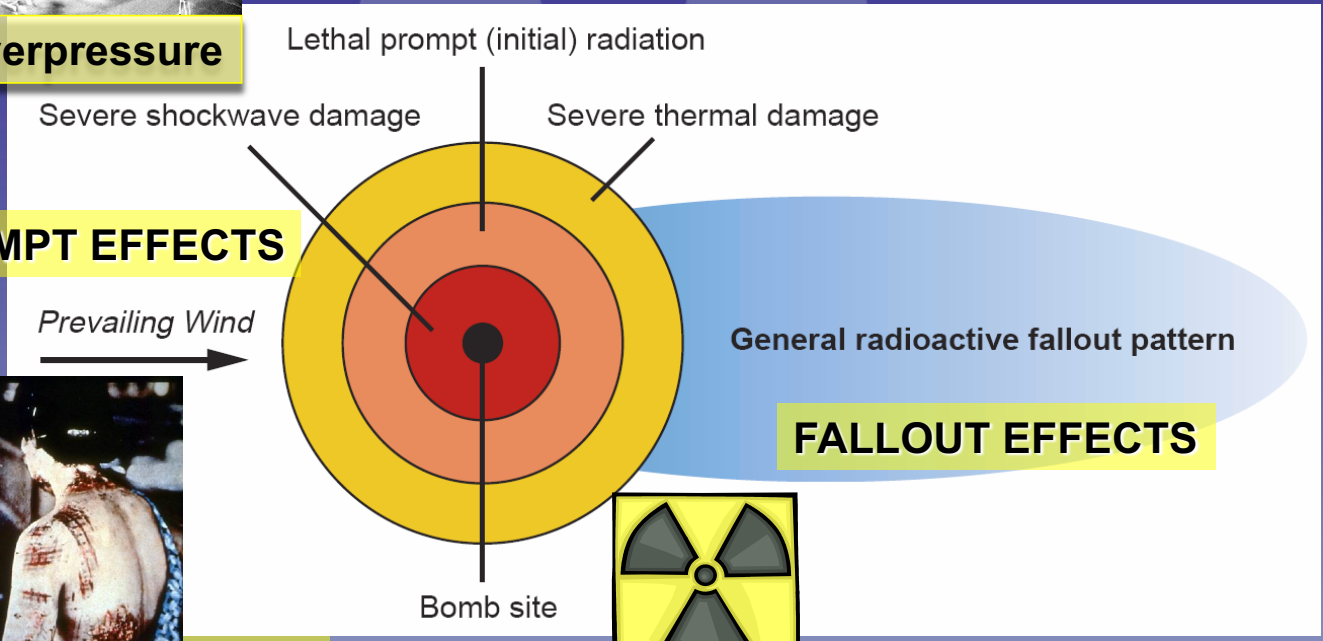
- Severe Damage Zone (SDZ)
  - Destroyed infrastructure
  - High radiation levels
- Moderate Damage Zone (MDZ)
  - Significant building damage and rubble
  - Downed utility lines and some downed poles
  - Overturned automobiles
  - Fires
  - Serious injuries
- Light Damage Zone (LDZ)
  - Broken windows
  - Easily managed injuries



10 kT Ground Burst Nuclear Detonation

Blast overpressure

- Many **Prompt** Casualties come from Blast and Thermal Effects
- **Fallout** Casualties are from Radiation

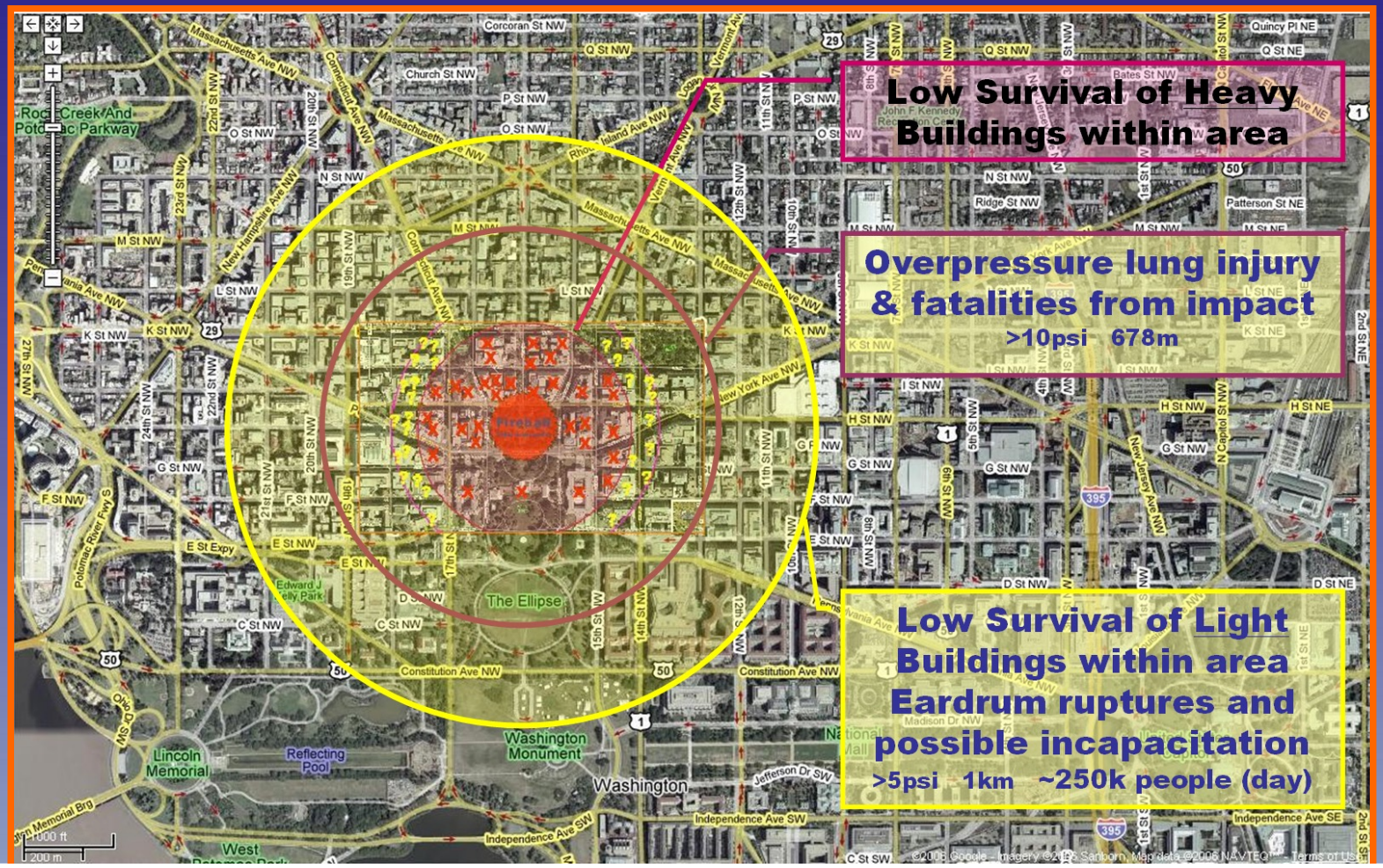


Burns

Ionizing radiation

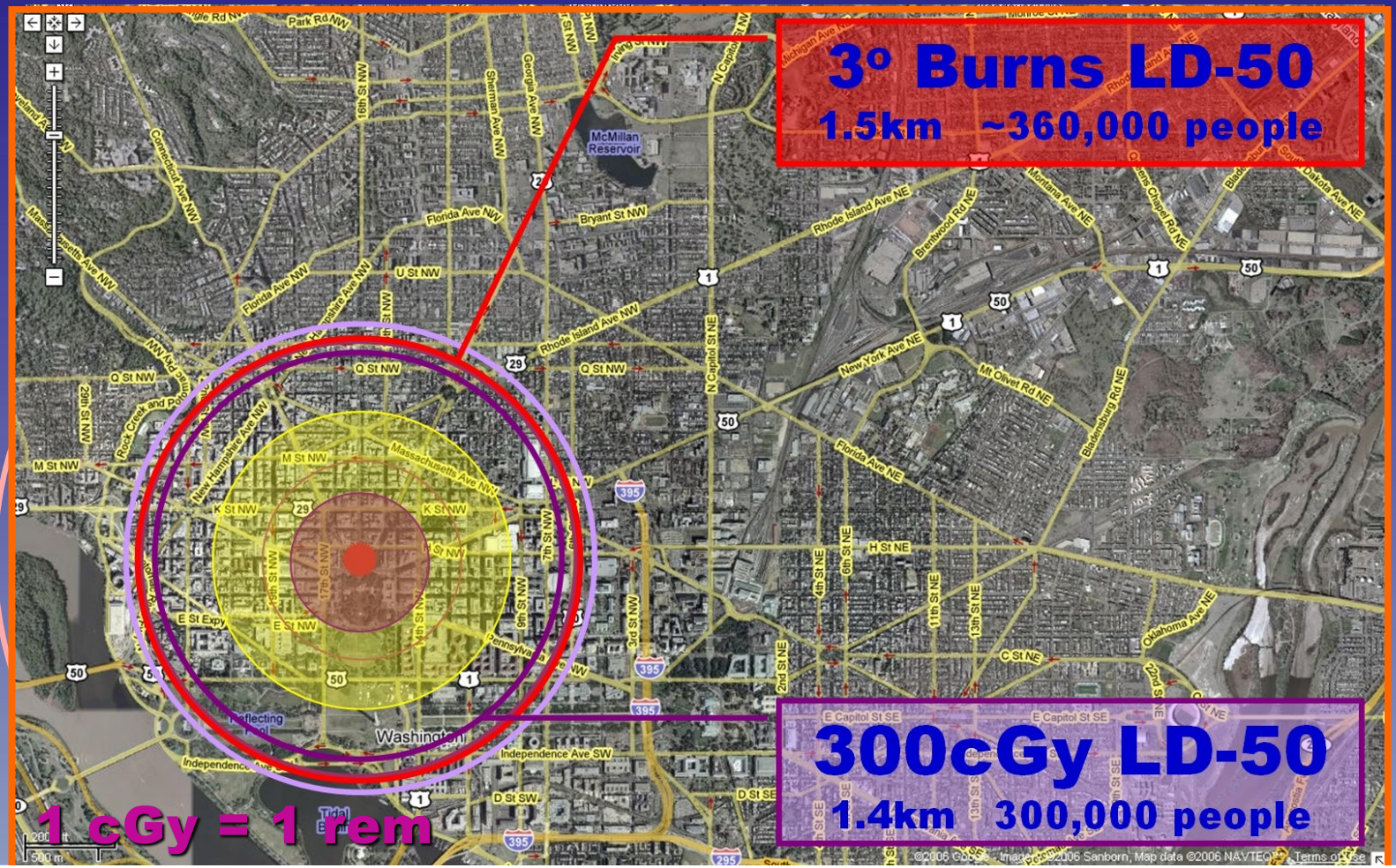
Heavy Building Effects

Blast Effects: Buildings & People

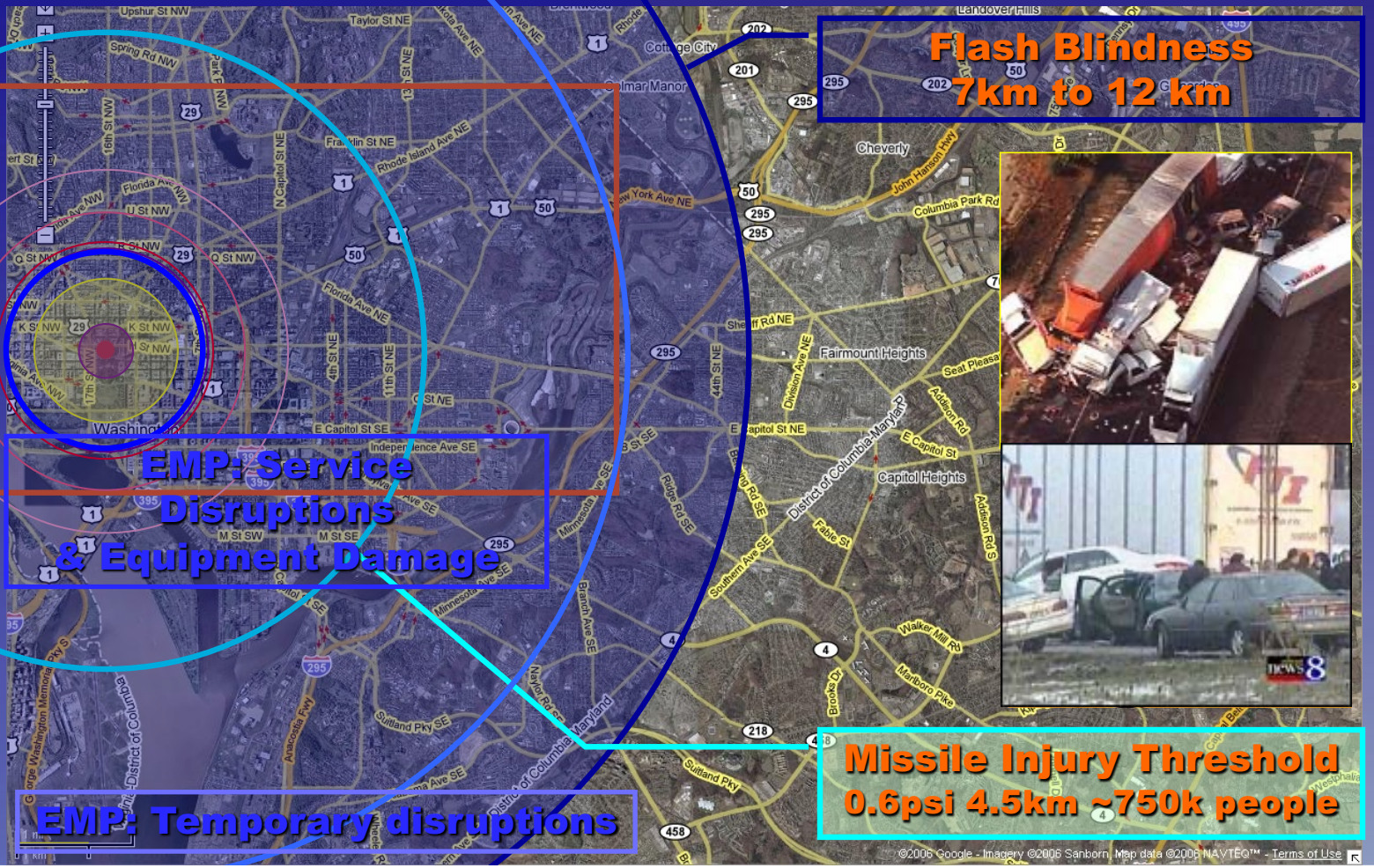


Radiation and Thermal Effects

Unprotected Population (Clear Day & Line of Sight)

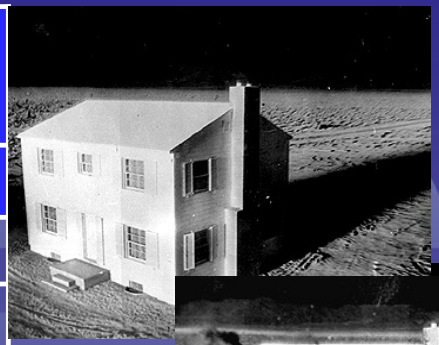


Long Range Prompt Effects

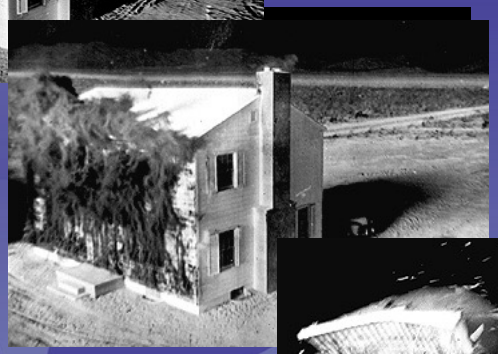


Combined Effects

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



Nighttime shot, the only light is from the blast



Thermal pulse ignites paint and wood

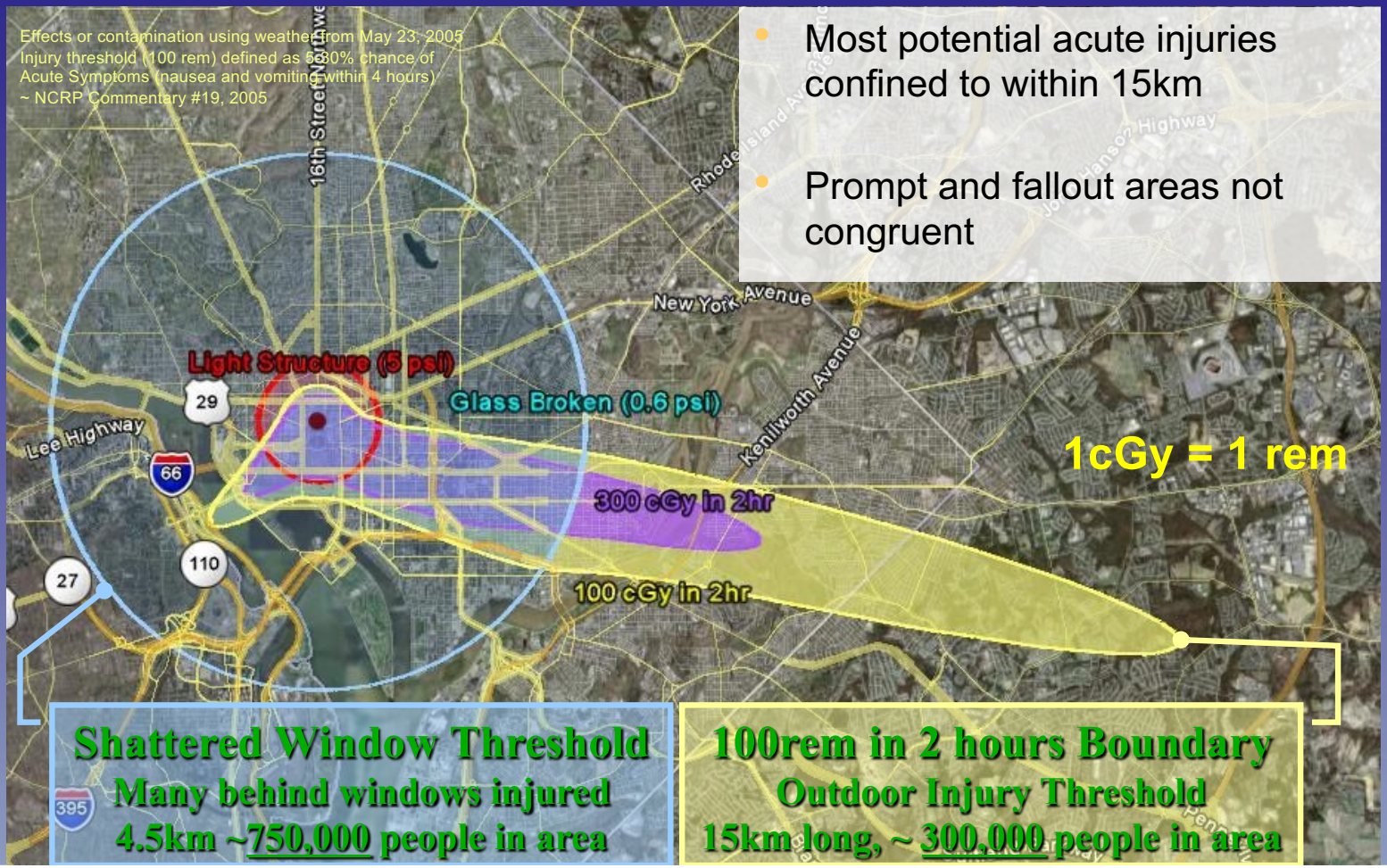
Pressure wave destroys house

1km from ~16kT yields (~ 6 psi)

Fallout

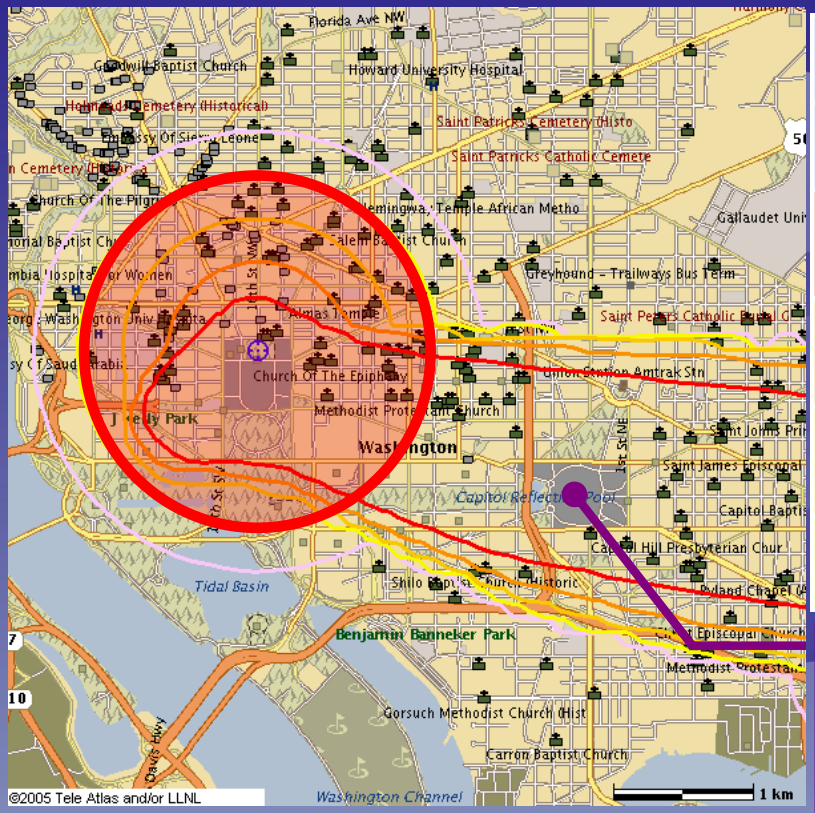
- Nuclear detonation creates large cloud of radioactive dust and water vapor which falls **back to earth contaminating horizontal surfaces**
- Dangerous levels of fallout creates visible dust and debris which are radioactive and can injure people (even in cars or inadequate shelter)
- **Fallout decays rapidly away with time** and is most dangerous in the first few hours after the detonation

Prompt Effects & 2-Hour Integrated Outdoor Exposure



- Most potential acute injuries confined to within 15km
- Prompt and fallout areas not congruent

Downwind Dose Rate @ 15 Minutes



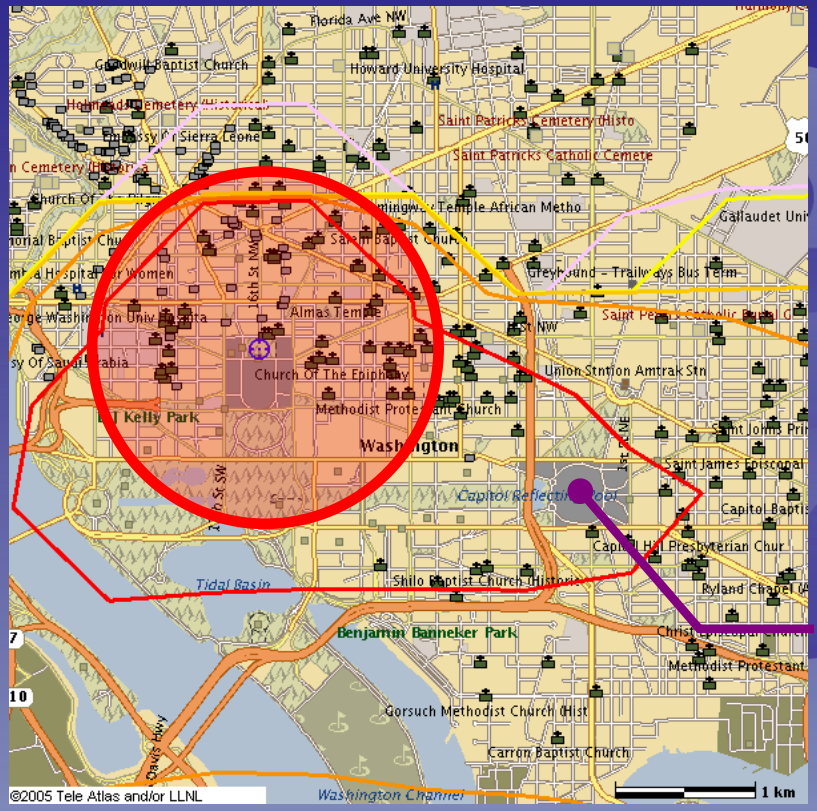
Fallout Effects	
	Dose Rate
	100 rem/hr
	10 rem/hr
	1 rem/hr
	0.1 rem/hr

1,500 rem/hr

~ 8 minutes until fatality threshold at that dose rate

Fatality threshold (2 rem) defined as 5% chance of acute death from radiation without medical treatment (NCRP Commentary #19, 2005)

Downwind Dose Rate @ 2 hours



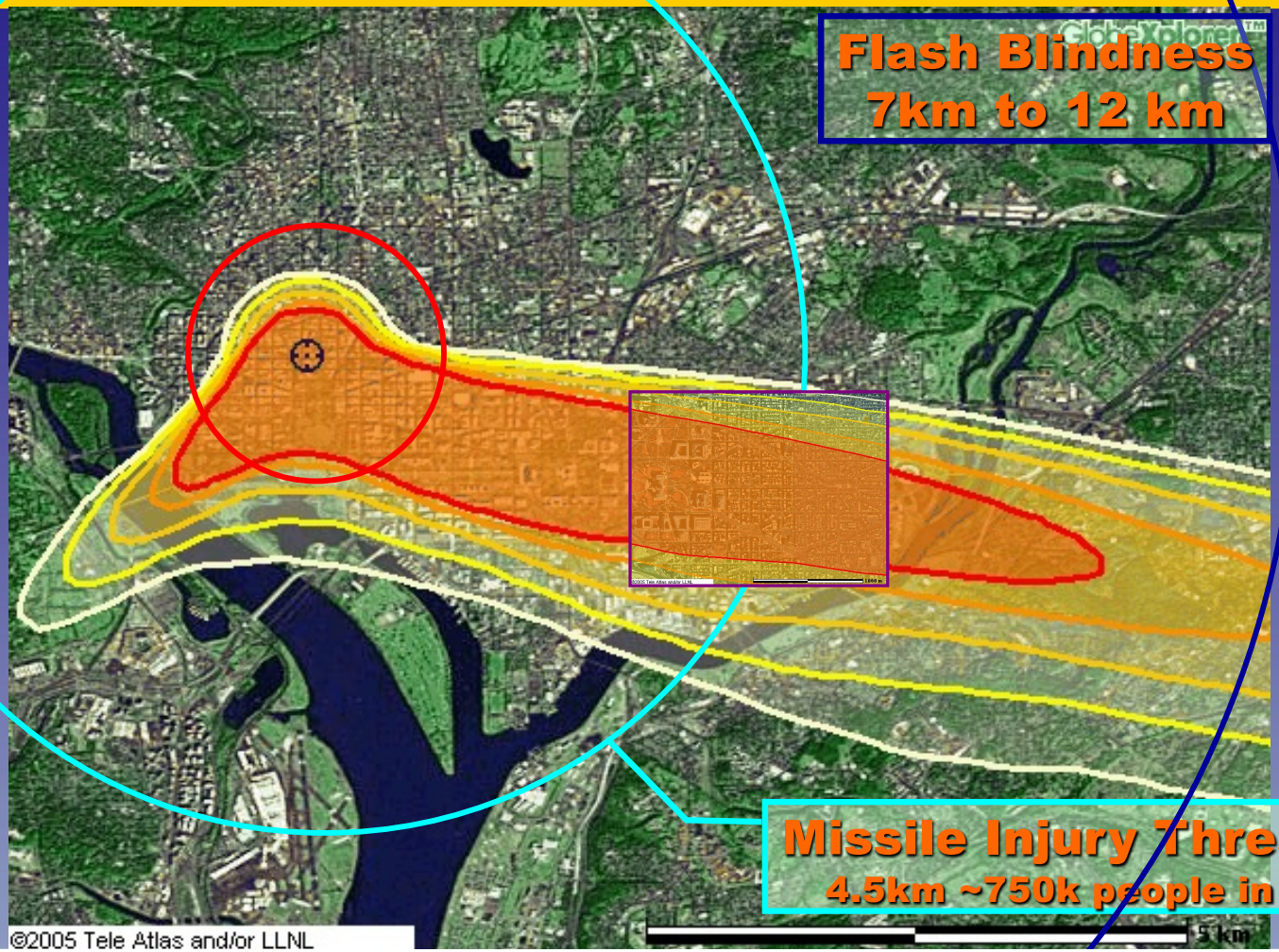
Fatality threshold (2 rem) defined as 5% chance of acute death from radiation without medical treatment (NCRP Commentary #19, 2005)

Fallout Effects	
	Dose Rate
	100 rem/hr
	10 rem/hr
	1 rem/hr
	0.1 rem/hr

180 rem/hr

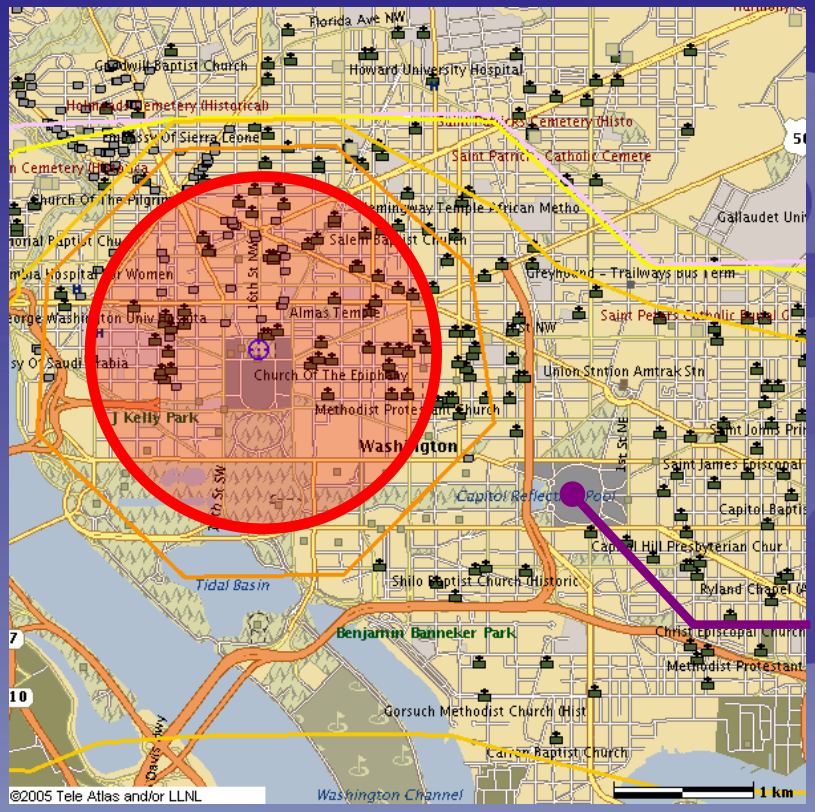
~ **1 hour** until fatality threshold at that dose rate

2 Hour Integrated Outdoor Exposure



	Extent Area
	>300 rem 7.6km 8.8 km2
	>200 rem 10.0km 13.3 km2
	>100 rem 14.8km 25.1 km2
	>50 rem 20.3km 44.1 km2
	>25 rem 26.6km 73.9 km2

Downwind Dose Rate @ 48 hours



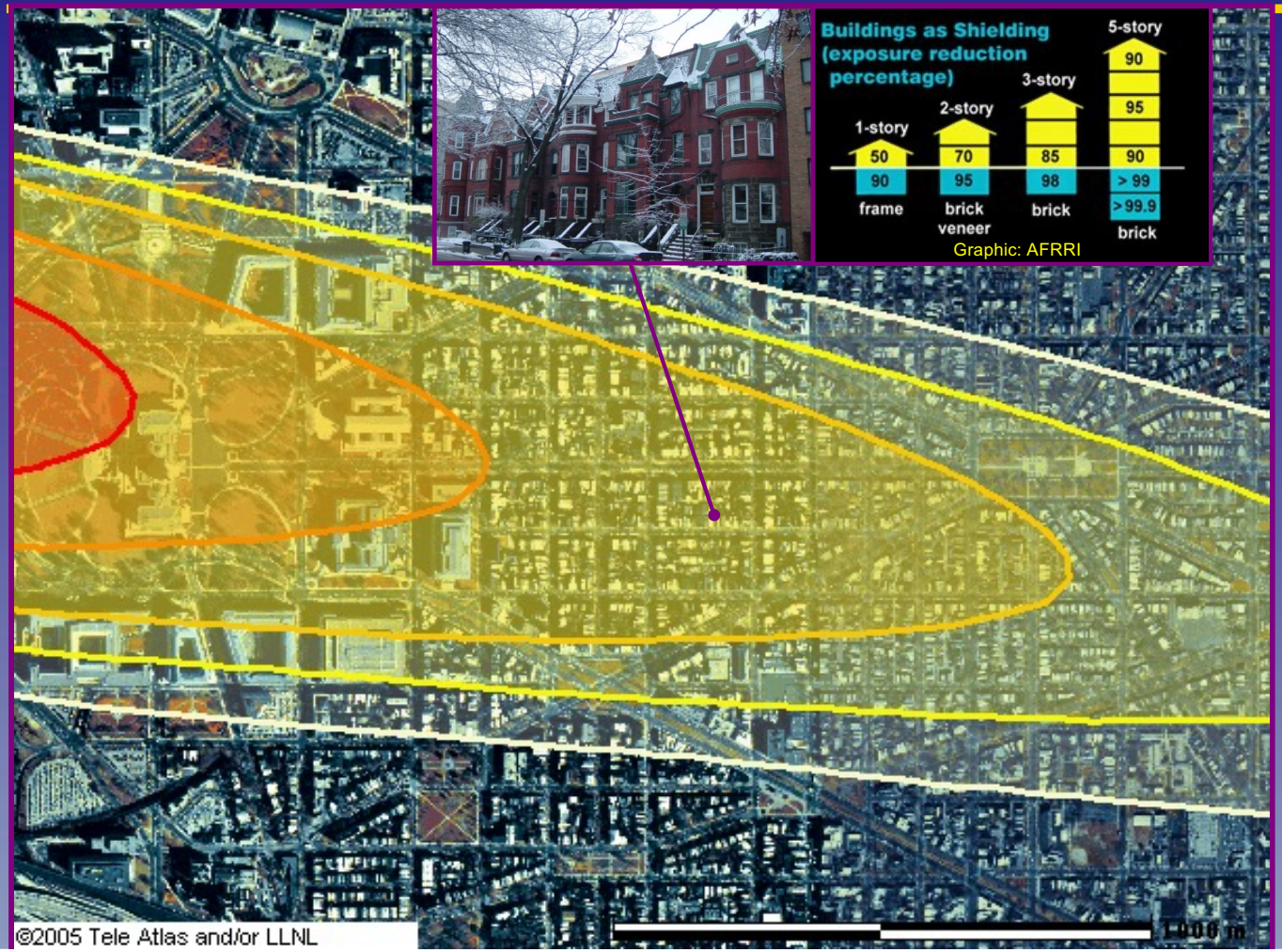
Fatality threshold (2 rem) defined as 5% chance of acute death from radiation without medical treatment (NCRP Commentary #19, 2005)

Fallout Effects	
	Dose Rate
	100 rem/hr (Not Present)
	10 rem/hr
	1 rem/hr
	0.1 rem/hr

7 rem/hr

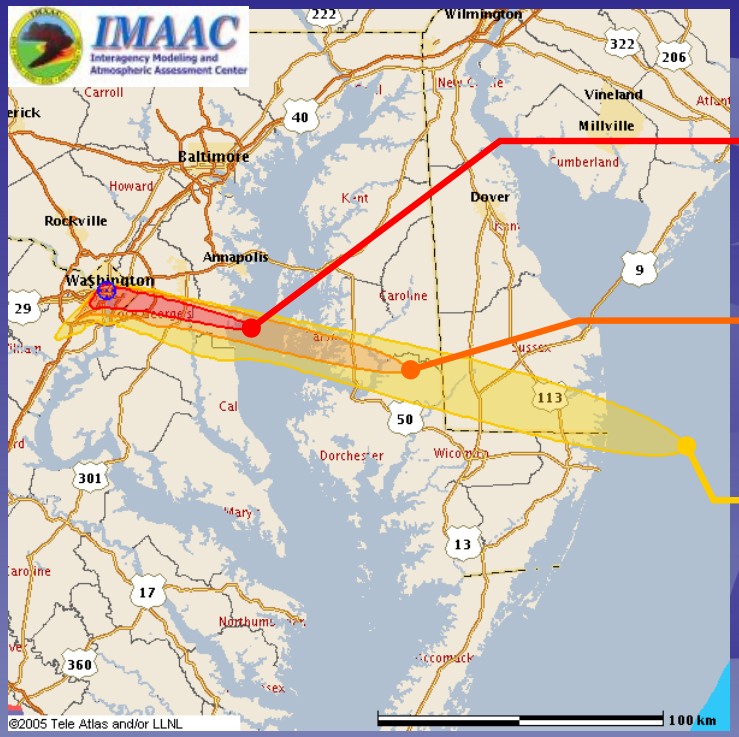
~ 1 day until fatality threshold at that dose rate

2-Hour Integrated Outdoor Exposure



	Extent Area
	>300 rem 7.6km 8.8 km2
	>200 rem 10km 13.3 km2
	>100 rem 14.8km 25.1 km2
	>50 rem 20.3km 44.1 km2
	>25 rem 26.6km 73.9 km2

4-Day Integrated Outdoor Exposure



Long range, non-acute 4-day dose boundaries

25 rem (30 min arrival)
~50km

5 rem (1 hr arrival)
~100km

1 rem (2 hr arrival)
~200km ~1,000,000 people
Protective Action Guideline threshold for shelter or evacuation

- Large population and short arrival times make evacuation difficult
- Model uncertainties and "shadow evacuation" likely to greatly increase effected population

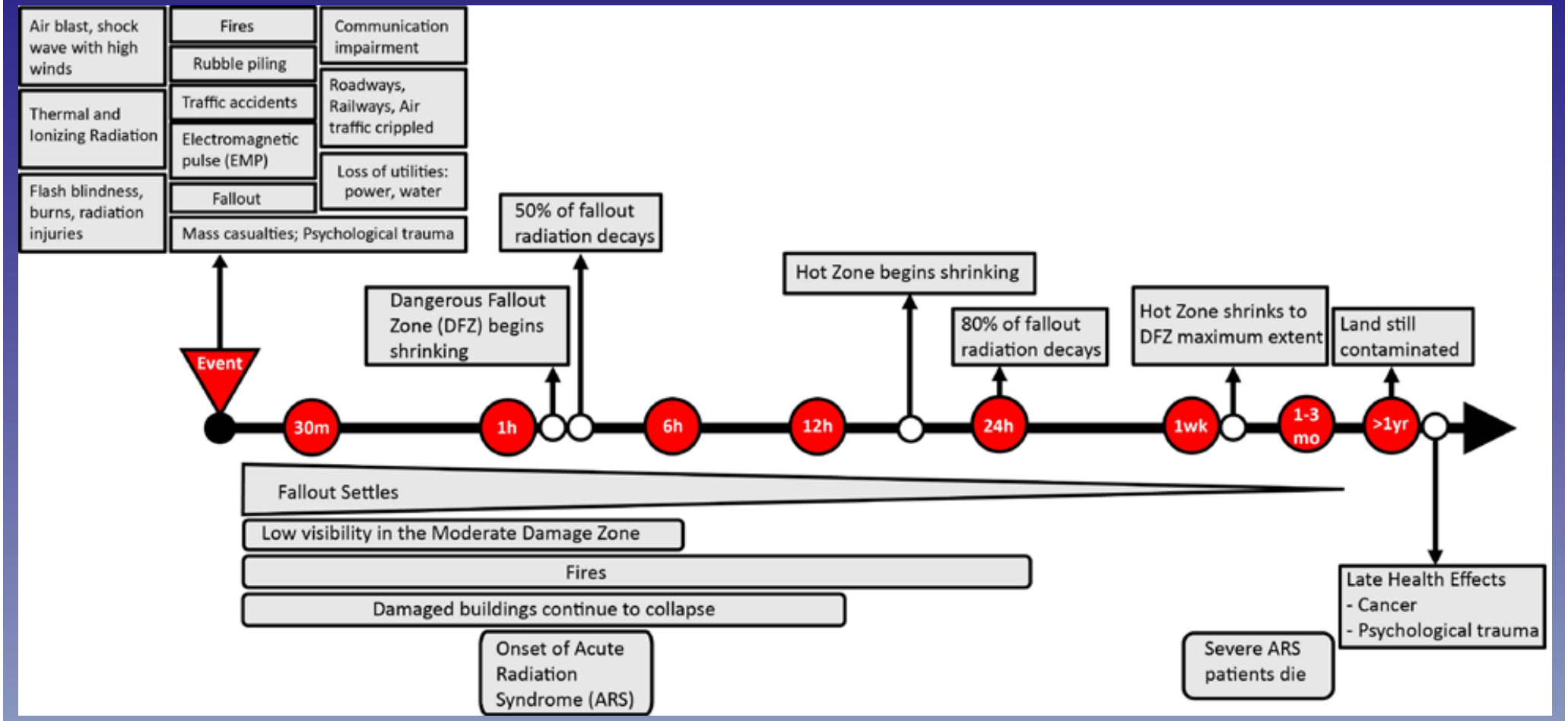
Fallout Effects Summary

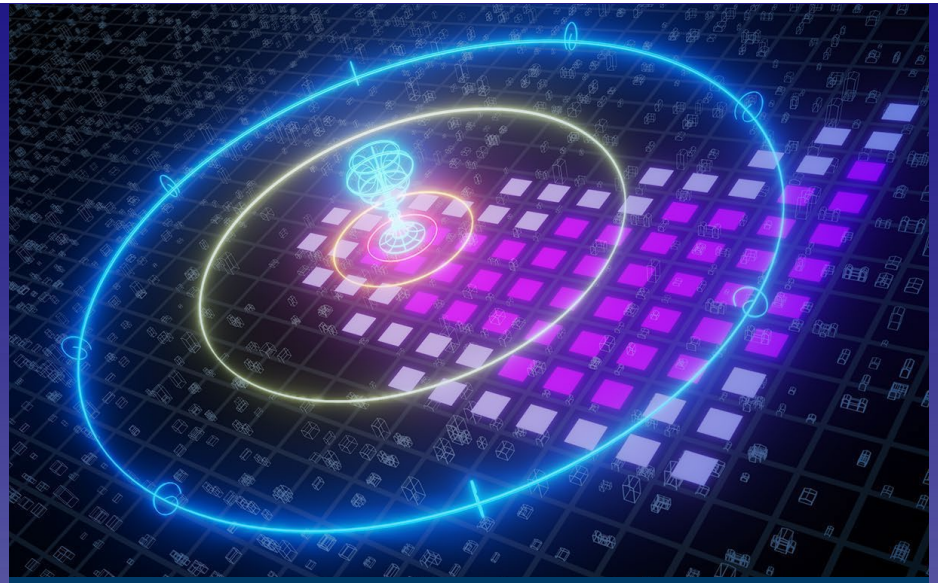
- Fallout cloud could climb **8km (5 miles) high** and will be carried by upper atmosphere winds (often at high speeds)
- 100,000s of **acute casualties from radioactive fallout *can* occur within 15km (9 miles)** downwind of ground zero
- Number of fallout casualties can be **reduced by action (shelter / evacuation)**

Fallout Effects Summary

- Radiation levels **decay rapidly with time**
- First few days, **primary** health hazard is **external gamma radiation** from fallout on horizontal surfaces and breathing in fallout dust is a minor concern
- Radiation has a **delayed effect;** although radiation sickness may occur within a few hours, victims of lethal radiation may not succumb for days or weeks

Detonation Timeline





Nuclear Detonation Response Guidance

Planning for the First 72 Hours

March 2023

FEMA

Missions and Tactics

- Mission: Protect Responders and the Public
  - Tactic 1: Immediately Issue Alert to Get Inside
- Mission: Gather Information
  - Tactic 2: Characterize the Impacts
  - Tactic 3: Develop a Common Operating Picture
- Mission: Organize the Response
  - Tactic 4: Initiate a Zone-Based Response
  - Tactic 5: Establish Area Command
  - Tactic 6: Sustain Critical Infrastructure

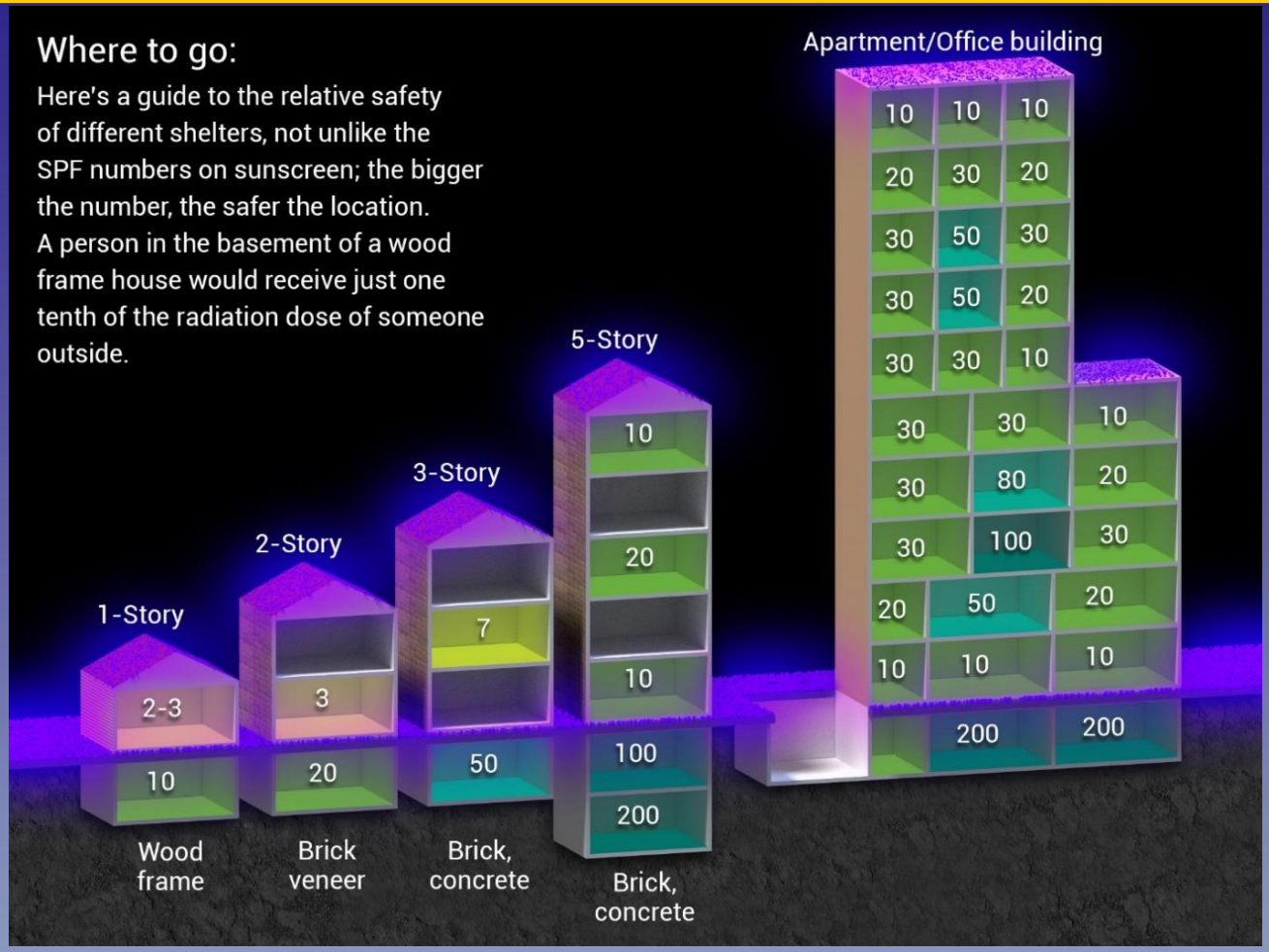
Missions and Tactics

- Mission: Provide Care to Survivors
  - Tactic 7: Evacuate
  - Tactic 8: Triage, Stabilize, and Transport
  - Tactic 9: Decontaminate
- Mission: Prepare for Intermediate Phase
  - Tactic 10: Transition to a Prolonged Response

Mission: Protect Responders and Public

- Tactic 1: Immediately Issue Alert to Get Inside
- First few minutes are most critical and will prime success for remainder of the response
- Shelter-in-Place within 50 miles (protection from fallout)
- Approximately 15 minutes to get inside
- Could saves 100,000s of lives

Building Protection Factors



Mission: Gather Information

- Tactic 2: Characterize the Impacts
  - Damage assessment

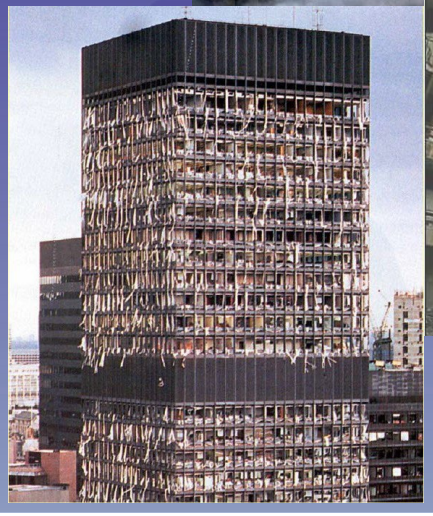
Blast Zone Type	Indicators
Light Damage Zone (LDZ)	▪ Nearly all windows shattered and building facades damaged ▪ Most injuries not life-threatening, many injuries from flying glass and debris
Moderate Damage Zone (MDZ)	▪ Light buildings destroyed ▪ Interiors of larger buildings blown out ▪ Significant number of major injuries
Severe Damage Zone (SDZ)	▪ Nearly all buildings destroyed ▪ Hazardous outdoor conditions ▪ Few survivors

  - Radiation measurements

Radiation Hazard Zone Type	Indicators	Outdoor Response Restrictions
N/A	▪ Below 0.01 R/h (10mR/h)	▪ Assess impacts in the immediate area. Support all operations as needed while monitoring radiation levels.
Hot Zone (HZ)*	▪ Above 0.01 R/h (10mR/h) and Below 10 R/h	▪ Assess impacts in the immediate area. Support only emergency operations (lifesaving, firefighting, etc.) as needed while monitoring radiation levels. Track dose of all responders.
Dangerous Radiation Zone (DRZ)*	▪ Above 10 R/h	▪ Do not exit shelter or enter areas if radiation exposures exceed 10 R/h outside unless there is a time-critical, life-safety issue (e.g., avoiding fire, building collapse) or to conduct quick, critical, lifesaving activities.

Damage Zones

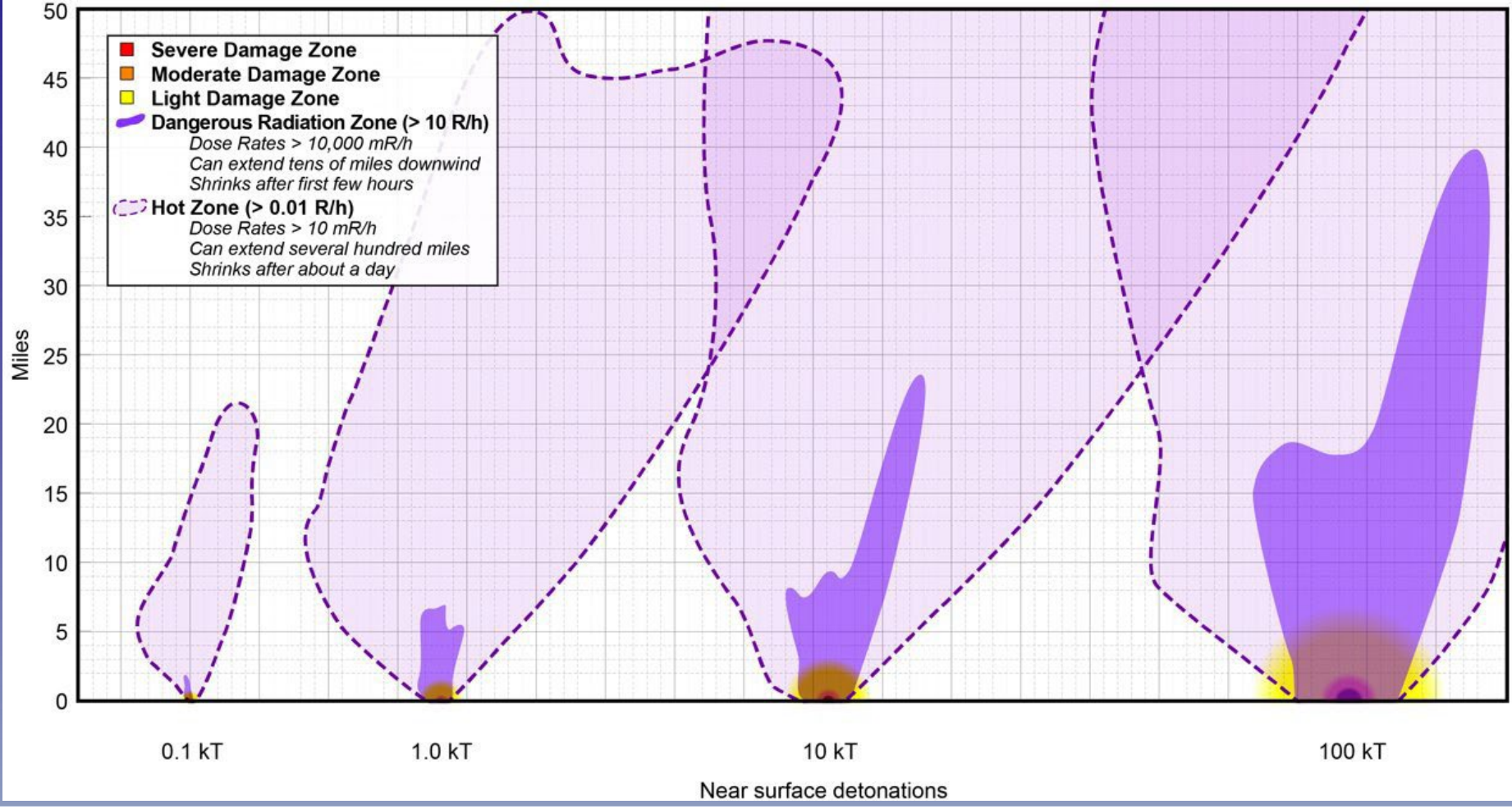
- Severe Damage Zone (SDZ)
  - Destroyed infrastructure
  - High radiation levels
- Moderate Damage Zone (MDZ)
  - Significant building damage and rubble
  - Downed utility lines and some downed poles
  - Overturned automobiles
  - Fires
  - Serious injuries
- Light Damage Zone (LDZ)
  - Broken windows
  - Easily managed injuries



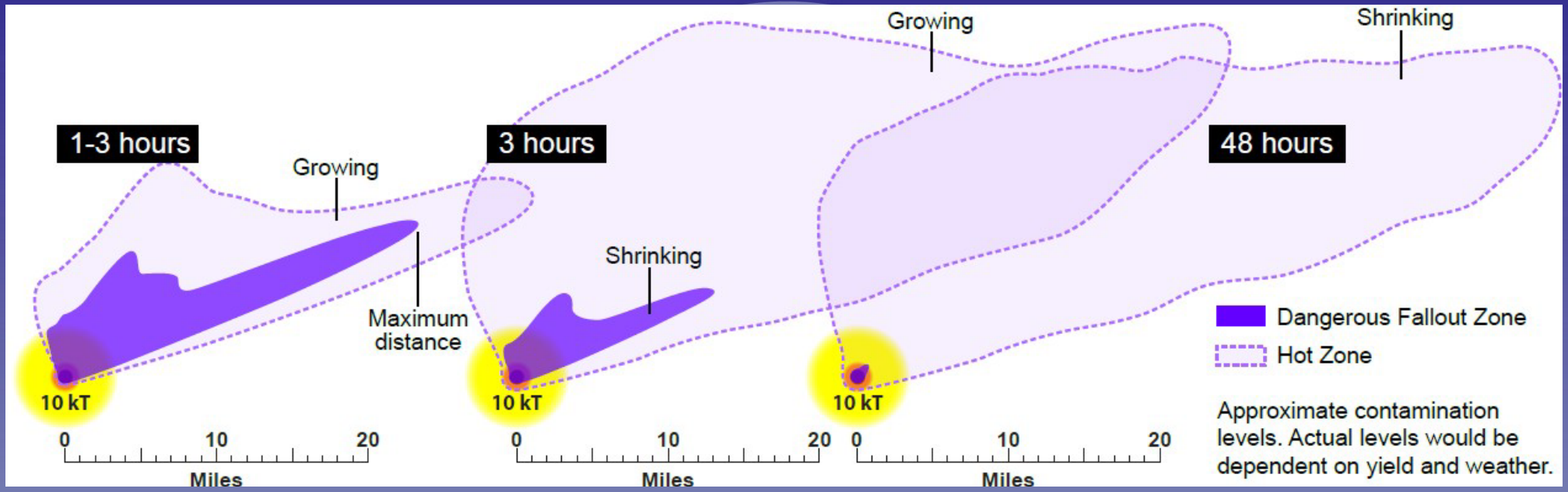
Radiation Zones

- Hot Zone
  - > 10 mR/hr < 10 R/hr
  - Actions warranted to reduce radiation exposure
  - Possibility of long-term health effects
- Dangerous Radiation Zone (DRZ)
  - > 10 R/hr
  - Prolonged outdoor exposure can result in injury or death

Five Zones


Severe Damage Zone
Moderate Damage Zone
Light Damage Zone
Dangerous Radiation Zone (> 10 R/h)
Dose Rates > 10,000 mR/h
Can extend tens of miles downwind
Shrinks after first few hours
Hot Zone (> 0.01 R/h)
Dose Rates > 10 mR/h
Can extend several hundred miles
Shrinks after about a day
Miles
50
45
40
35
30
25
20
15
10
5
0
0.1 kT
1.0 kT
10 kT
100 kT
Near surface detonations

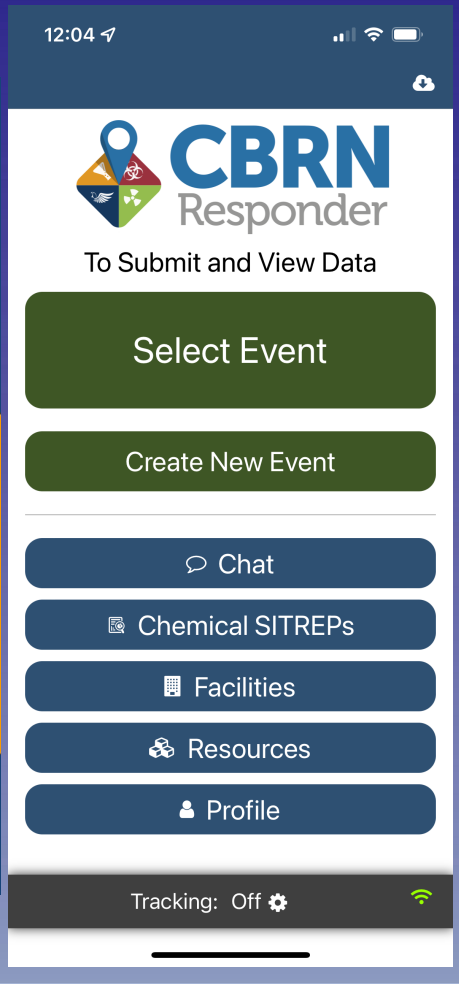
Zone Growing and Shrinking



RadResponder

CBRN Responder

CBRNRESPONDER MOBILE APP



Mission: Gather Information

- Tactic 3: Develop a Common Operating Picture

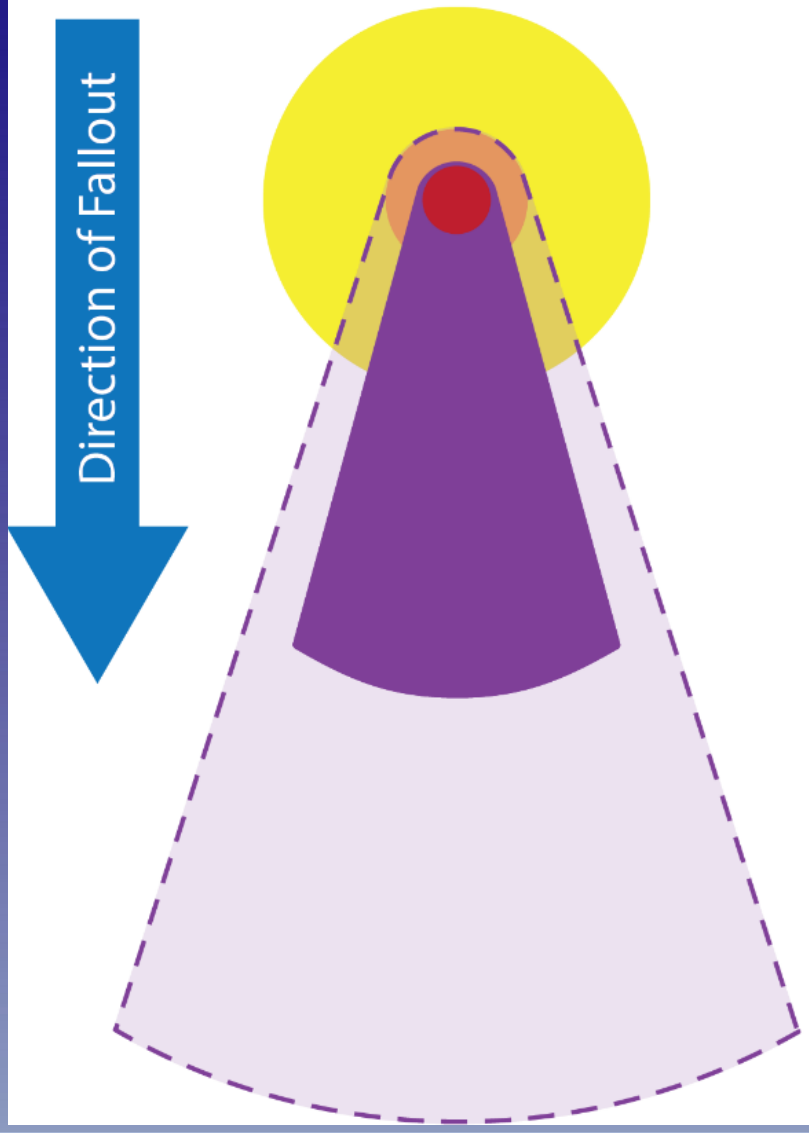
Prioritize situational awareness for

Fallout | Blast Damage | Fires | Casualties | Critical Infrastructure

Mission: Organize the Response

- Tactic 4: Initiate a Zone-Based Response
  - Focus on the Moderate Damage Zone (MDZ)
  - See checklists and information cards

Example Immediate Post-Detonation First Responder's Checklist	
☐	All responders: Go inside a thick-walled building/underground basement immediately. Move if shelter threatened by fire or collapse.
	Responders without radiation detection equipment: ☐ Shelter inside for up to 24 hours or until informed it is safe to respond
	Responders with radiation detection equipment: Assess exposure rate outside ☐ If outside radiation levels are greater than 10 R/h, stay inside and sheltered from fallout. Only conduct quick/critical lifesaving outside. ☐ When outside radiation levels are less than 10 R/h, conduct lifesaving activities outside
☐	Monitor total dose for each responder or use group dosimetry
Observe and Identify Immediate Impacts	
☐	Determine blast damage zone: • Light Damage Zone (LDZ): Building facade damage, nearly all windows broken, mostly injuries due to glass and falling debris • Moderate Damage Zone (MDZ): Large number of collapsed and unstable structures, significant injuries • Severe Damage Zone (SDZ): Most sturdy buildings destroyed, few survivors
☐	Determine radiation hazard zone: • Hot Zone (HZ): Greater than 0.01 R/h (same as 10 mR/h) • Dangerous Radiation Zone (DRZ): Greater than 10 R/h
☐	Assess other impacts in your area, including: • Critical infrastructure, especially blocked roadways • Injuries: types and severity • Fires
Communicate Your Information	
☐	Establish communication with firehouses, police stations, hospitals, emergency operations centers (EOCs), etc.
☐	Communicate blast damage zone, outdoor radiation levels, and other impacts to operations centers or an EOC
Save Lives	
☐	Refer to relevant zone-based Response Card for lifesaving priorities: • If in DRZ, refer to card #1, otherwise: LDZ #2; MDZ #3; SDZ #4; HZ #5 • MDZ is the early response priority with the greatest lifesaving potential



Light Damage Zone (LDZ)

Extensive window/exterior damage and minor injuries. Manage fires, encourage public shelter.

Moderate Damage Zone (MDZ)

Significant damage and injuries. Establish and maintain evacuation corridors. Greatest life-saving potential.

Severe Damage Zone (SDZ)

Radiation and complete destruction of most buildings. Delay response until radiation decays. Survivors unlikely.

Dangerous Radiation Zone (DRZ)

Dangerous radiation levels (> 10 R/h) outside. Minimize use of responders outside. Shelter public to save lives.

Hot Zone (HZ)

Elevated radiation levels (> 0.01 R/h). Respond as needed, minimize time outside. Shelter public to minimize dose.

Response Card: #1

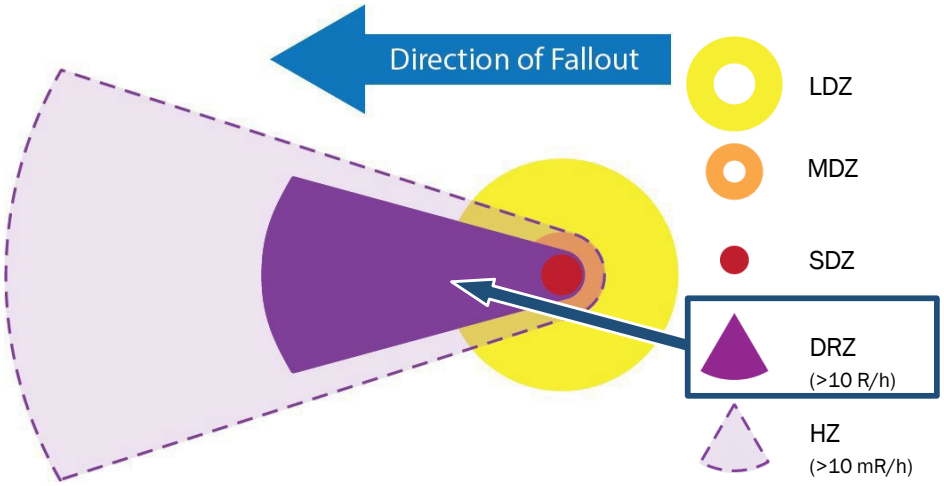
Dangerous Radiation Zone (DRZ)

Observable Indicators:

- Greater than 10 R/h radiation exposure rate

Major Hazards:

- Dangerous radiation levels outside. Shelter inside. Move if shelter threatened by fire or collapse.
- Additional hazards if in Light or Moderate Damage Zones (e.g., toxic smoke, fire, debris). Avoid these hazards and wear appropriate PPE.



Lifesaving Priorities (DRZ)

Evacuation/Shelter:

- Everyone – responders included – remain sheltered indoors
- Prepare to evacuate once radiation levels are less than 10 R/h (likely in 12-24 hours)
- Consider evacuating through subterranean structures (e.g., subways, tunnels), if possible

Medical:

- Responders already in DRZ: Establish ad hoc triage/treatment sites inside sturdy, thick-walled structures
- Conduct only quick, critical, lifesaving activities outdoors in the DRZ
- Prioritize rapid dry decontamination methods: Remove outer clothing or wipe exposed surfaces

Infrastructure:

- Conduct remote/unmanned damage assessment and fire management, if possible
- Stabilize hazardous infrastructure if failure presents immediate danger to life and safety

Special Consideration:

- Responders with radiation detection equipment should closely monitor their exposure/total dose

Response Card: #2

Light Damage Zone (LDZ)

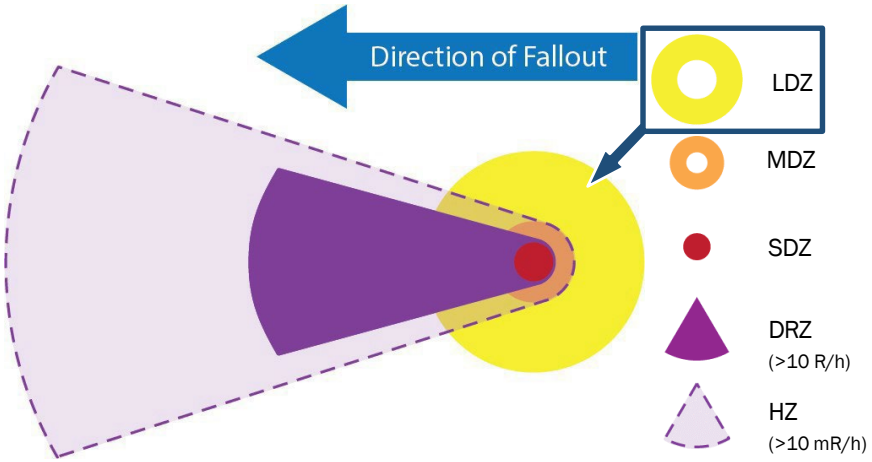
Outside of the Dangerous Radiation Zone

Observable Indicators:

- Nearly all windows shattered
- Damage to building facades
- Mostly injuries from flying glass and debris

Major Hazards:

- Inhalation hazards from toxic smoke from fire/debris. Avoid these hazards and wear appropriate PPE.



Lifesaving Priorities (LDZ)

Evacuation/Shelter:

- Instruct public to shelter inside
- Targeted evacuation of unsafe areas (e.g., fires, heavy smoke, unstable structures)
- Do not prevent spontaneous evacuation. Direct self-evacuees towards safety and away from the Hot Zone (area > 10 mR/h).

Medical:

- Establish ad hoc triage/treatment sites for injured evacuees
- Stabilize life-/limb-threatening injuries
- Prioritize rapid dry decontamination methods: Remove outer clothing or wipe exposed surfaces

Infrastructure:

- Clear and maintain evacuation & logistics routes (fuel, light towers, medical) from the Moderate Damage Zone (MDZ) to supporting areas outside the LDZ
- Isolate and manage spot fires
- Stabilize hazardous materials and infrastructure

Special Consideration:

- The Moderate Damage Zone (MDZ) is an early response priority with the greatest lifesaving potential: Consider responding to MDZ first.

Response Card: #3

Moderate Damage Zone (MDZ)

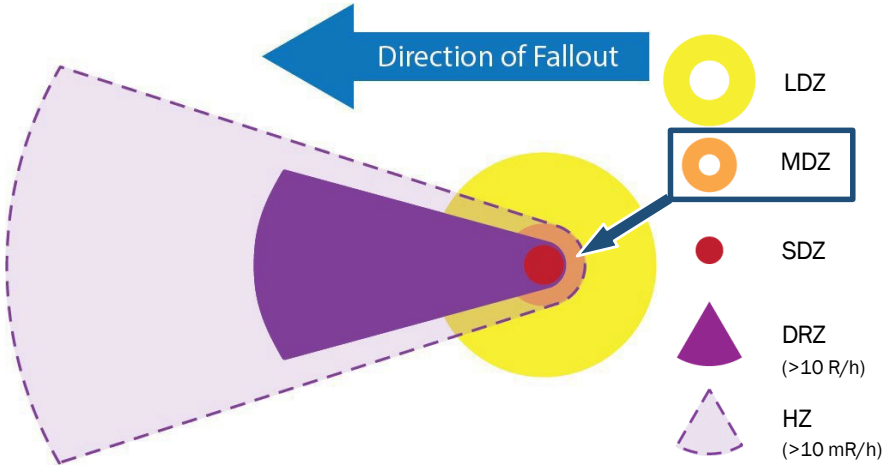
Outside of the Dangerous Radiation Zone

Observable Indicators:

- Light buildings destroyed
- Blown out interiors of larger buildings
- Significant number of major injuries

Major Hazards:

- Significant building damage
- Rapidly spreading fires
- Inhalation hazard from toxic smoke from fire/debris. Avoid smoke, wear appropriate PPE.



Lifesaving Priorities (MDZ)

Evacuation/Shelter:

- Instruct public to evacuate towards the Light Damage Zone (LDZ) and away from the Hot Zone (HZ)
- Prioritize assisted evacuation for the non-ambulatory
- Recruit volunteers to support evacuation

Medical:

- Conduct search and rescue operations
- Stabilize life-/limb-threatening injuries
- Transport injured to hospitals or ad hoc triage/treatment sites in Light Damage Zone (LDZ) or beyond
- Prioritize rapid dry decontamination methods: Remove outer clothing or wipe exposed surfaces with a brush, adhesive tape, or moist towelettes

Infrastructure:

- Clear and maintain evacuation & logistics routes (fuel, light towers, medical) from the Light Damage Zone (LDZ)
- Use defensive fire tactics to protect transportation corridors
- Stabilize hazardous infrastructure

Response Card: #4

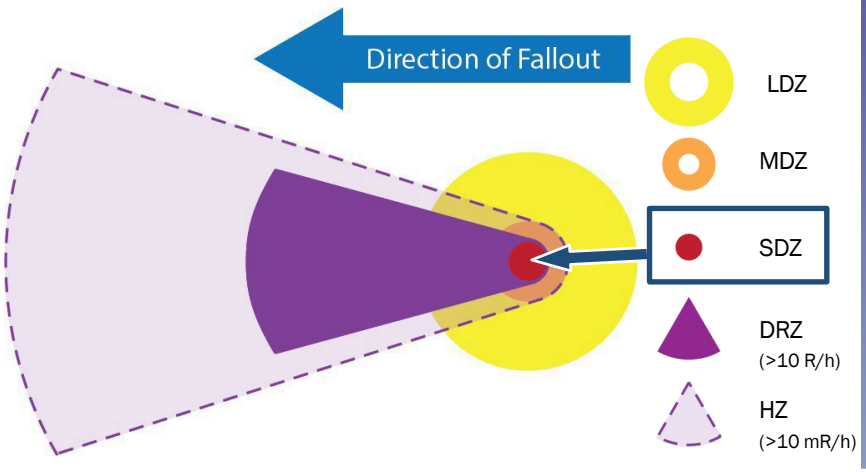
Severe Damage Zone (SDZ)

Observable Indicators:

- Nearly all buildings destroyed
- Few survivors
- Impassable, high piles of debris

Major Hazards:

- Immediate dangerous radiation levels outside. Shelter inside. Move if shelter threatened by fire or collapse.
- Significant secondary hazards: fire, smoke, etc. Avoid these hazards and wear appropriate PPE.



Lifesaving Priorities (SDZ)

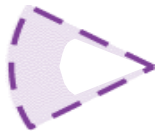
Evacuation/Shelter:

- Everyone – responders included – remain sheltered indoors
- Seek very robust shelter: Thick cement walls and deep subterranean structures
- Move if shelter threatened by fire, collapse, or other hazards
- Prepare to evacuate once radiation levels are less than 10 R/h
- Consider evacuating through subterranean structures (e.g., subways, tunnels), if possible

Medical:

- Conduct medical triage and stabilization indoors. May conduct outdoors if necessary and radiation levels are less than 10 R/h.
- Prioritize rapid dry decontamination methods: Remove outer clothing or wipe exposed surfaces with a brush, adhesive tape, or moist towelettes

Response Card: #5



Hot Zone (HZ)

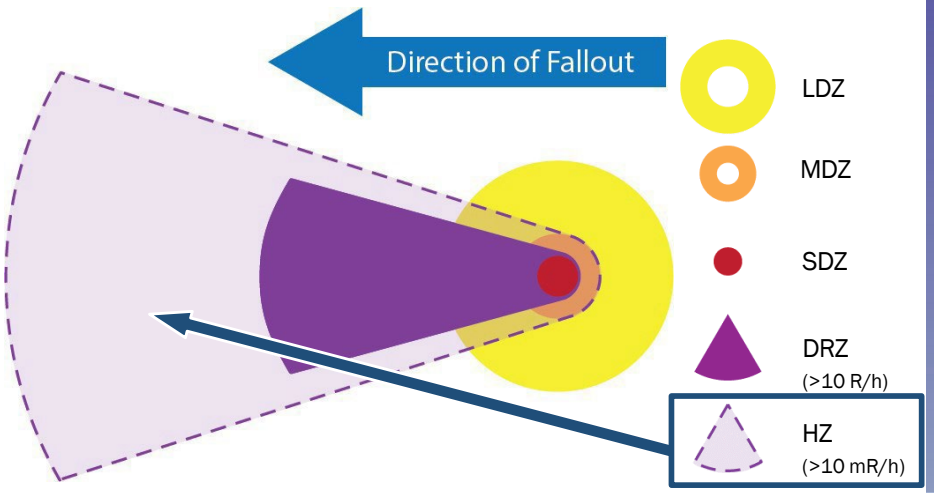
Outside of the Light & Moderate Damage Zones

Observable Indicators:

- Greater than 0.01 R/h (same as 10 mR/h) radiation exposure rate, but less than 10 R/h

Major Hazards:

- Fallout may take several hours to arrive
- Outdoor radiation levels not life-threatening and will significantly decrease over first 48 hours



Lifesaving Priorities (HZ)

Evacuation/Shelter:

- Instruct public to shelter inside their building/home. Large-scale public evacuation is not necessary in first 72 hours.
- Do not prevent spontaneous evacuation. Direct self-evacuees towards safety/away from Hot Zone (HZ).

Medical:

- Conduct lifesaving activities, but minimize time outside when possible
- Prioritize rapid dry decontamination methods: Remove outer clothing or wipe exposed surfaces with a brush, adhesive tape, or moist towelettes

Infrastructure:

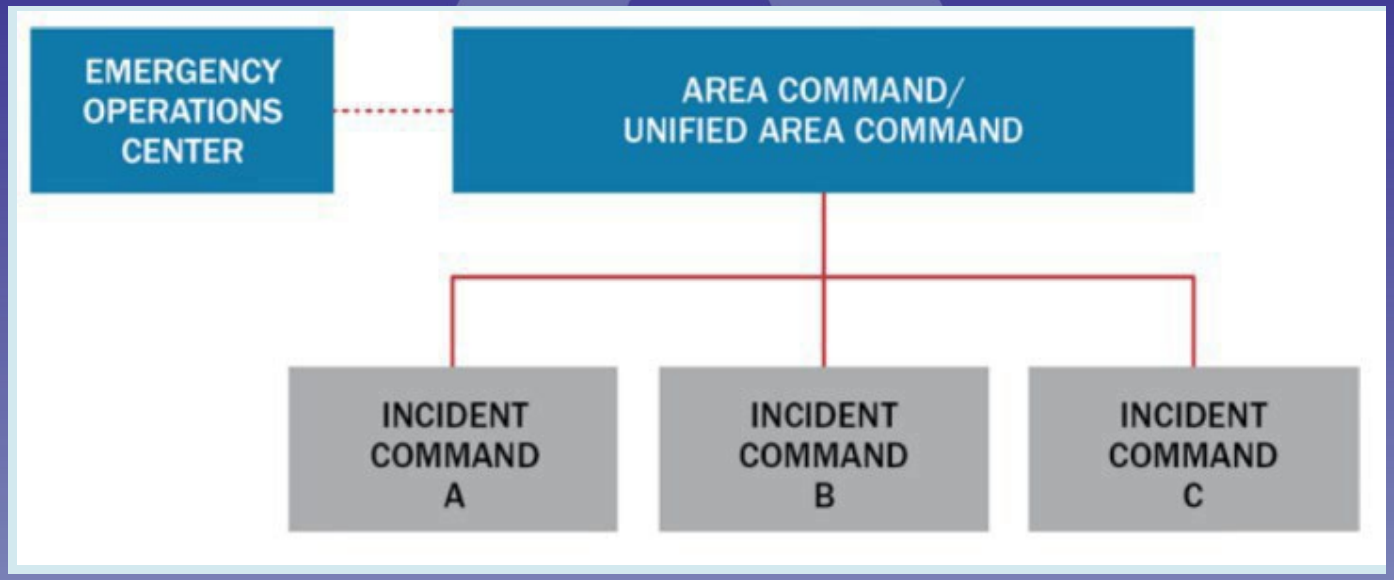
- Clear and maintain evacuation & logistics routes (fuel, light towers, medical) into the Light Damage Zone (LDZ)
- Begin to stabilize and restore infrastructure, where possible

Special Consideration:

- The Moderate Damage Zone (MDZ) is an early response priority with the greatest lifesaving potential: Consider responding to MDZ first.

Mission: Organize the Response

- Tactic 5: Establish Area Command



Mission: Organize the Response

- Tactic 6: Sustain Critical Infrastructure
  - Communications
  - Power
  - Firefighting capabilities
  - Hazmat infrastructure
  - Clear roadways

Light Damage Zone Impacts

Mission: Provide Care to Survivors

- Tactic 7: Evacuate
  - Clear corridors and support evacuation zones
  - Allow spontaneous evacuees to egress
  - Support jurisdictions receiving evacuees

LDZ	Public shelter inside
MDZ	Public evacuate toward LDZ and away from HZ
SDZ	Public and Responders shelter inside
DRZ	Public and Responders shelter inside
HZ	Public shelter inside

Mission: Provide Care to Survivors

- Tactic 8: Triage, Stabilize and Transport
  - Establish ad hoc triage sites near damage zones
    - Trauma
    - Burns
    - Radiation
  - Transport patients to medical facilities in supporting jurisdictions
  - Implement crisis standards of care, if necessary
  - Radiation Injury Treatment Network (RITN): ritn.net
  - Radiation Emergency Medical Management: remm.hhs.gov/index.html

Combined injury with Good Resource Availability

Exposure	Radiation Only or Minimal Trauma	Combined Injury	
	Minimal Trauma	*Moderate Trauma*	*Severe Trauma*
>1000 rad Likely Fatal	Expectant Immediate	Expectant	Expectant
>600–1000 rad Severe	Immediate	Delayed	Expectant
≥ 200–600 rad Moderate	Immediate	Immediate	Delayed
Resource Availability	Normal or Good		

Combined injury with Fair/Poor Resource Availability

Exposure	Radiation Only or Minimal Trauma		Combined Injury	
	Minimal Trauma		*Moderate Trauma*	*Severe Trauma*
>1000 rad Likely Fatal	Expectant	Expectant	Expectant	Expectant
>600–1000 rad Severe	Delayed	Expectant	Expectant	Expectant
≥ 200–600 rad Moderate	Immediate	Immediate	Delayed	Expectant
Resource Availability	Fair	Poor	Fair and Poor	

Note: If > 20% total body surface area (BSA) burn to trauma, lower triage priority 1 level.

Mission: Provide Care to Survivors

- Tactic 9: Decontaminate
  - Implement dry, rapid decon
  - No public radiation monitoring (during early phase)
  - Instruct public to self-decon
  - Provide new clothing for evacuees arriving in support jurisdictions

Mission: Prepare for Intermediate Response

- Tactic 10: Transition to a Prolonged Response
  - Establish system to collect public health and environmental data
  - Assess resources/capabilities for needs and shortages
  - Integrate communications staff
  - Initiate fatality management plans

Fatality Management		
Zone	Description	Priority
SDZ	Inaccessible	None
MDZ/LDZ/DRZ	Accessible	First 72 hours
Beyond		After first week

Federal Response

- National Response Framework – primary guide to how United States responds to domestic terrorism

- Nuclear/Radiological Incident Annex
  - 24 incidents with different primary authorities
  - Primary Authorities: CBP, DHS, DOD, DOE/NNSA, DOS/USAID, EPA, NASA, NRC, USCG (also DOJ/FBI and FEMA)
  - Supporting Agencies: DOL/OSHA, DOT, HHS, NOAA, USACE, USDA, VA

Health Care Worker Absenteeism for Radiological Events

Commitment to Help Staff Non-hospital, Field Medical Facilities		
Incident	Physician (559)	Nurse (2775)
Natural Disaster	83%	90%
Explosion Incident	67%	70%
Chemical Incident	59%	59%
Biological Incident	56%	53%
Contagious Epidemic	56%	49%
Radiological Incident	**52%**	**45%**

Lanzilotte, S., "Hawaii Medical Professionals Assessment", Hawaii Medical Journal, Vol 61. August 2002

Health Care Worker Absenteeism for Radiological Events

Health Care Workers' Ability and Willingness to Report to Duty During Catastrophic Disasters (n=6,428, 47 facilities)		
Disaster	**Willing**	**Able**
Snow Storm	80%	49%
Bioterrorism (smallpox)	61%	69%
Chemical Terrorism	68%	71%
Explosion Incident (MCI)	86%	83%
Environmental Disaster	84%	81%
Radiological Terrorism	**57%**	**64%**
SARs outbreak	48%	64%

Willing

Fear and concern for family and self

Able

Transportation & Dependent Care

Qureshi, K, Gershon, R., Gebbie, E., Straub, T, and Morse, S. (2005). Healthcare workers ability and willingness to report to duty during a catastrophic disaster. *Journal of Urban Health*. 82(3):378-88.

Three Myths That Can Paralyze Medical Response

Myth 1

Radioactive Contamination is Highly Dangerous and Requires Extraordinary Protective Measures

Fact 1

"Skin or wound contamination is never immediately life threatening to affected people or medical personnel"

~ International Commission on Radiological Protection, report # 96

- Radioactive contamination:
  - Is NOT immediately dangerous to life and health
  - Is *easily* managed and contained using basic antiseptic practices (good hygiene, proper attire, proper gloving practices, etc.)
  - Presents *little* hazard to medical staff (unlike biological or chemical agents)

Myth 2

Decontamination of the Patient is the Highest Medical Priority

Fact 2

"rescue and medical emergencies take precedence over radiological concerns"

"...radioactive material contamination rarely represents an immediate danger to the health of the victim or the responder. This reduces the immediacy of the need for decontamination and allows the emergency response community greater flexibility in selecting decontamination options"

~ National Council on Radiation Protection and Measurements, Commentary # 19

- Critical care takes precedence over monitoring or decontamination
- Simple decontamination: outer clothing removal and wiping exposed skin can often be sufficient

Myth 3

You need “special skills” to handle radioactive patients

Fact 3

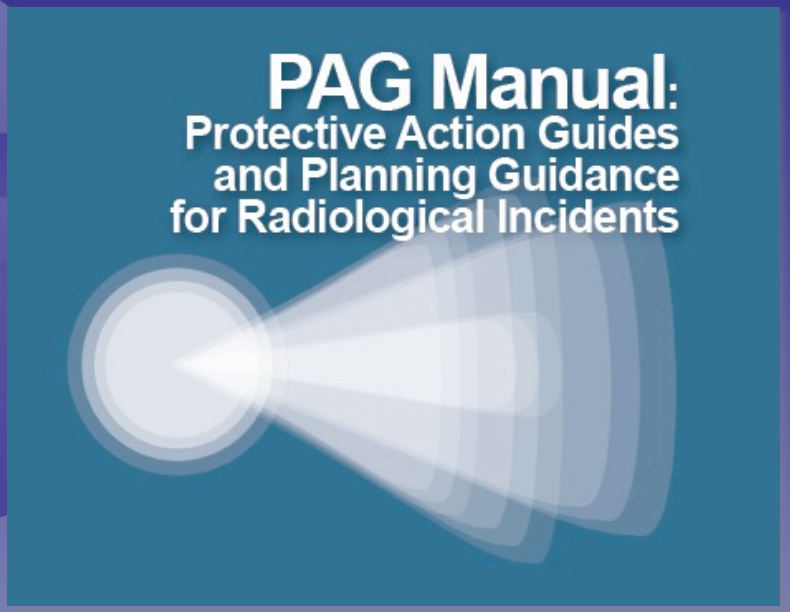
"Universal precautions (i.e., standard hospital personal protection procedures) in the emergency room are generally sufficient for treatment of victims of nuclear and radiological incidents"

~ National Council on Radiation Protection and Measurements, Commentary # 19

- Radioactivity can be easily and immediately measured with radiation meters (e.g., Geiger counters)
  - They are easy to use
  - Many hospitals already have them
  - Most fire departments already have them
- Contamination surveys are easily taught and easily performed with just-in-time training

EPA PAGs

- *Protective Action Guides and and Planning Guidance for Radiological Incidents*, January 2017
- Made for state and local authorities
- PAGs are a guideline to AVOID
- Covers three phases of an incident
  - Early Phase (emergency) - hours to days
  - Intermediate Phase - weeks to months
  - Late or Recovery Phase - months to years



Responder Health and Safety

- Do NOT rush into ground zero (SDZ)!
- Use radiation instruments to determine exposure rate
- Practice As Low As Reasonably Achievable (ALARA)
- Wear Air Purifying Respirator (APR) or Powered Air Purifying Respirator (PAPR)
- Rotate teams to reduce dose
- Avoid moving or touching debris

Please

- Save the living, not the dead (stay out of the SDZ)
- Re-establish command and control ASAP
- Stop fires/firestorms outside of radiation area
- Save critical infrastructure (especially hospitals)
- Make quick decisions about shelter or evacuation
- Use your common sense – lots of other people won't

Considerations

- Vehicles – close doors/windows
- Change of clothes
- High range meters
- Dosimeters
- Need food and water for evacuated population
- Need basic sanitation

Family Protection

- Get inside, stay inside and stay tuned
- Use an N-95 mask if you go outside
- Can you see a plume? Don't be under it
- Children – more susceptible
- Immune compromised individuals – also of concern
- Initially leave at right angles to direction of the plume/wind
- Figure out weather – probably evacuate south, southwest, west (depends on your local weather and time of year)
- Shelter important (cars aren't much good)
- Wash off particulate as soon as possible
- Medical assistance can help those with radiation sickness (lower doses)

Media Messaging

- Fill the void with prescript messaging to prevent media from spinning out of control with bad information

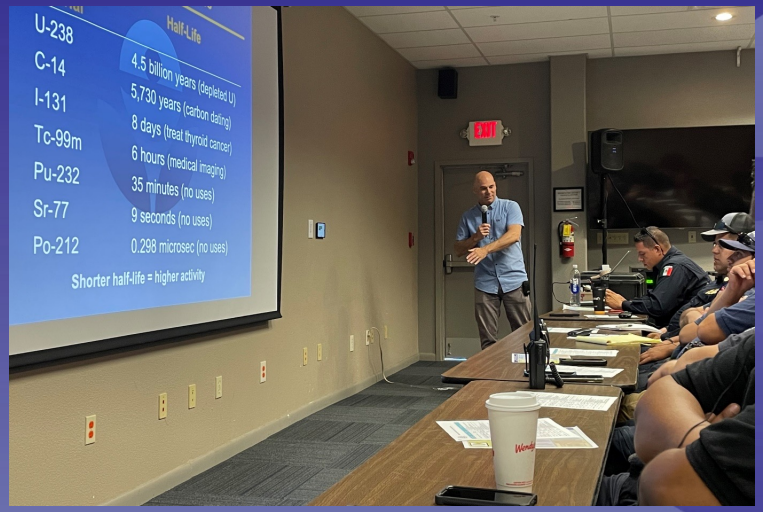
Warning. This is not a test. A nuclear detonation has occurred. People within 50 miles of downtown Nukeville – get inside, stay inside, stay tuned for more information. Prepare to stay inside for at least 24 hours unless officials provide other instructions, or your building is threatened by fire or collapse. Follow instructions from officials – this can save your life.

Preparedness

Public Education

- Get Inside, Stay Inside, Stay Tuned!!
  - (within 50 miles of ground zero until fallout zone is defined)

Responders



Training

Detectors

Dosimeters

Rad Resilient City Initiative

- Checklists for preparedness actions for cities and communities
  - Obtain community backing and understanding of nuclear incident preparedness
  - Conduct an ongoing public education program
  - Enable building owners (private to skyscraper) how to assess shelter protection
  - Strengthen region's ability to deliver public warnings
  - Establish a rapid system for mapping and monitoring the dangerous fallout zone
  - Develop planning strategies/logistical capabilities for large-scale, phased evacuation
  - Conduct training on above elements for comprehensive fallout preparedness and public warning system

- https://centerforhealthsecurity.org/our-work/research-projects/completed-projects/rad-resilient-city-initiative

References

References

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- *Nuclear Detonation Response Guidance, Planning for the First 72 Hours*, FEMA, March 2023
- FEMA video series: https://www.youtube.com/playlist?list=PL720Kw_OojII5Jgazq6PeapAcQB4sQtLp
- Bomb test videos: https://www.youtube.com/playlist?list=PLvGO_dWo8VfcmG166wKRy5z-GIJ_OQND5

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- *Health and Safety Guide for Protecting First Responders Following a Nuclear Detonation and Health and Safety Handbook for First Responders Following a Nuclear Detonation*, National Security Council Staff, 2016

- *Improvised Nuclear Device Response and Recovery: Communicating in the Immediate Aftermath*, FEMA, 2013

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- *Management of Persons Contaminated with Radionuclides: Handbook*, NCRP, Report 161I, 2008

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- *A Guide to Operating Public Shelters in a Radiation Emergency*, CDC, 2015
- *Population Monitoring in Radiation Emergencies, 2nd Edition*, CDC, 2014
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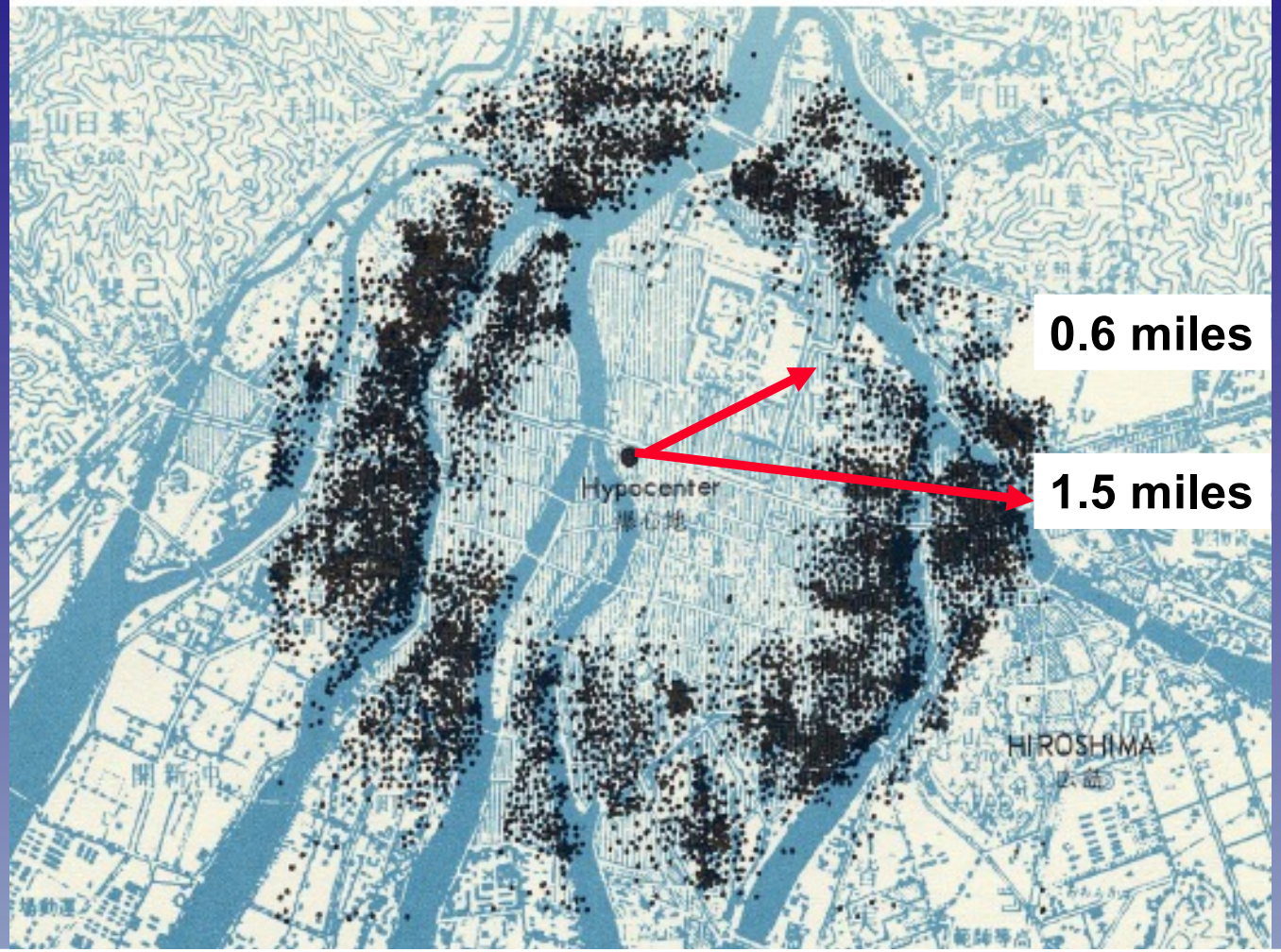
Hiroshima Injured Survivors



How to Survive a Nuclear Detonation

Questions?

PDF of presentation at EPA's website:
https://response.epa.gov/site/doc_list.aspx?site_id=16637