Detecting, weathering, and surviving radiological and nuclear terrorism

Christine Hartmann Siantar

Outline

- Detecting radiological dispersion devices (RDDs) and nuclear weapons
- Weathering the effects of RDDs and nuclear weapons
- Surviving radiation injury

Detecting RDDs and nuclear weapons

A layered, defense-in-depth approach is required to counter nuclear terrorism

A Layered defense includes:

- Eliminating or protecting excess stocks of nuclear materials and weapons
- Detecting and interdicting illicit movement of nuclear or radiological material overseas
- Screening incoming cargo and conveyances for nuclear or radiological materials
- Enhancing domestic detection and interdiction efforts
- Implementing an effective nuclear forensics and attribution program

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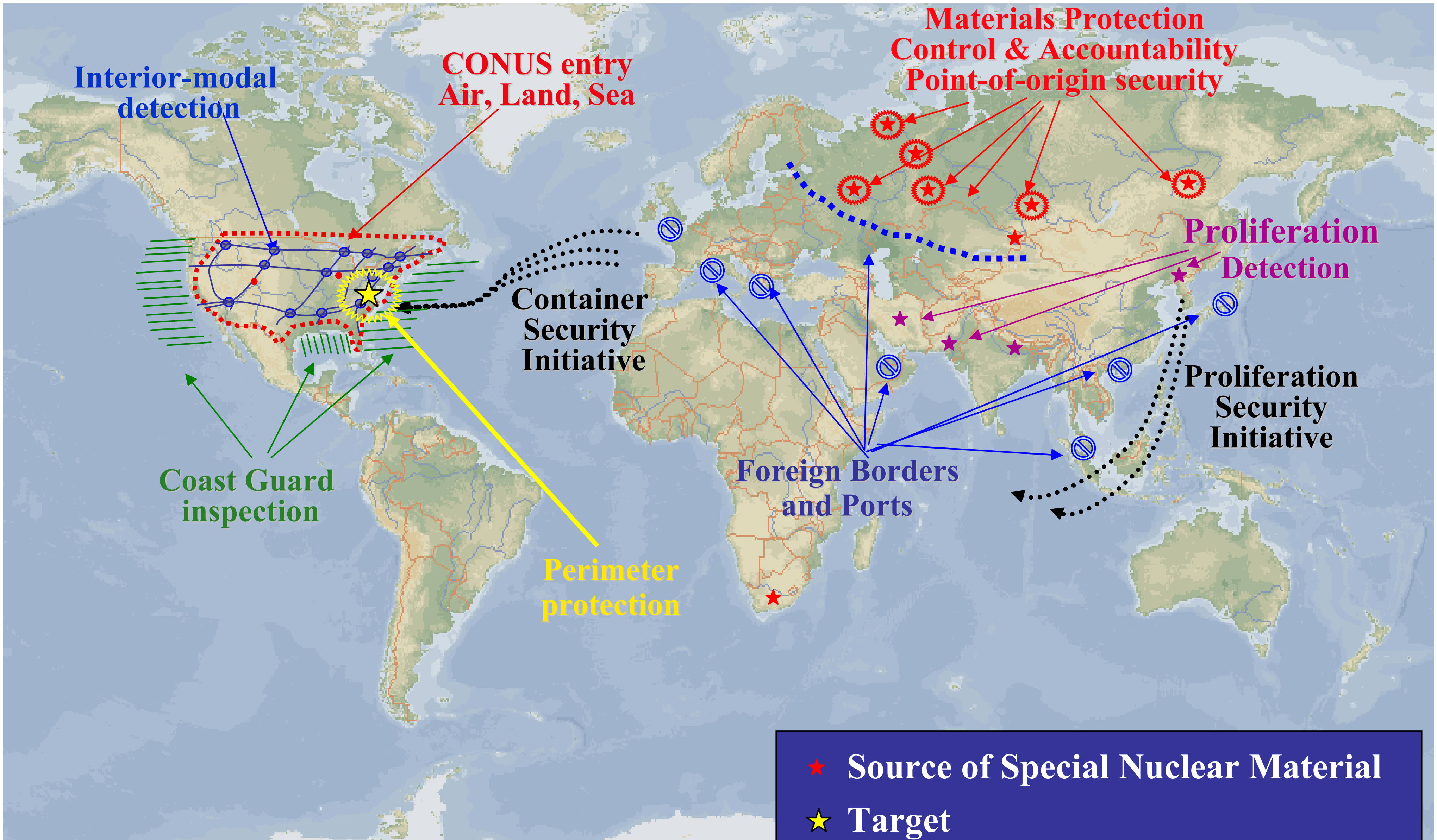
A global defense architecture is required for an effective deterrent



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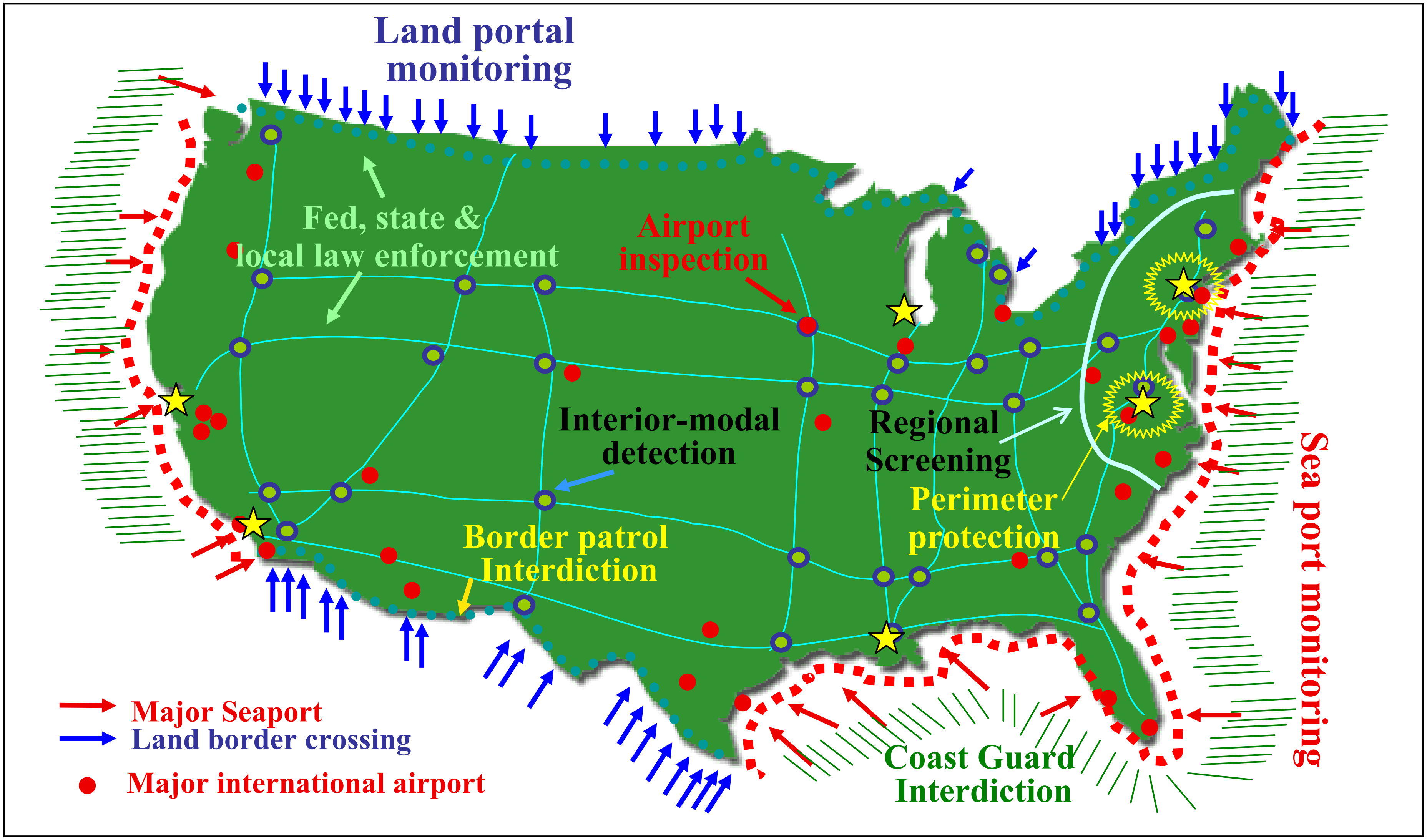
Nuclear and radiological countermeasures demands a layered defense at home



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Success is more than just detection

Encounter the adversary

- Detect the threat

- Identify or classify the threat

- Interdict

$$P_{success} = P_{encounter} * P_{detection} * P_{identification} * P_{interdiction}$$

All with a sustainable operational burden

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Several recurring themes have been identified

- Security of SNM is critical
- No single detection initiative has sufficient performance to assure successful detection and interdiction
- Radiation signatures are only one factor contributing to successful detection and interdiction
- Active interrogation can provide an effective means for detection of shielded materials and/or shielding
- Response concept of operations is critical (detection, interdiction, and alarm resolution)
    - Training, exercise and assessment programs are necessary
- The performance of current radiation detection technology is limited; <u>vigorous R&D program is essential</u>

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We must consider a broad range of delivery vectors

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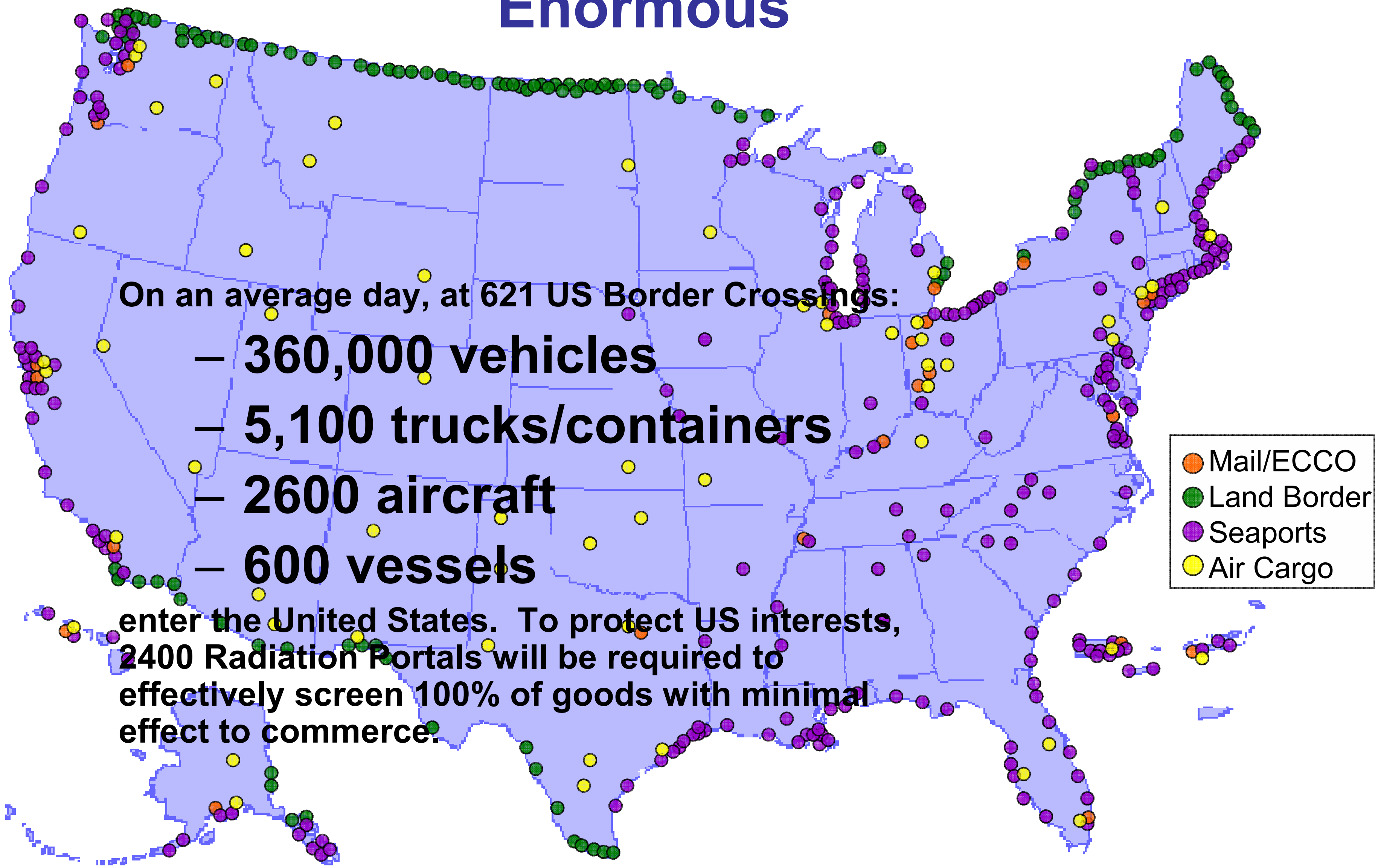
The Magnitude of the Border Screening Effort is Enormous



On an average day, at 621 US Border Crossings:

- 360,000 vehicles
- 5,100 trucks/containers
- 2600 aircraft
- 600 vessels

enter the United States. To protect US interests, 2400 Radiation Portals will be required to effectively screen 100% of goods with minimal effect to commerce.

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USCG patrols 95,000 miles of US Coastline

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US Border Patrol is responsible for: 6,000 miles of land border & 2,000 miles of waterway

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DHS is developing and deploying radiation detection technologies in many venues

- Enhance border security
  - Complete deployment of today's technologies at legal POEs
    - Passive γ,n detection
    - Radiography
- Develop and deploy the next generation of passive and active detection technologies
- Develop and deploy defense architectures within our borders
  - Interior-modal detection and Perimeter defense
  - Routine radiological surveillance
- Develop and integrate new technologies to improve system effectiveness
  - Evolutionary and Transformational R&D

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Radiation portal monitors and radiography are being deployed at our Points Of Entry

- Customs and Border Protection is deploying portals and radiography systems at
  - International mail and express consignment courier facilities (ECCFs)
  - Land and Rail crossings
  - Seaports
  - International Airports

Port of New York/New Jersey

Northern Border

Mobile Radiography

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Many technical challenges remain

- Primary screening sensitivity is often limited by the capacity to resolve nuisance alarms
  - People, physical capacity and technology at POEs
- Shielding limits ability to detect certain threat materials
  - Radiography can be employed to detect the presence of shielding materials
  - Active interrogation (γ, n probes) can be employed to detect SNM directly

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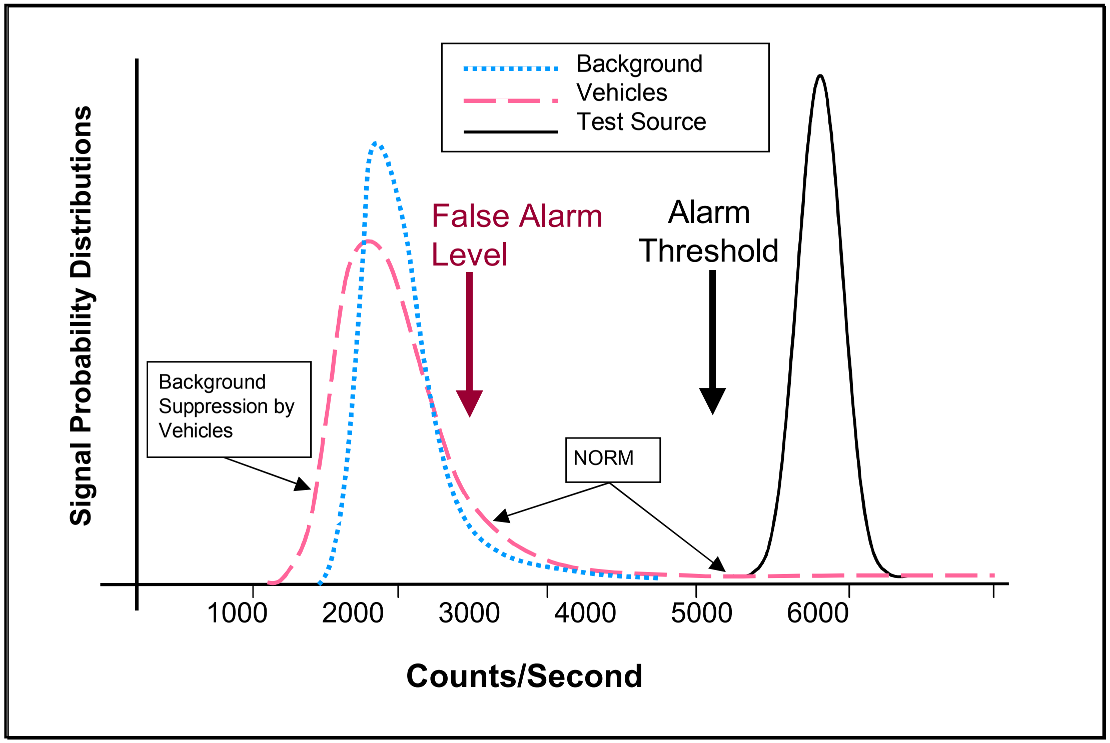
Radiological screening thresholds are limited by alarm rate not by the sensitivity of the technology



Alarms are dominated by Naturally Occurring Radioactive Materials (NORMS) at current threshold settings

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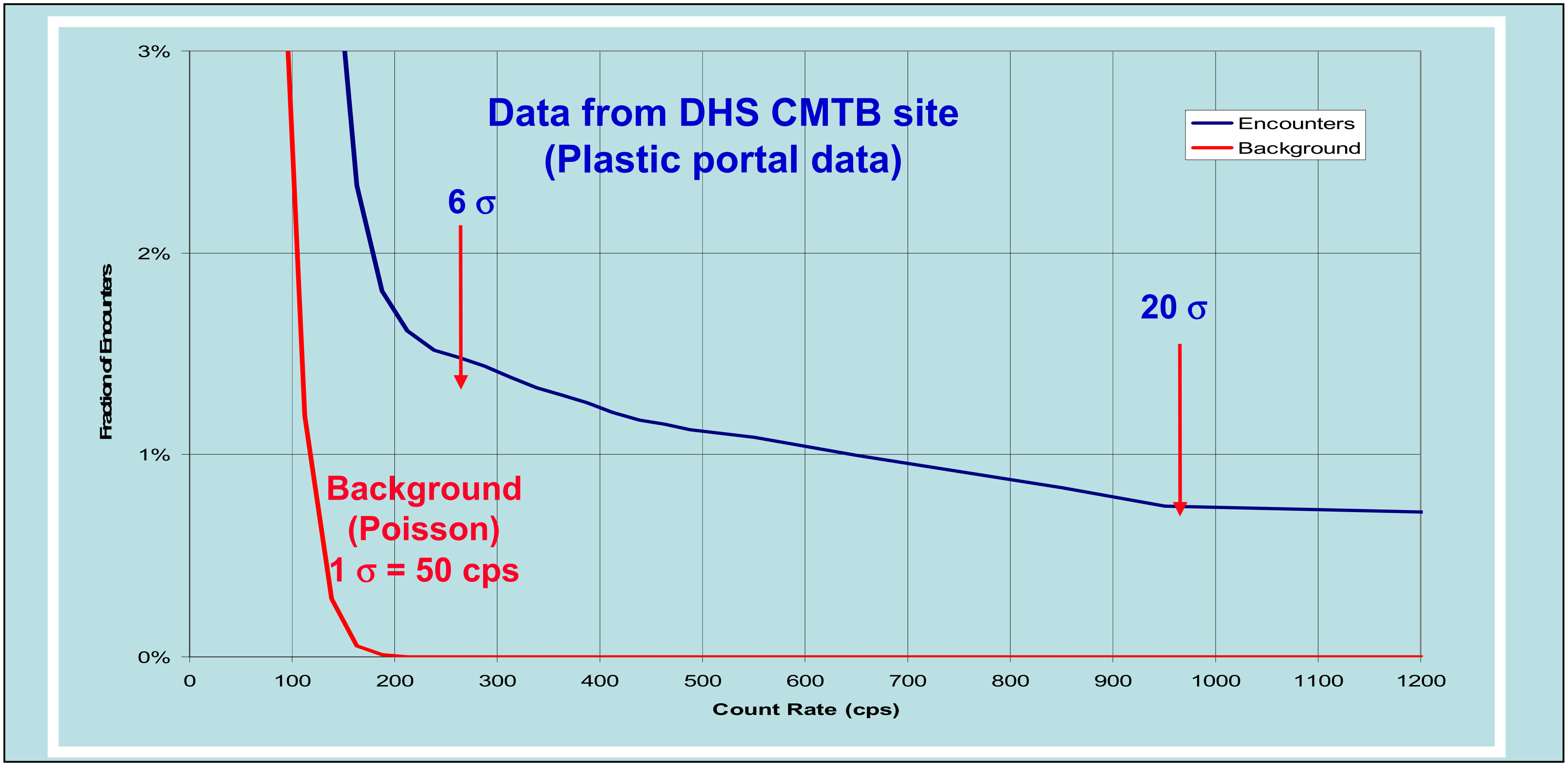
Naturally-occurring materials drive the secondary inspection rate in two level systems.



- Long tail of NORM distribution drives very high detection thresholds to reduce secondary inspections and increase throughput.

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The operational impact of nuisance alarms is significant

- Certain NORM materials are a majority of alarms
- Medical treatments account for significant alarms
- One in <u>2600</u> Americans carries radioactive burden
- Smart algorithms to reduce NORM alarms

	% of Alarming Loads
Kitty litter	34%
Medical (In, I, Tc, Tl)	16%
Abrasives	8%
Refractory material	8%
Scouring pads	6%
Mica	5%
Potassium/Potash	5%
Granite slabs	4%
Toilet bowls & tile	4%
Trucks/cars	2%

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Spectroscopic portals will provide the next-generation of performance in passive screening for radiological materials

- Spectroscopic portals can provide:
  - More robust identification capability in secondary inspection
  - Automated NORM rejection in primary screening
  - Decreased detection thresholds without increased operational burden

Spectroscopic Portal

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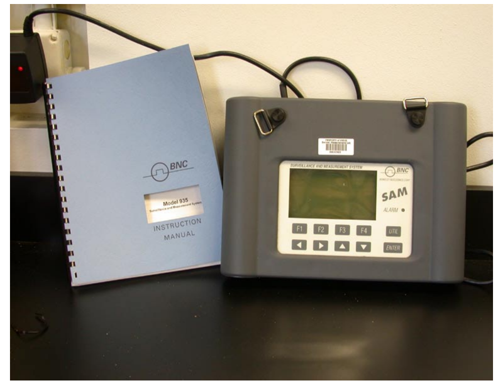
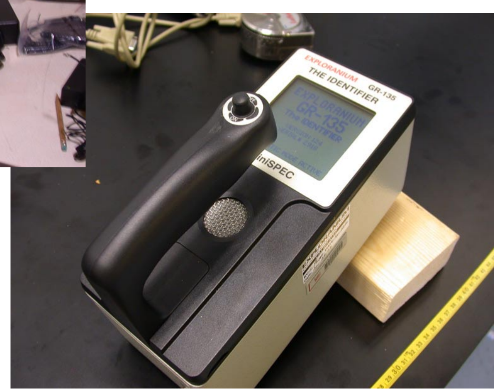
Hand-Held Isotope Identifiers will continue to play a key role in alarm resolution

- Need more sensitive detectors
- More robust ID
- Simplify software
  - Robust end-user interface
  - Streamline data downloads





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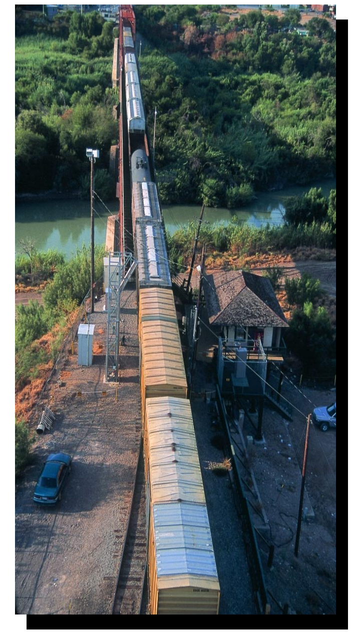
Advancing the state-of-the-art in non-intrusive inspection

- Mobile and relocatable systems
- Dual-Energy Imaging for High-Z Materials Detection
- Advanced Imaging Analysis

Relocatable systems



Rail systems

Portal systems

Mobile systems

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Multiple domestic screening opportunities are being evaluated

Frequency of Travel From 29 Source Points To 31 Destinations

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Potential grand challenges R&D to address the key limitations of current technology

- Detection of shielded SNM
- Distributed sensing
- Long-dwell detection in transit
- Standoff detection
- Alternate signatures of radiological materials
- Innovative detector materials
- Signal processing and data fusion

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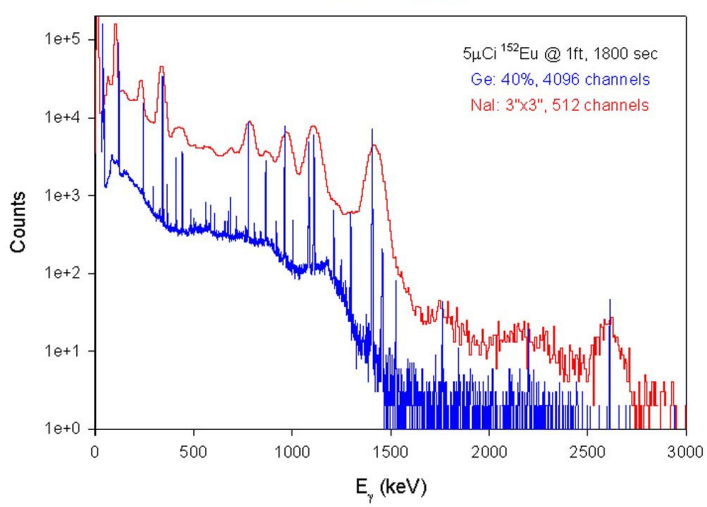
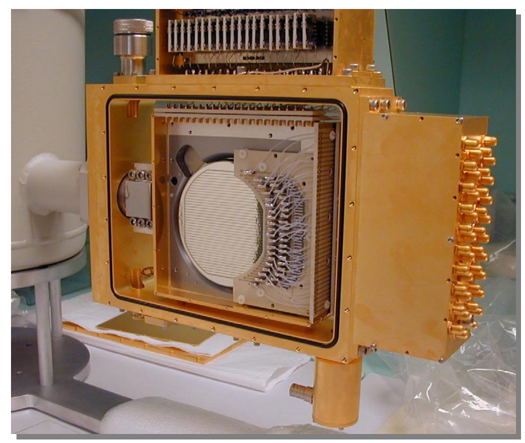
Long-term passive technology development initiatives address the key challenges - performance and cost

- Low-cost gamma/neutron detection
- Advanced materials development
- Improved algorithms

Detector Resolution:
Ge vs NaI



Large-area 2-D gamma imaging detector



Germanium-based 3-D gamma Imager

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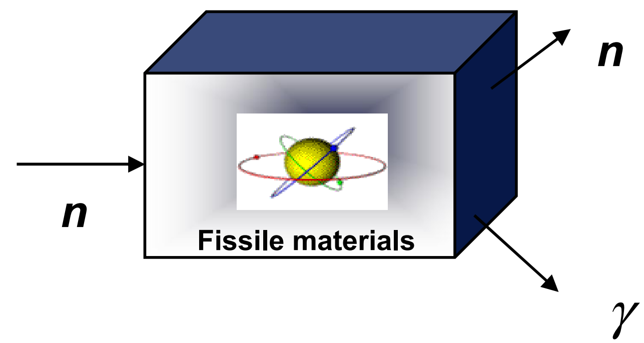
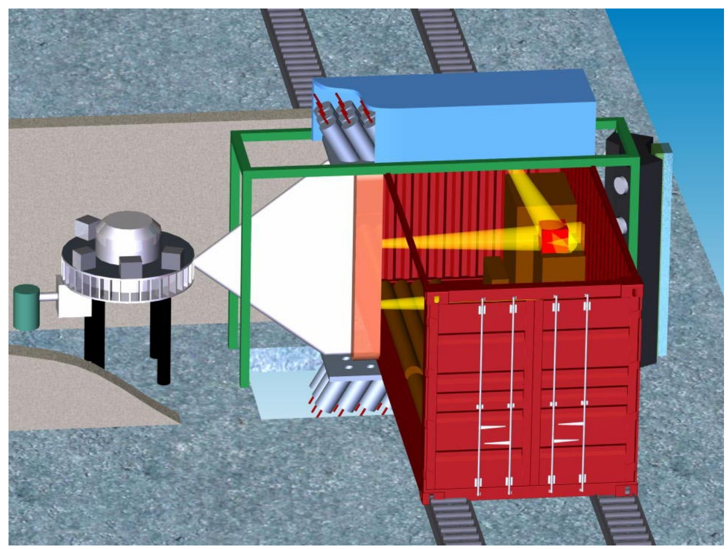
Long-term active technology development initiatives are focused on direct detection of SNM

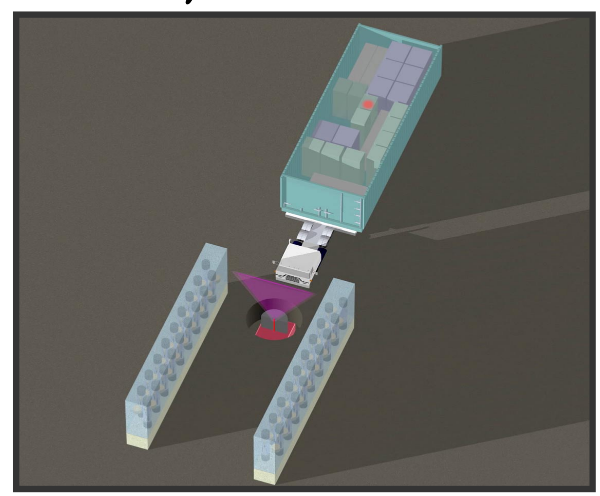
- Gamma interrogation
- Neutron interrogation
- Advanced concepts



Portable, Low-energy Neutron source



Conceptual portable gamma interrogation concept



Conceptual "nuclear car wash"

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Clarity is king

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

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If you think this is easy…

- *Law Enforcement personnel are already fully burdened*

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The operational environments are challenging

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There’s plenty of room..

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Plenty of office space

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And, you can't beat the weather

The public is ready to cooperate

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What if we fail?

Effects of RDDs and nuclear weapons

Baseline consequences for RDDs and nuclear weapons

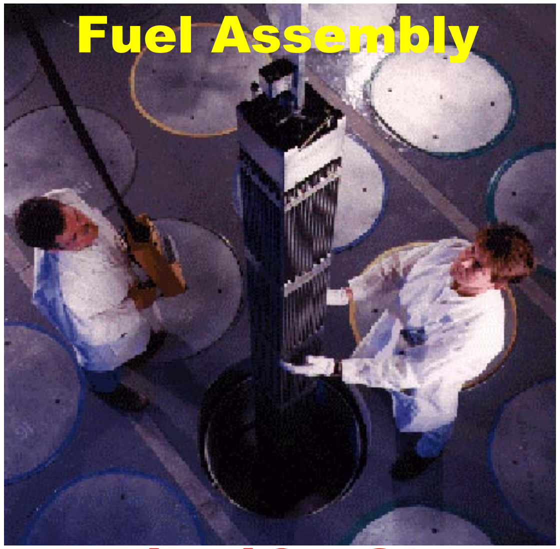
Threat Scenario	Deaths	Injuries
RDD	1 – 10’s	1 – 10’s
Nuclear weapon	100K’s	100K’s

Radiological Dispersion Devices

WHAT IS A 'DIRTY BOMB'?

- A "Dirty Bomb" is conventional explosives combined with radioactive material with the intention of spreading the radioactive material over a relatively large area.
- This is **NOT** a nuclear explosion, the radioactive material does not enhance the explosion.
- Very few deaths would be expected from acute radiological exposure (the greatest hazard would likely be from the effects of the conventional explosives).
- The contamination will hamper emergency response efforts and can delay hospital treatment.
- Widespread contamination can deny the use of facilities and areas and have a significant psychological impact on the exposed population.

Potential RDD sources: High Activity Radioactive Material



1 - 10 kCi
(when spent)

1 - 500 kCi (when spent)

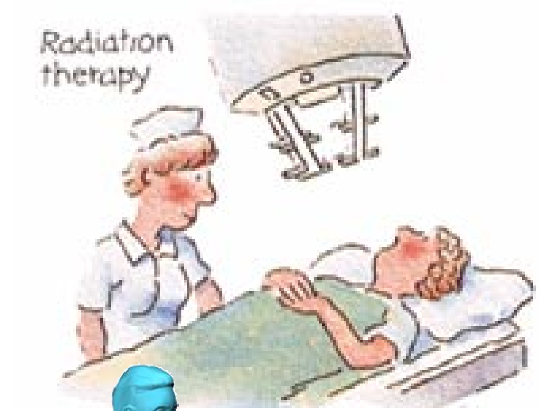
Sr-90 RTG at Burnt Mountain, Alaska

10 -100 kCi

- Spent Nuclear Fuel & High Level Waste
- Radioisotope Thermoelectric Generators (RTG)
- Medical & Radiographic sources

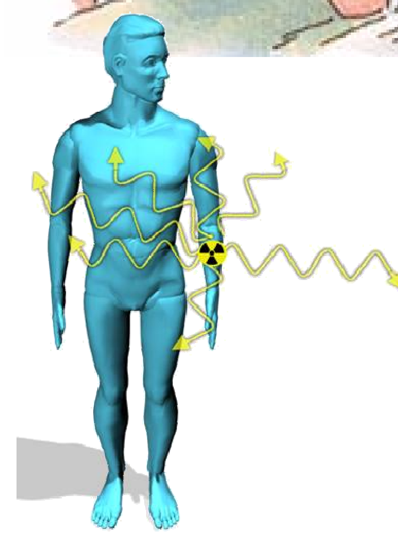
0.01 - 0.2 kCi

1-10 kCi

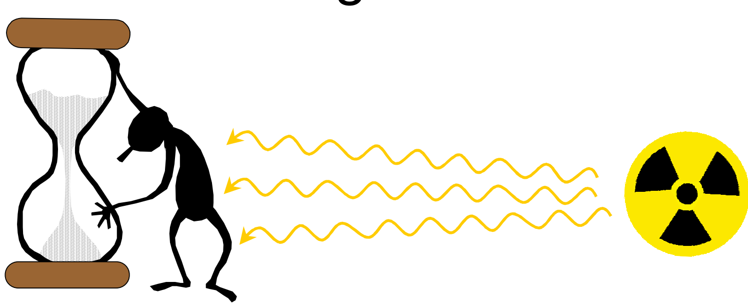


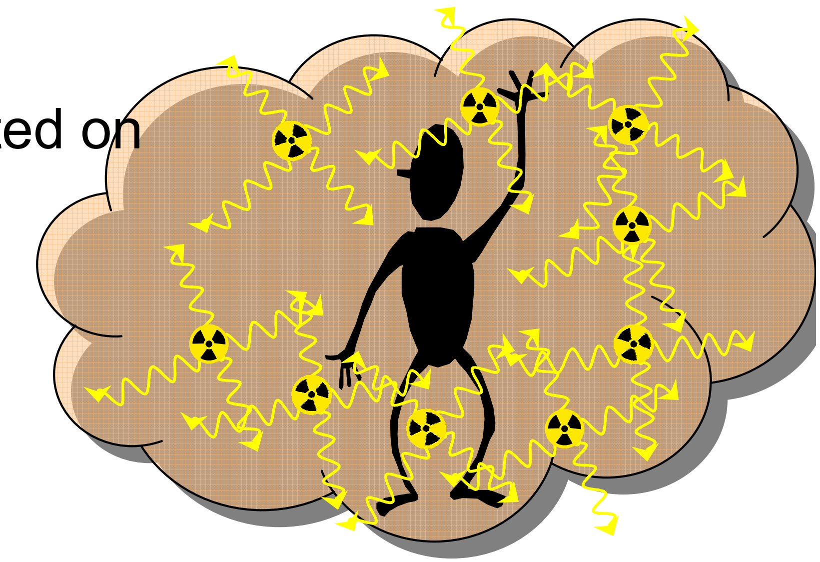
External Exposures

- Focused radiation or localized contamination can result in radiation effect to specific areas on the body



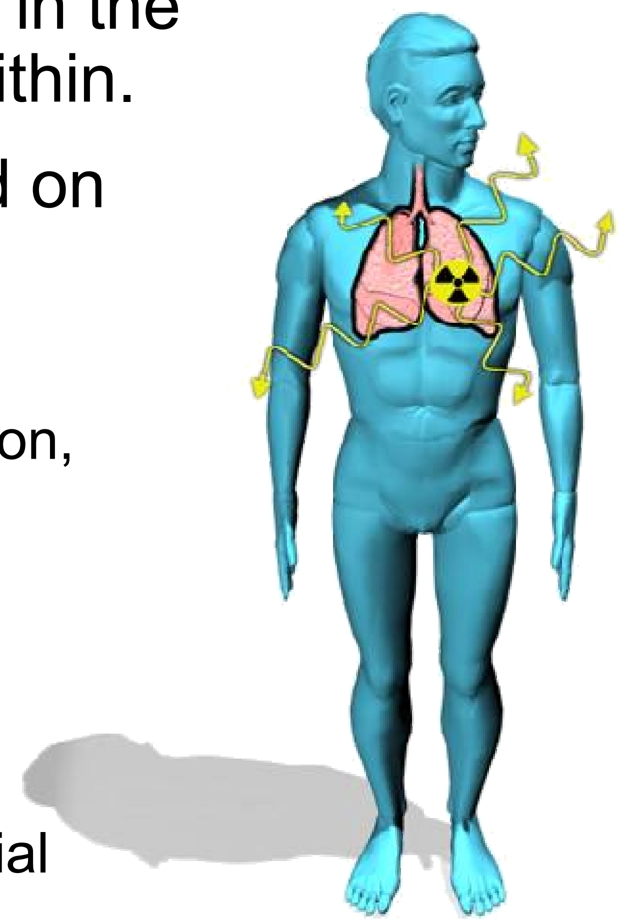
- Whole body exposure can result from:
  - A passing radioactive cloud or smoke
  - A large, distant point source
  - Exposure from contamination deposited on the ground





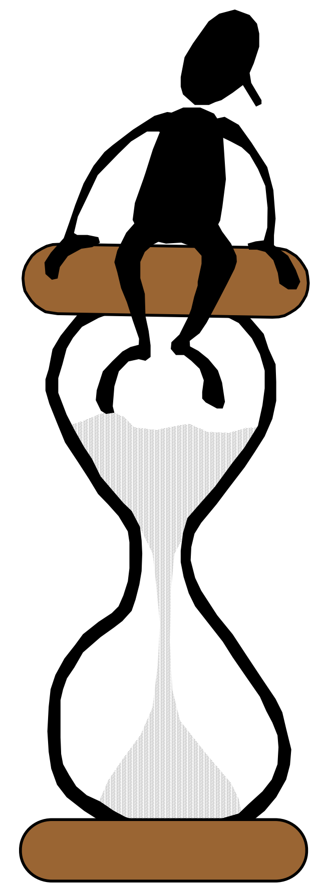
Internal Exposures

- Once radioactive material is deposited in the body, it can expose the person from within.
- The magnitude of the dose will depend on many factors:
  - How much material was deposited,
  - How it got into the body (ingestion, inhalation, absorption, or injection)
  - Chemical form of the radioactive material,
  - the radiation it produces,
  - How quickly it decays, and
  - How quickly the body eliminates the material



Internal Exposures

- Dose from internal radioisotope exposure are usually expressed by **summing dose that will be received over the next 50 years from a one time internal deposition**.
  - Referred to as Committed Effective Dose Equivalent (CEDE).
  - This dose calculation/estimate takes into account factors on the previous slide.
  - Even with a large CEDE, there may or may not be acute effects from the exposure.

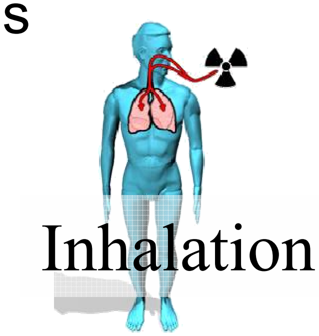


Do not use internal doses to predict acute exposure effects like nausea and vomiting.

Types of Exposure & Health Effects

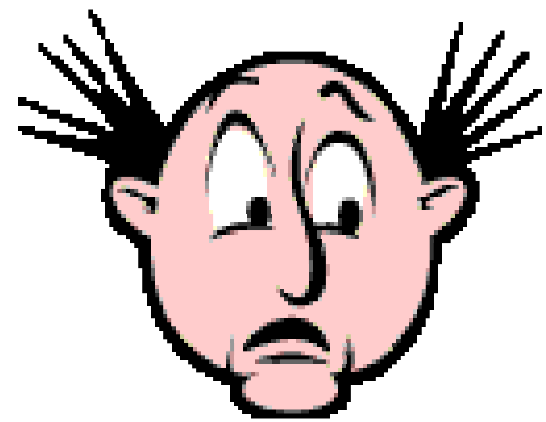
- **Acute Dose**
  - Large radiation dose in a short period of time
  - Large doses may result in observable health effe
    - Early: Nausea & vomiting
    - Hair loss, Fatigue, & medical complications
    - Burns and wounds heal slowly
  - Examples: Medical Exposures and accidental exposure to sealed sources

- **Chronic Dose**
  - Radiation dose received over a long period of time
  - Body more easily repairs damage from chronic doses
  - Does not usually result in observable effects
  - Examples: Background Radiation and Internal Deposition



The Human Factor

- Concerns about radiation and contamination often produce an exaggerated emotional response.
  - Can’t detect it with our 5 senses
  - Associated with cancer
  - Reminiscent of “cold war” fears
  - Science difficult to understand
  - Out of our control



- Possible results may be…
  - Unexposed people saturating the medical community
  - Health and economic effects from long term anxiety or depression in the community

Conclusion:
Misuse of Radioactive Material

- High activity sources can cause health effects, but only to those in close proximity.
- Acute health effects from distributed radioactive material unlikely without prolonged, high-concentration exposure.
- Radiation or contamination will hinder response efforts.
- Denial of facilities and areas will have a major cost effect
- Public anxiety and it’s effects may be the primary lasting health effect.

References

RadEFX(sm) Ionizing Radiation Health Effects Forum
Copyright © 1994-1997 Baylor College of Medicine, All rights reserved.
http://radefx.bcm.tmc.edu/ionizing/subject/risk/acute.htm

Disaster Preparedness for Radiology Professionals
Response to Radiological Terrorism
A Primer for Radiologists, Radiation Oncologists and Medical Physicists
©2002 American College of Radiology
http://www.acr.org/departments/educ/disaster_prep/disaster-planning.pdf

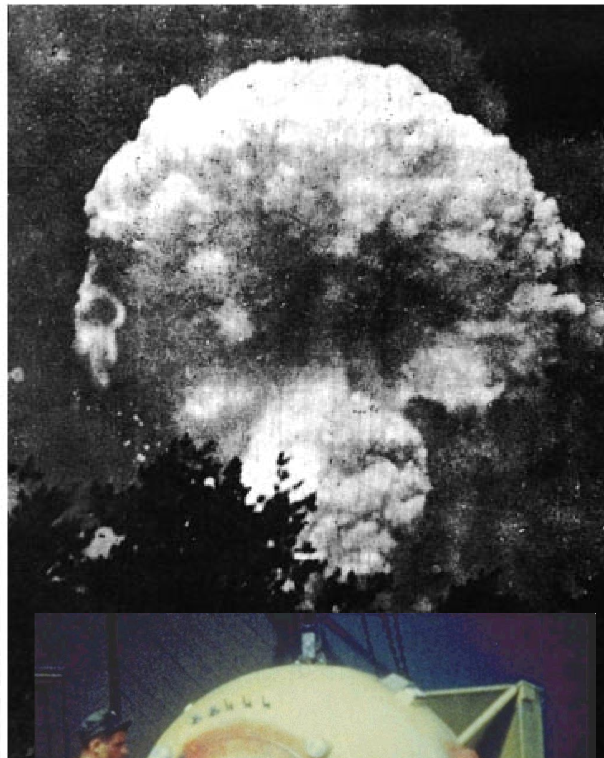
Uranium Information Centre
Melbourne, Australia
http://www.uic.com.au/index.htm

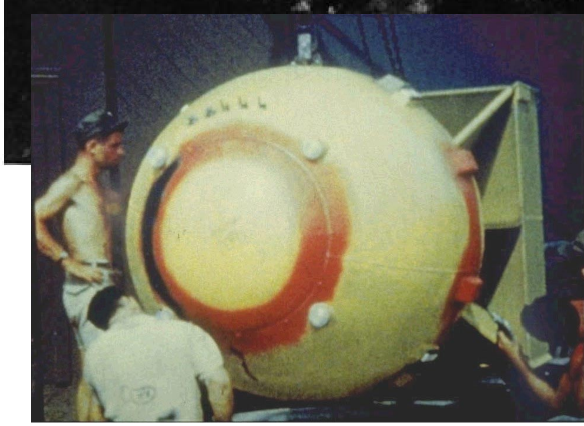
Transportation Emergency Preparedness Program (TEPP)
http://www.em.doe.gov/otem/program.html

Large Sources of Radioactive Material, SNL 02-024
Bill Rhodes, Fred Harper, Marvin Larsen

Effects of Nuclear Weapons

≤ kilotons





Hiroshima – 12.5 kilotons

Oklahoma City: 2 tons

Megatons

Brooke Buddemeier

Some sobering words about Nuclear Terrorism

- **“the single most serious threat to US national security”**

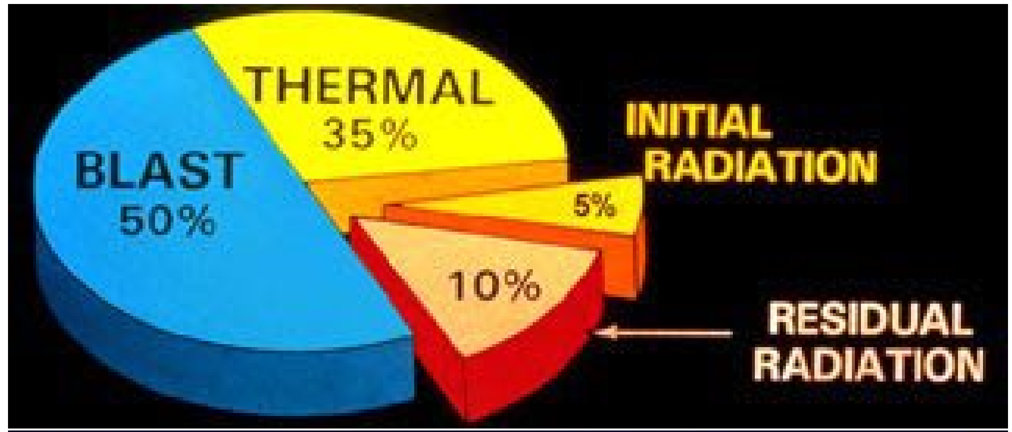
  President George W. Bush and Senator John F. Kerry – 1st Presidential Debate 2004

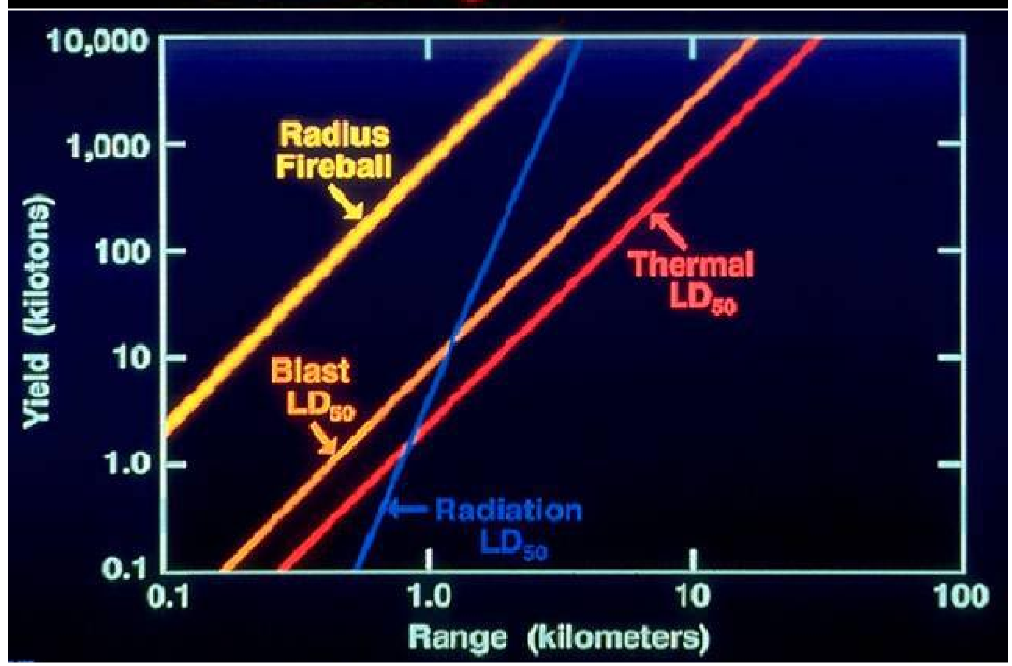
- **“nuclear terrorism is, in fact, preventable. It is a basic matter of physics: without fissile material, you can’t have a nuclear bomb. No nuclear bomb, no nuclear terrorism.”**

  Graham Allison, *Foreign Affairs*, January 2004

Radiation Not The Primary Hazard

- Blast and thermal effect comprise of the majority of effects/casualties
- Radiation lethality out-distances thermal and blast damage only in low yield weapons (≤ 1 kiloton)





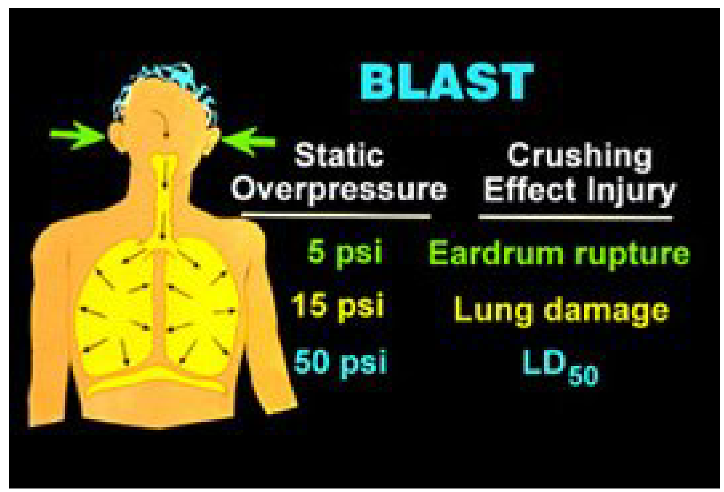
AFRRI

Blast: 50% of the Energy

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}

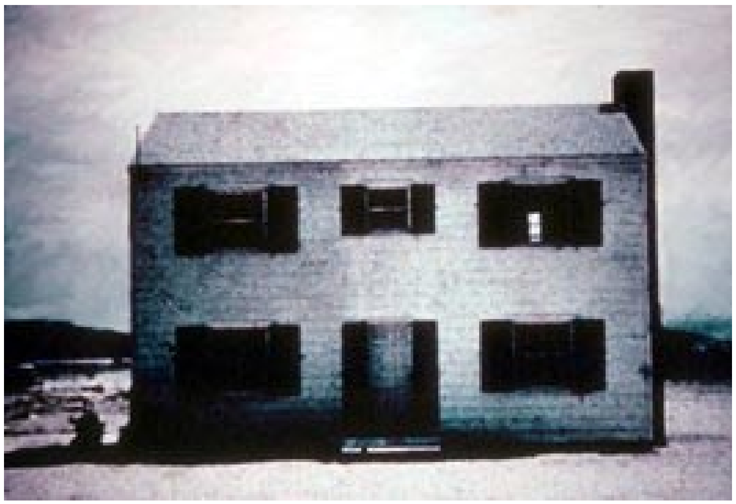
Missile injuries
Lacerations
Penetrating wounds
Blunt injuries h

A 10-gram glass fragment traveling 15 meters per second causes injuries and at 55 meters per second causes serious wounds.



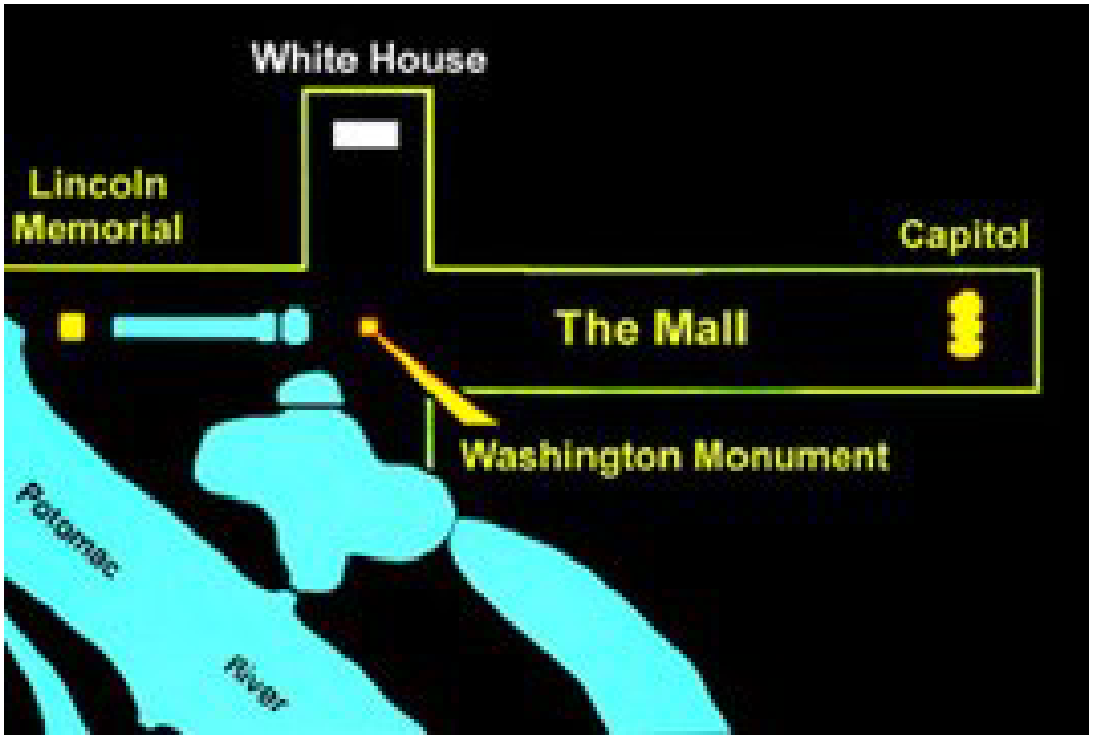
AFRRI

US Testing on Effects

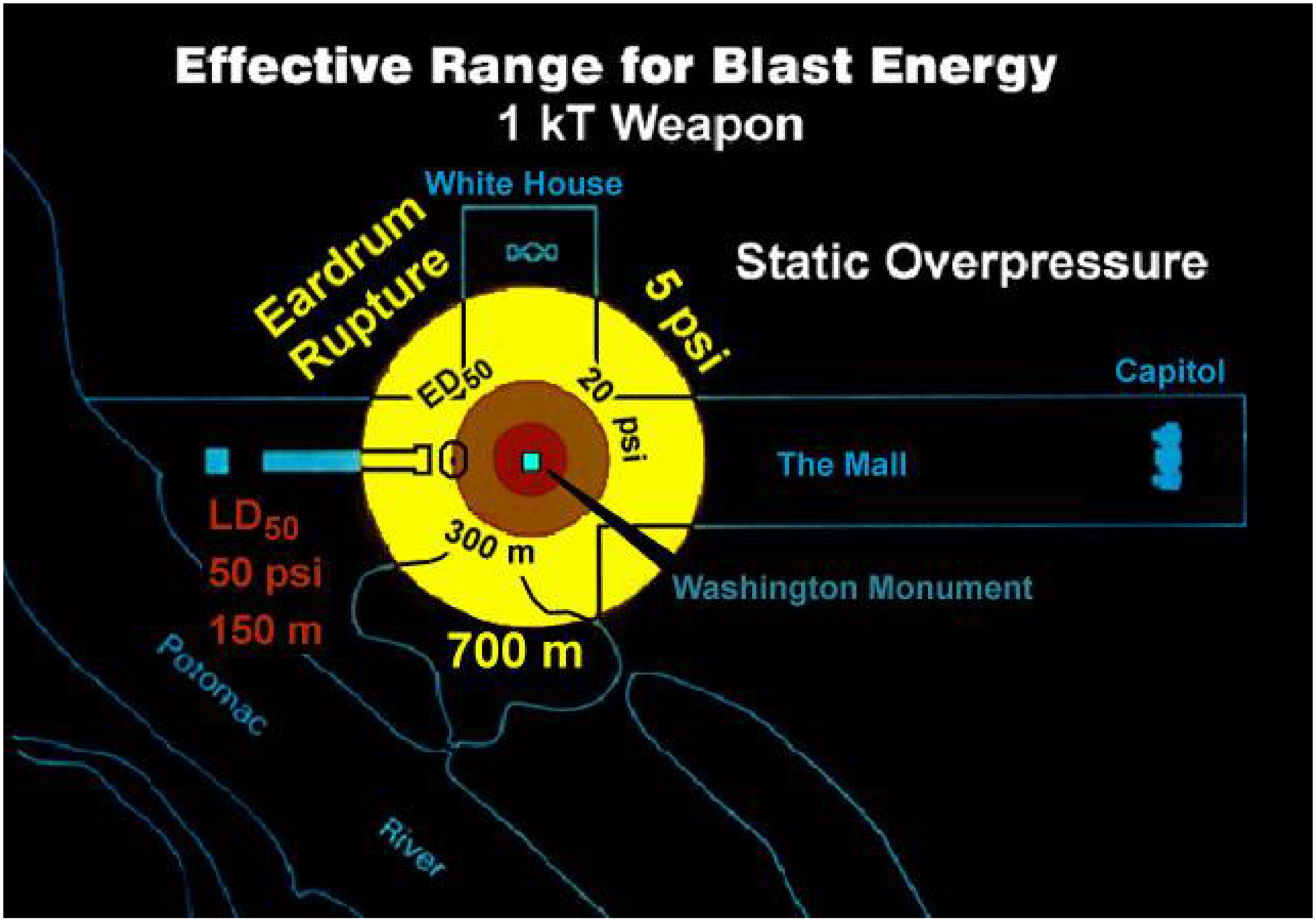
- A 1953 nuclear weapon detonation test at the Nevada Test Site used a house typical of those built in the United States at the time. The house was in the Mach reflection region where the peak overpressure was 5 pounds per square inch (Defense Nuclear Agency image).

Example: 1-kiloton device



Assume that a 1-kiloton nuclear device is detonated atop the Washington Monument in downtown Washington, DC. As shown, the monument is south of the White House and just west of the Lincoln Memorial. To the west of the monument is The Mall, comprised of the Smithsonian Institute buildings and the Capitol Building. The monument is slightly taller than 555 feet.

Blast Energy (1 kT)



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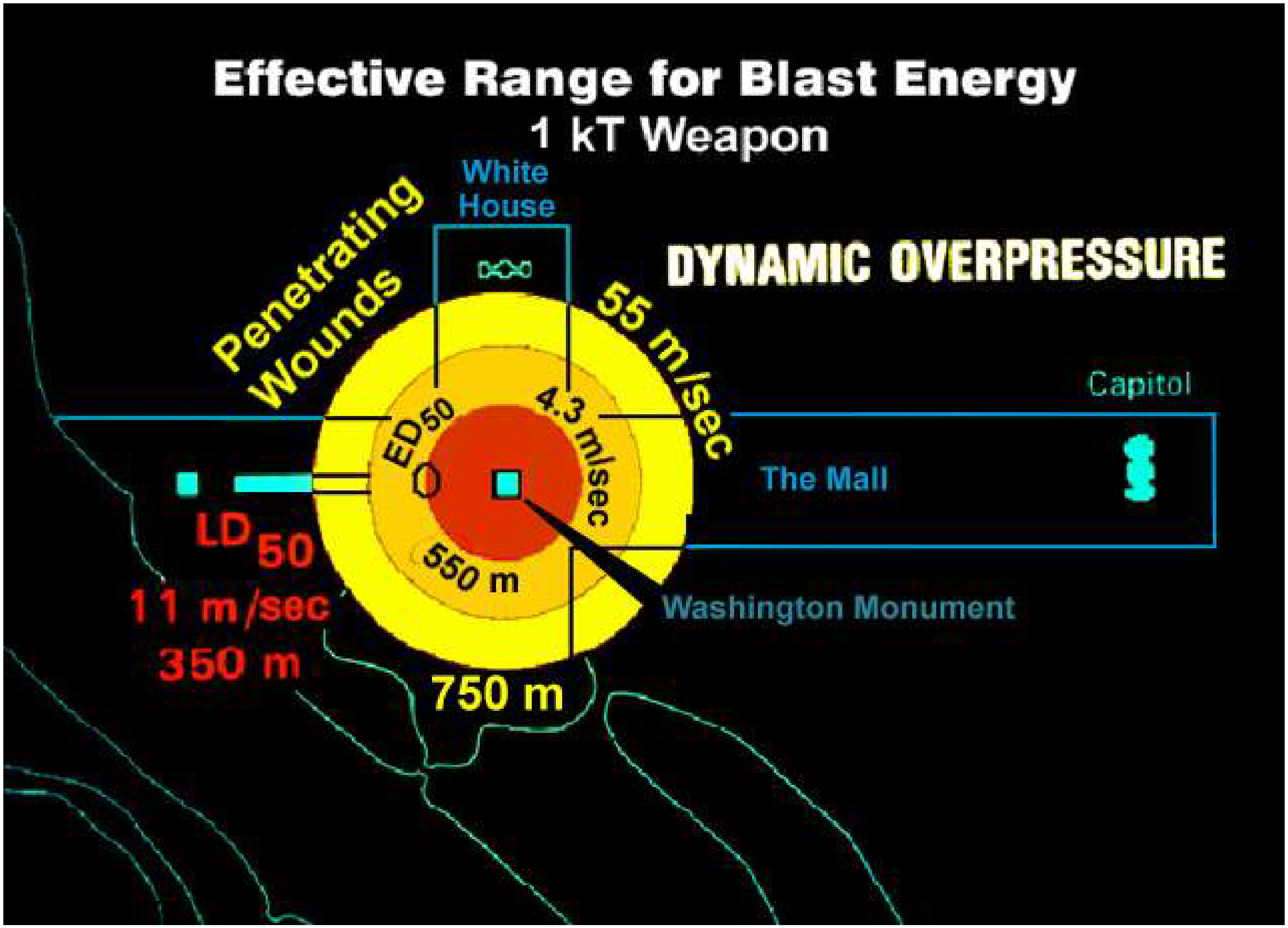
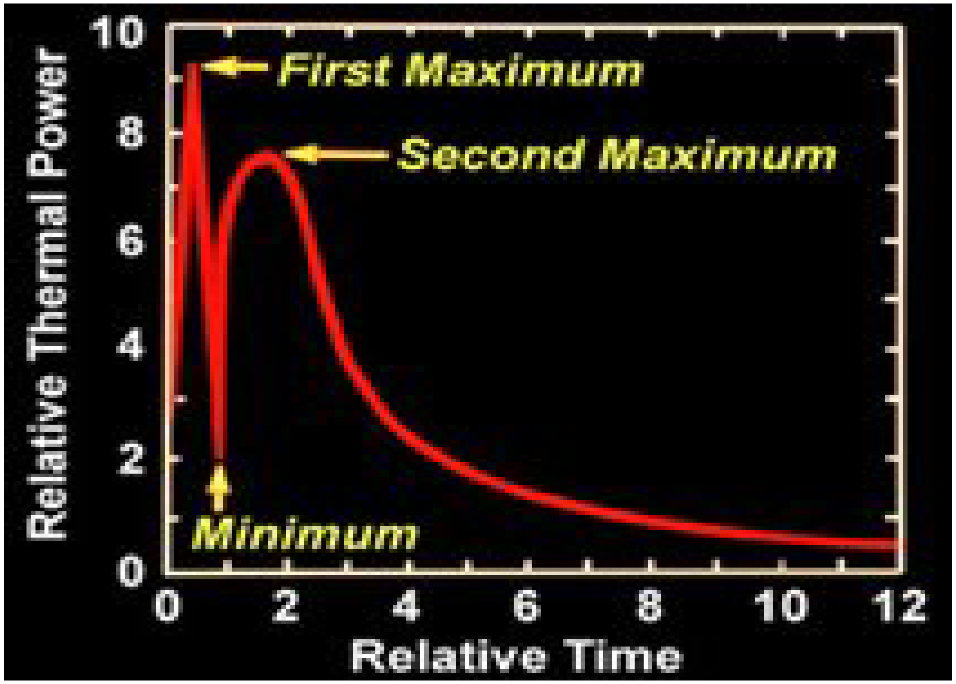
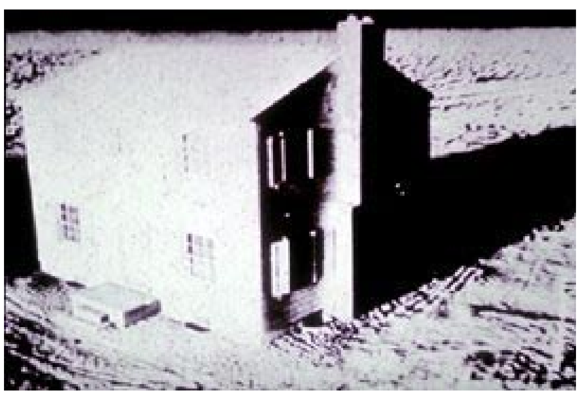
Flying Debris Lethal at longer ranges



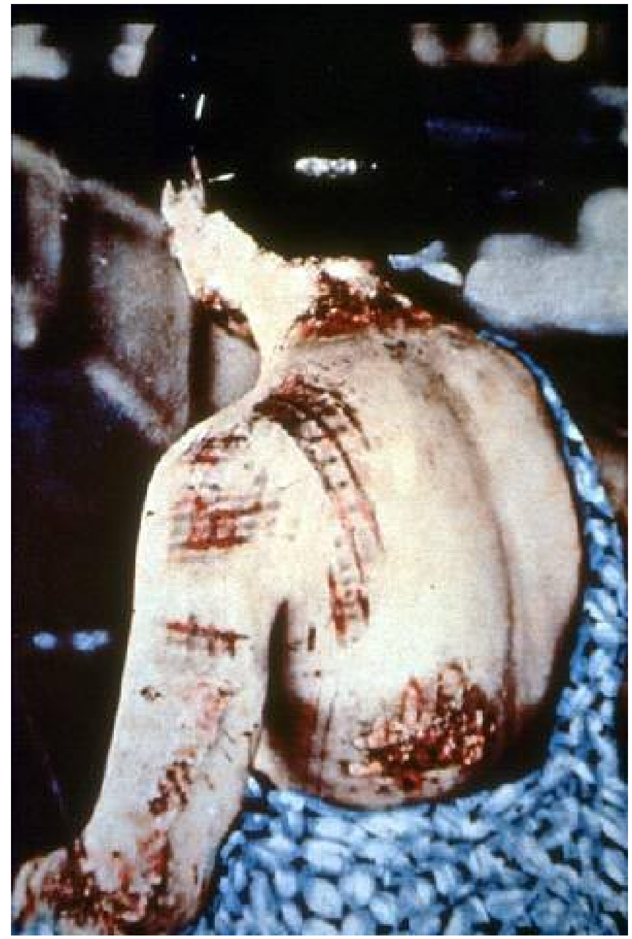
Thermal: 35% of the Energy





1st “flash” Pulse

2nd pulse (99% of the energy)



The pattern is from the dark colored areas on her kimono

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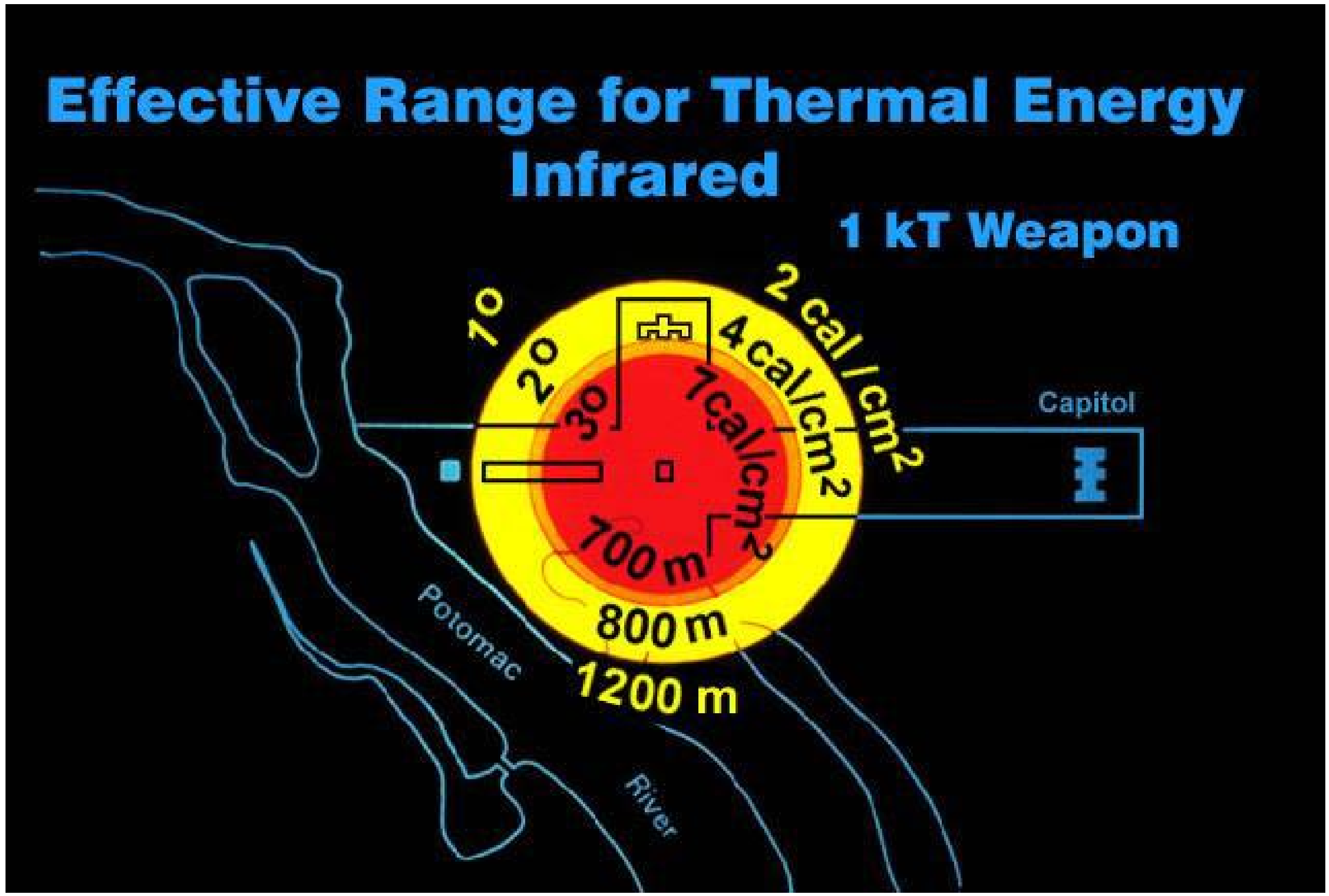
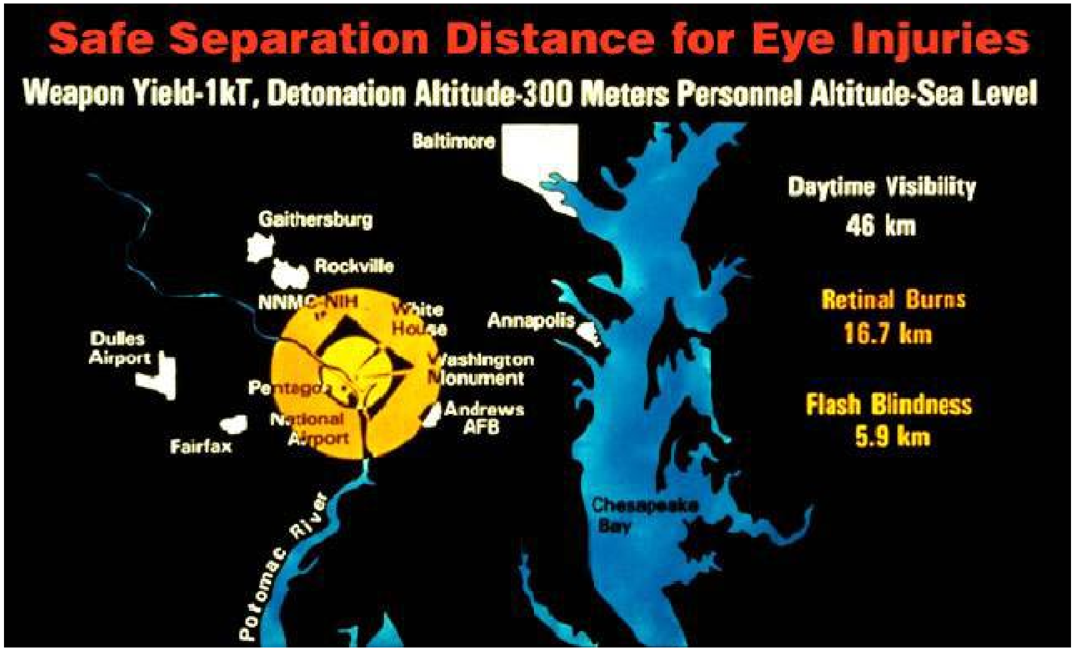
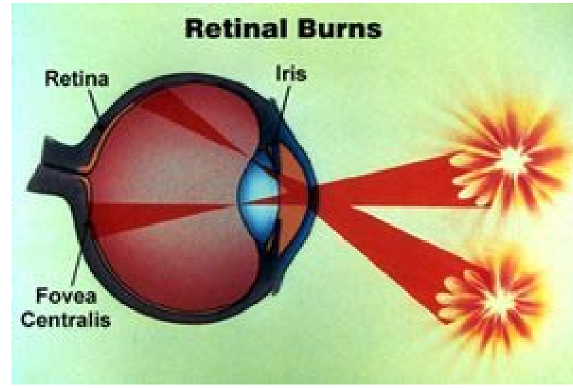
Thermal Energy

- Burn Effects
- 3rd Degree Burn – 7 Cal/cm^2



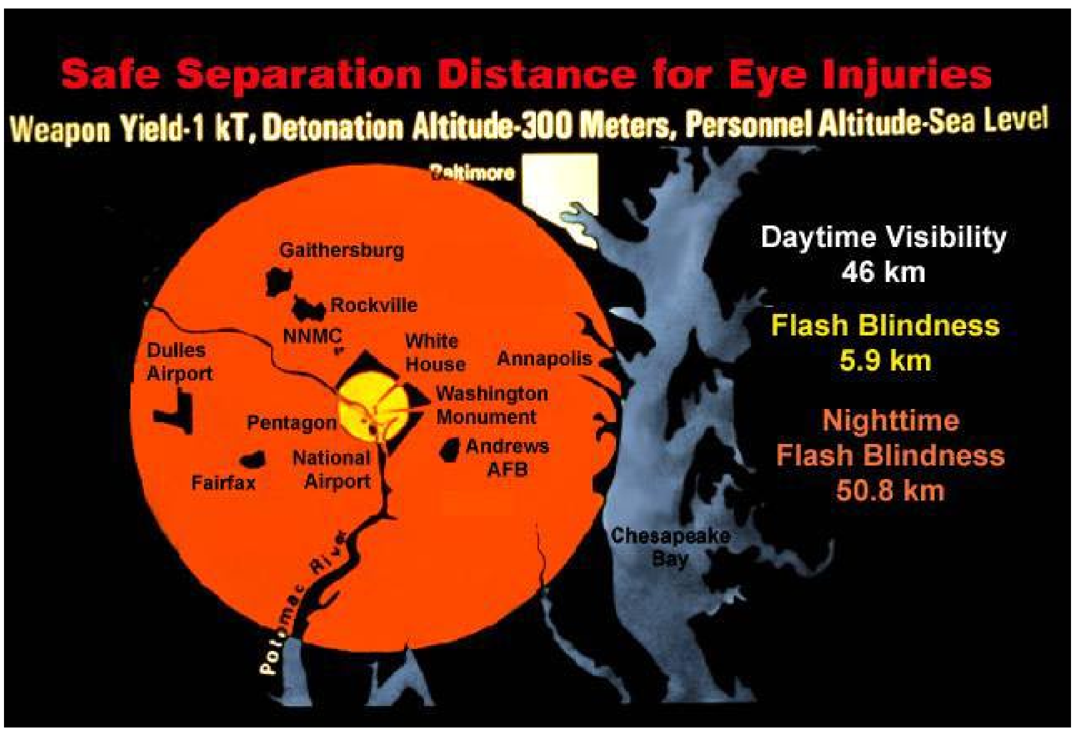
Long Distance Visual Effects

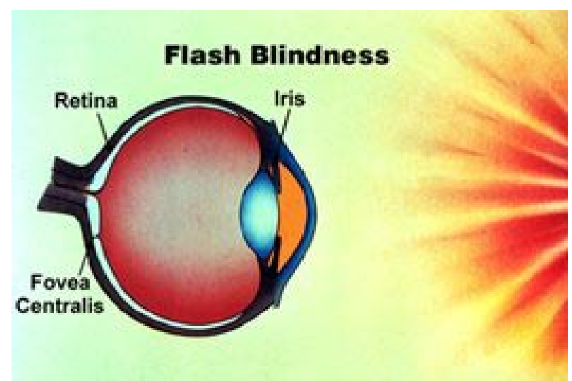




Retinal burn: visual capacity is permanently lost in the burned area.

Also worthy of note is that retinal burns can be produced at great distances from the nuclear detonation because the probability of occurrence does not follow the inverse square law as is true of many other types of nuclear radiation.





Flash Blindness, also referred to as "dazzle," is a temporary impairment of vision. Victim does not have to be looking directly at the source for this to occur. Nighttime greatly increases distance of effect

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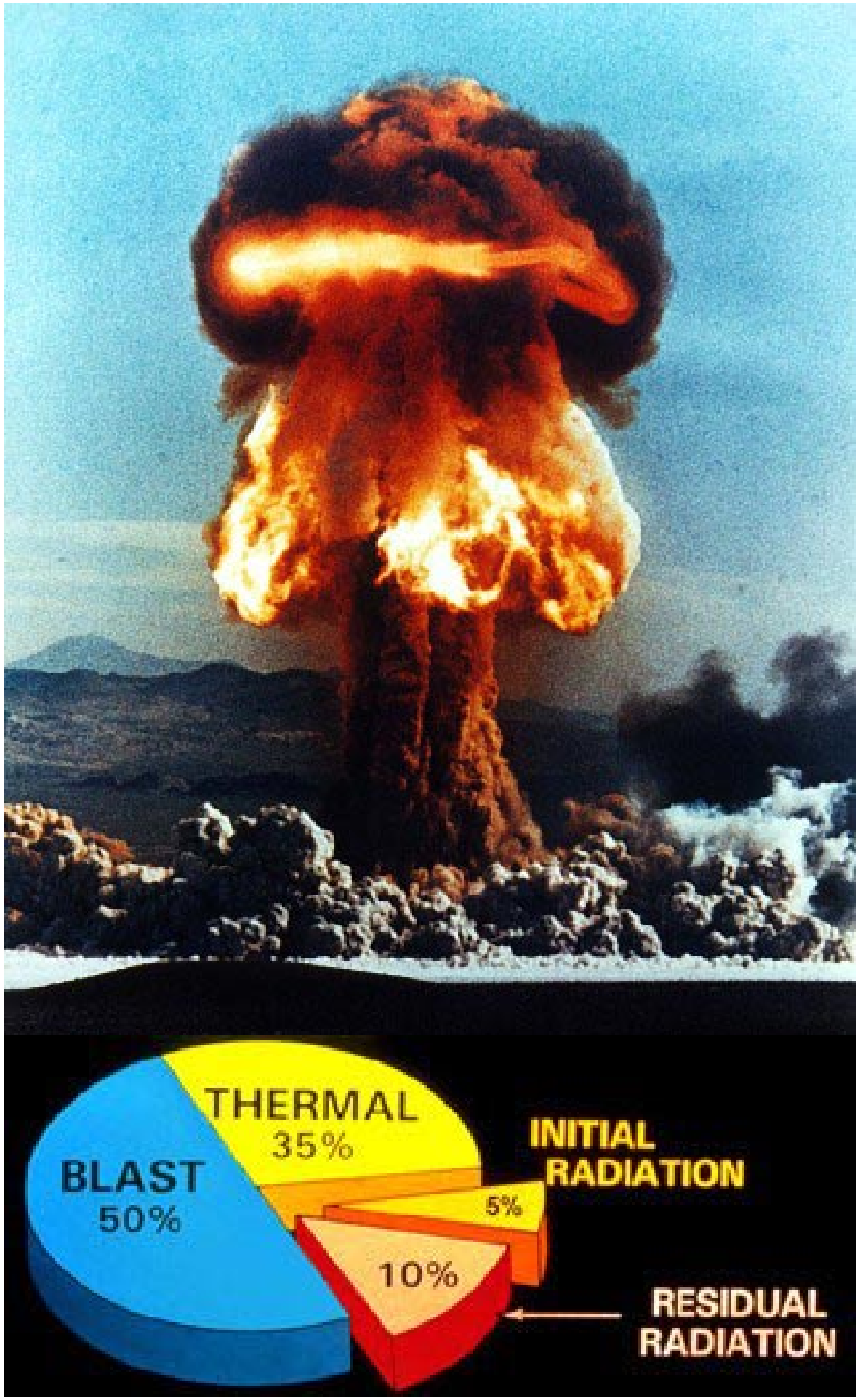
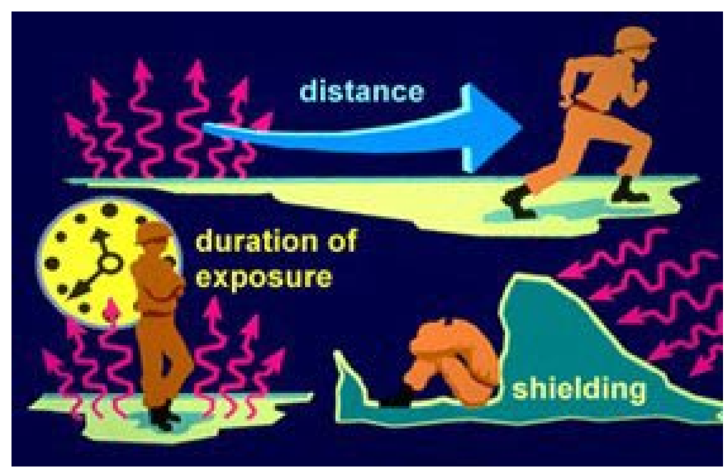
Fallout

- A nuclear detonation results in a fireball with a temperature estimated to be several tens of millions of degrees.
- The radioactive particles resulting from nuclear fission and activation of surrounding materials are carried up by the fireball and then drift downwind to later settle on the ground.

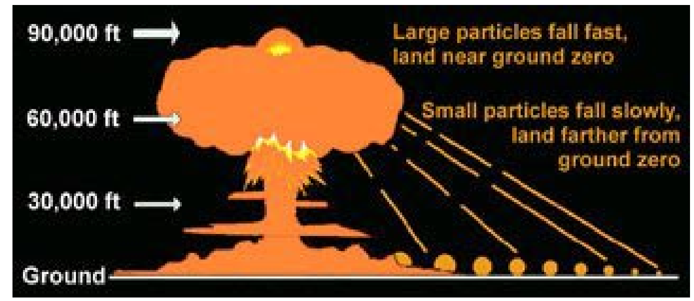




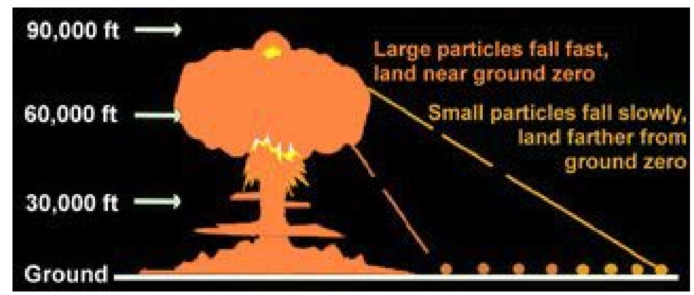
AFRRI

Factors that Effect Fallout

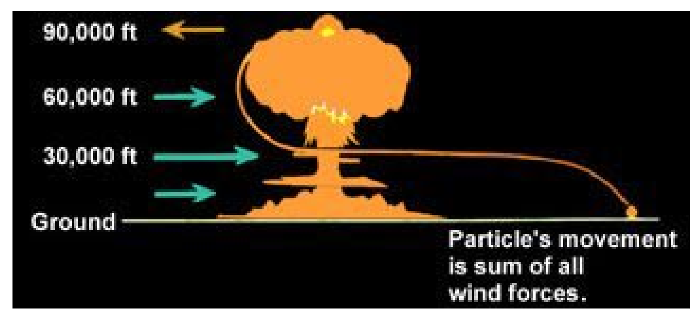
- **Particle size .** Assuming constant wind and altitude, larger particles land relatively close to ground zero and smaller particles land farther away.



- **Altitude .** The higher the initial altitude of a particle, the farther away from ground zero it lands, assuming constant wind speed and particle size.

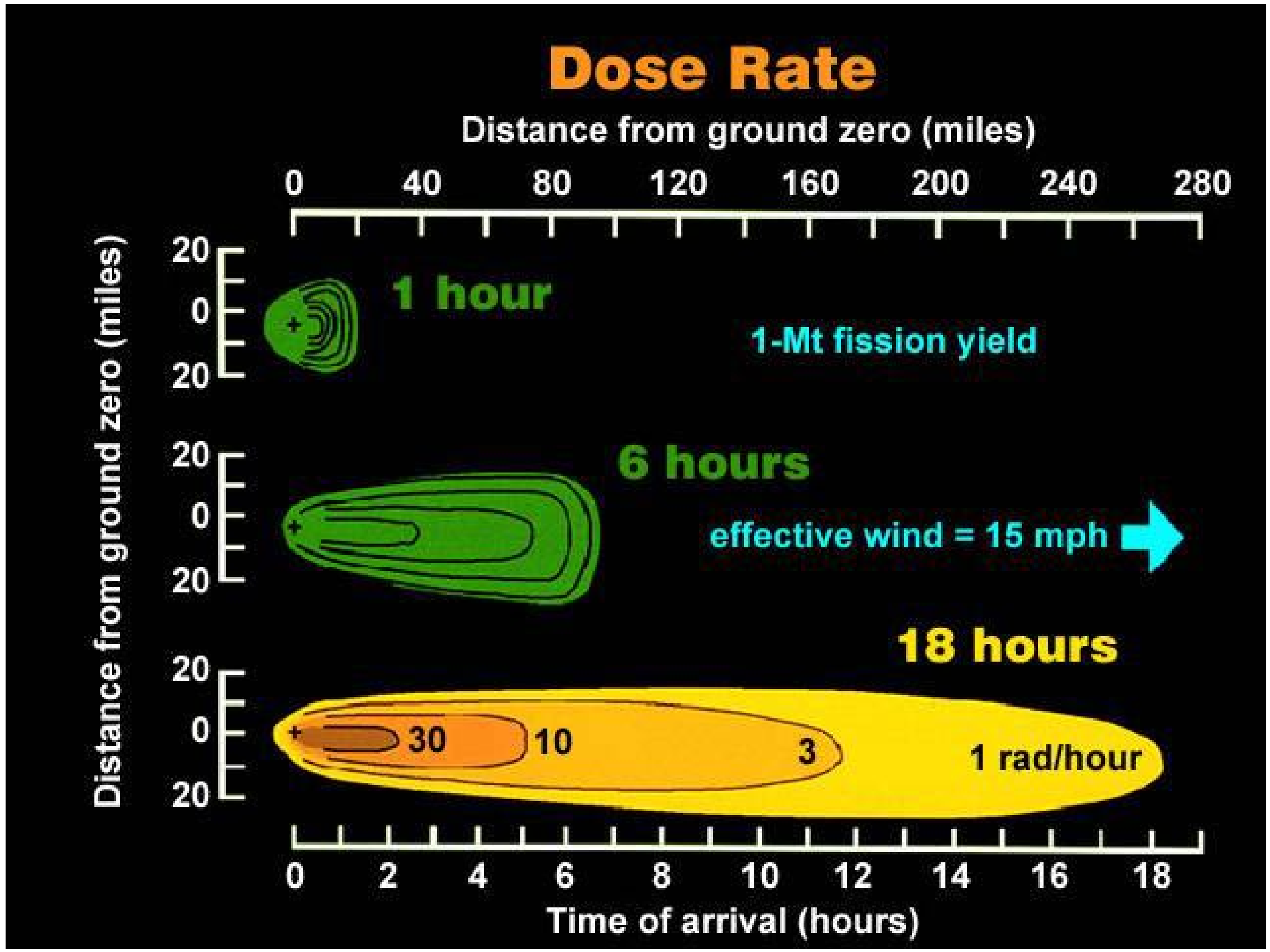


- **Wind .** Wind is the most difficult factor to predict. Different altitudes through which a particle falls may have different wind speeds and directions that affect the final destination of the fallout particle. This explains how fallout can occur miles upwind of a detonation.



The Fallout Path can extend well beyond the blast area

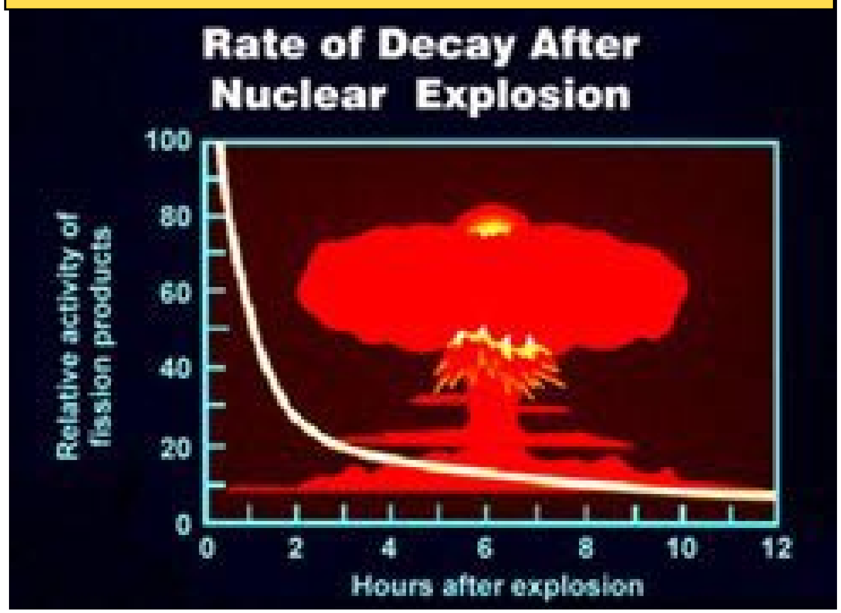
- Although dose rates are highest within the first few hours, this only represents a relatively small area
- Evacuating the fallout area **before fallout arrival** will save the most lives



AFRRI

Deaths from radiation injury can be dramatically reduced by evacuating, sheltering, and providing good medical care

Sheltering for 48 hr reduces exposure by a factor of 100!**



A substantial level of patient assessment and treatment could be delayed by >48 hr

Good medical care raises the LD_{50} by 50%, from 290 rem (bone marrow average dose) to 436 rem

* G. H. Anno, R. W. Young, R. M. Bloom, and J. R. Mercier, "Dose response relationships for acute ionizing-radiation lethality," Health Physics 84(5) 2003.

**The Medical Effects of Ionizing Radiation (MEIR) CD-ROM training, developed and presented by the Armed Forces Radiobiology Research Institute (AFRRI)

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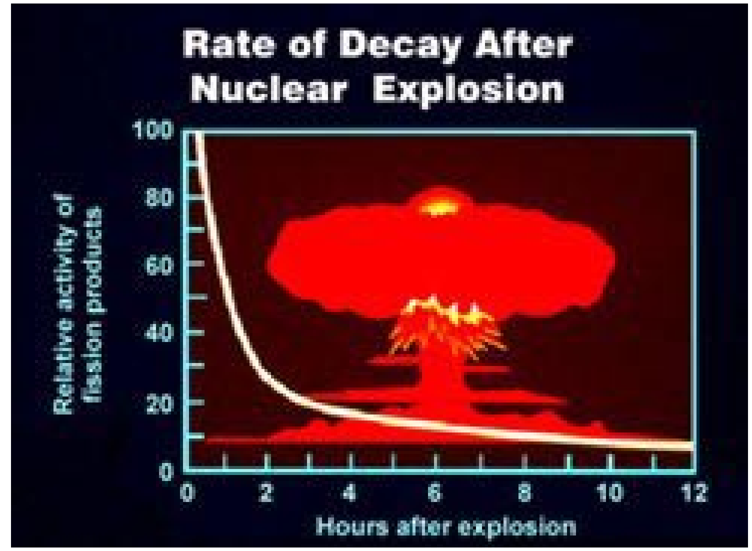
Fallout: The 7-10 Rule of Thumb

Time (hours)	Relative Fallout Dose Rates
H + 1*	100%
H + 7 (1•7)	10 %
H+49 (7•7)	**1%**
H+343 (7•7•7) ~14 Days	0.1%
H+2401 (7^4) ~100 Days	0.01%



- Shelter as long as possible before evacuating across fallout contamination. **Waiting 2 days will reduce exposure by a factor of 100!**

*Prior to H+1, the dose rates from fall out is significantly higher

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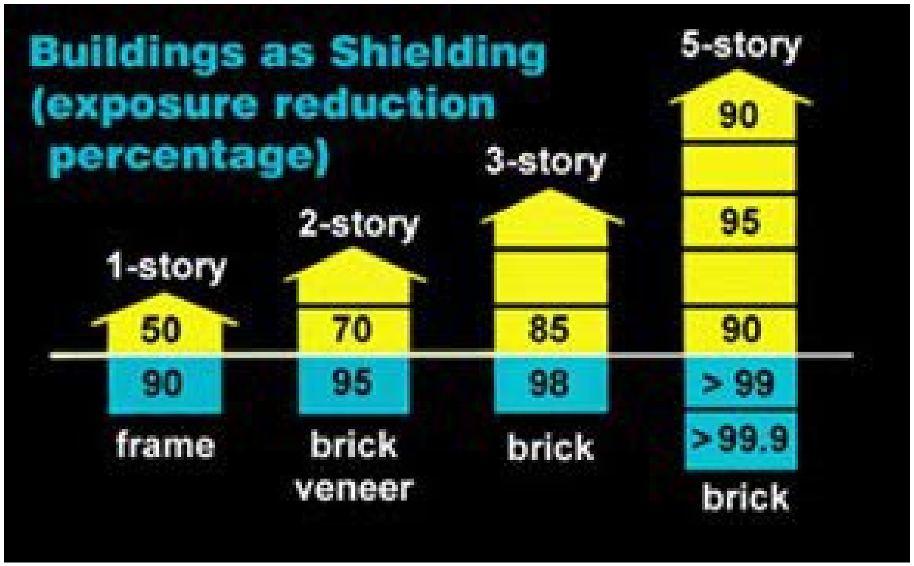
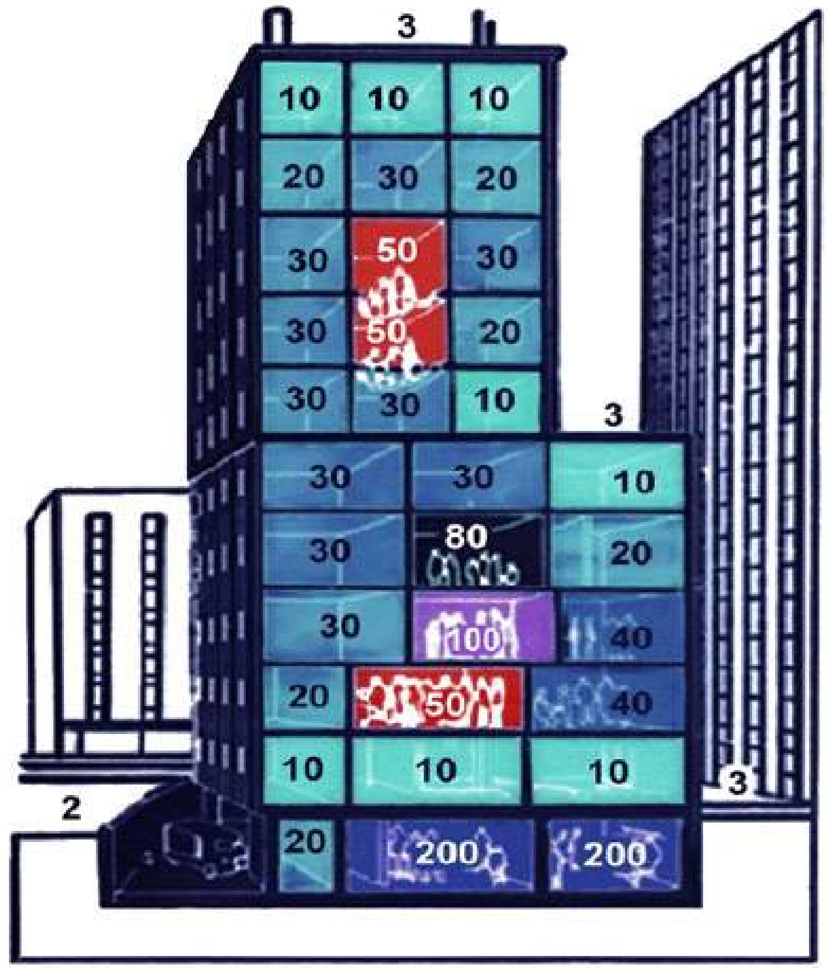
A well-executed response could save lives and dramatically reduce fear and confusion

Response	Prompt	Fallout
Triage: optimize immediate assistance to casualties with multiple injuries	X	
Plan and drill: evacuate, shelter		X
Start treatment early for radiation exposure	X	X

Shelter If You Can't Evacuate





- Use the Shelter to **<u>Shield</u>** and **<u>Distance</u>** yourself from the fallout contamination.

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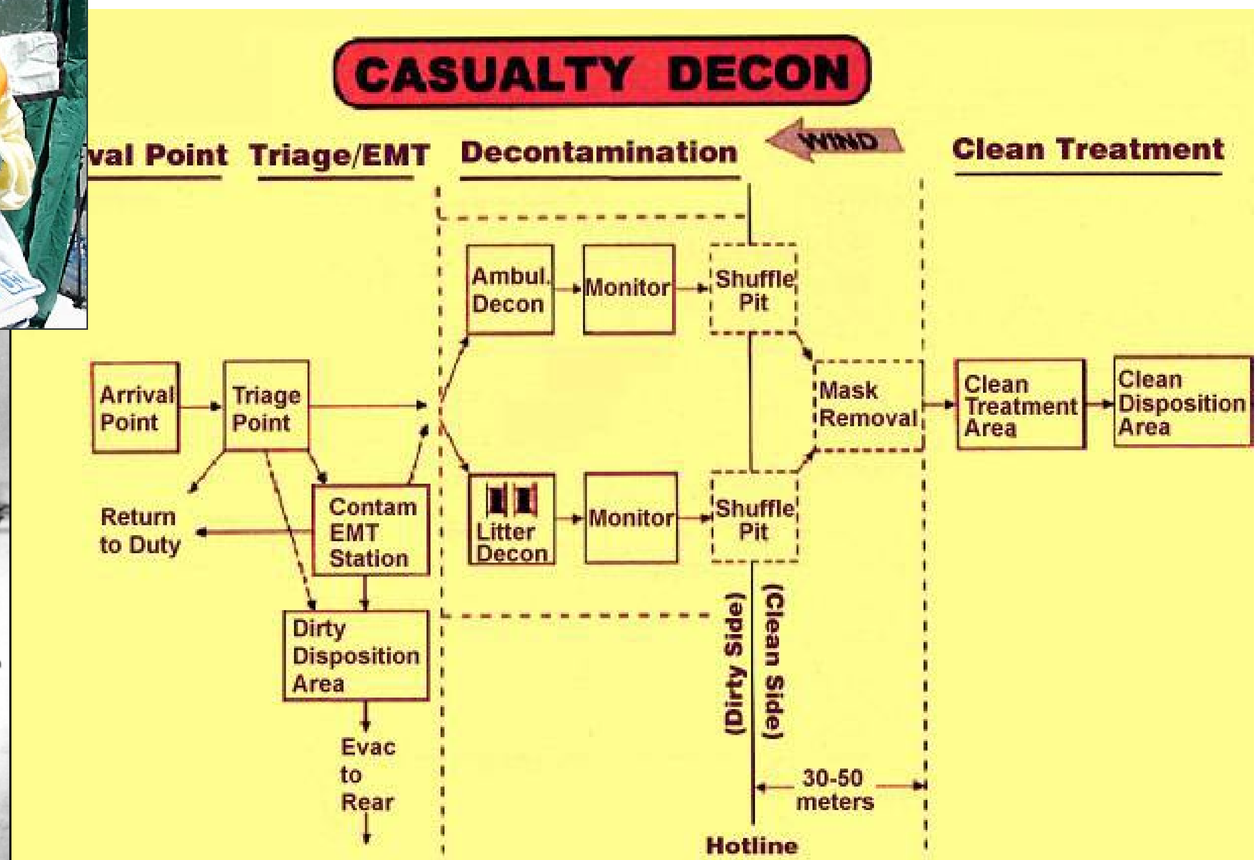
Decontamination will also be a critical issue



This information taken from:

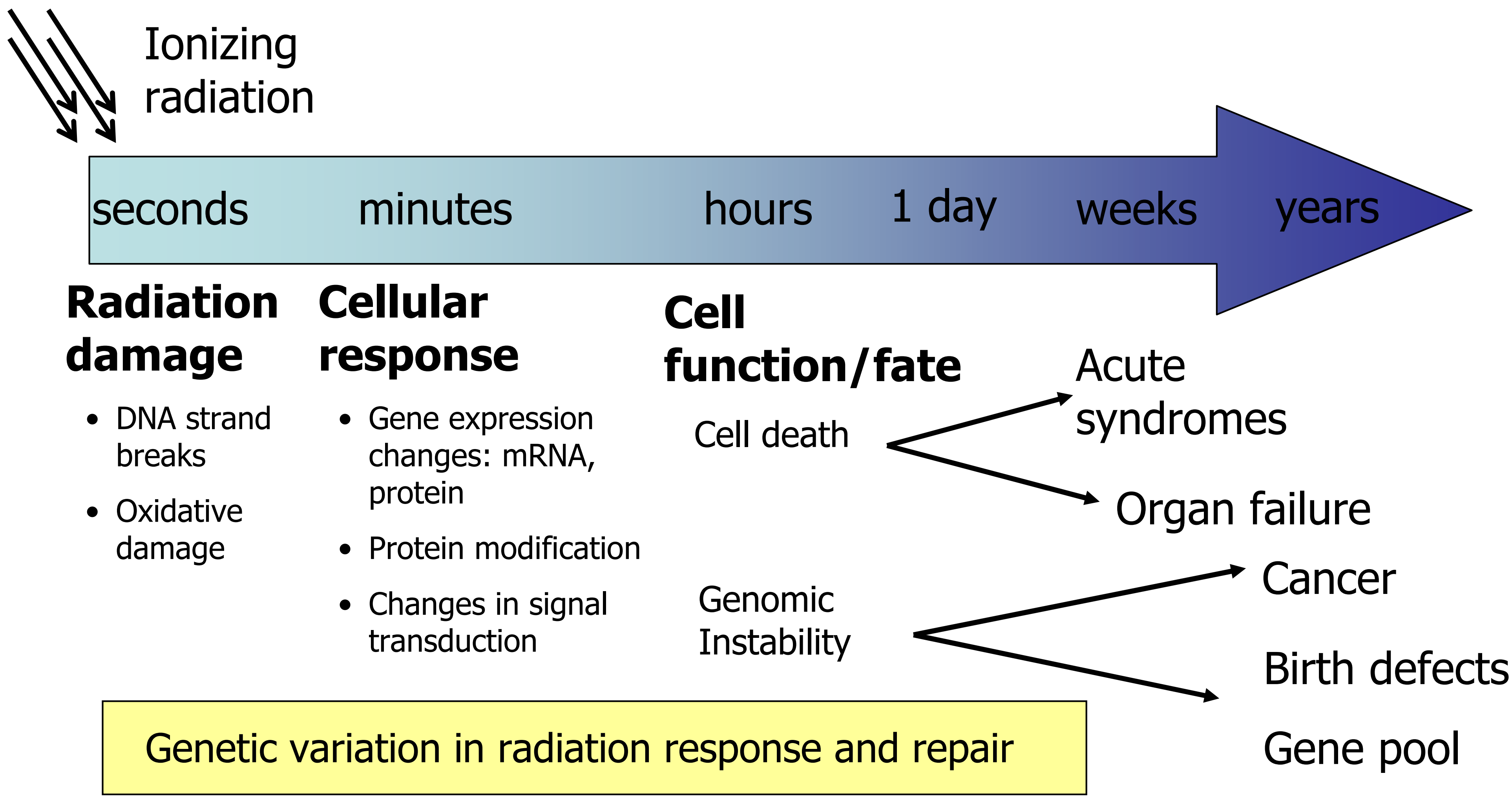
MEIR Medical Effects of Ionizing Radiation

- The Medical Effects of Ionizing Radiation (MEIR) CD-ROM training, developed and presented by the Armed Forces Radiobiology Research Institute (AFRRI), improves the operational capabilities of the military services by providing health care and disaster preparedness personnel with the latest information concerning the biomedical consequences of radiation exposure and the medical management of casualties. The training includes nuclear incidents that can occur on or off the battlefield and that go beyond nuclear weapons events. In addition to this interactive CD-ROM version, MEIR training is provided as a comprehensive series of classroom lectures, as selected lectures for specialized audiences, and as a set of lectures on video.

What if we fail?

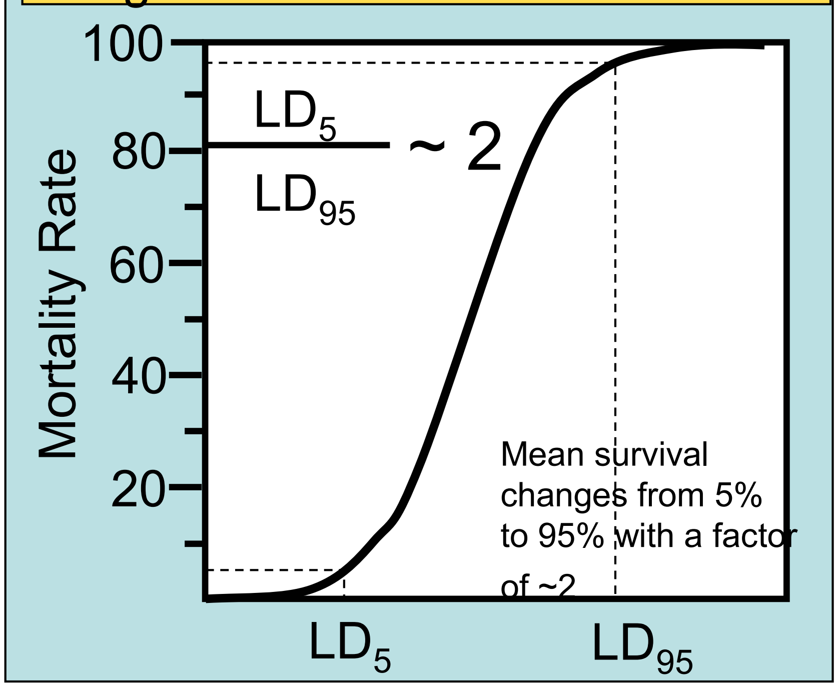
Effects of RDDs and nuclear weapons

Biological response to ionizing radiation starts from the moment of exposure and ends in observed clinical symptoms

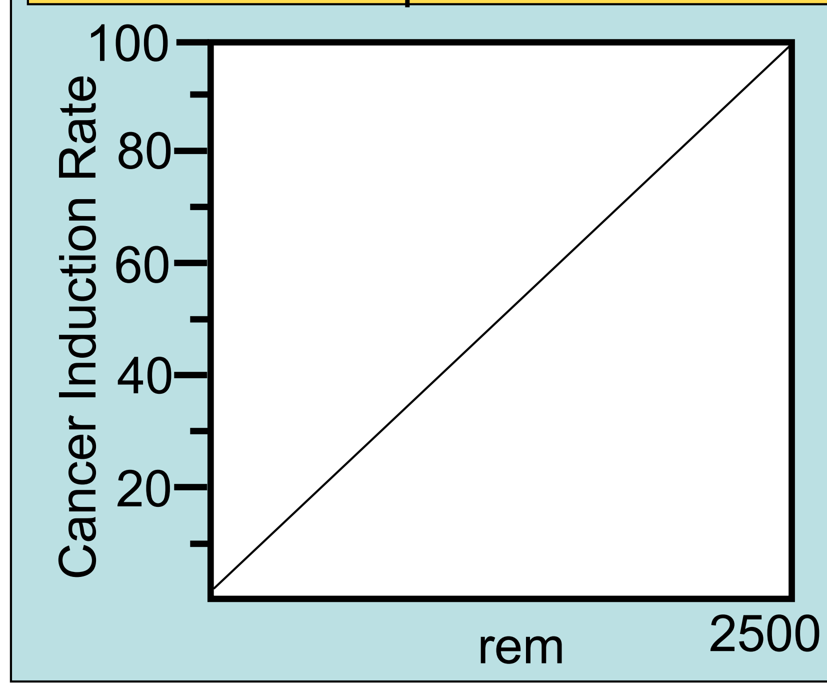


There are two kinds of radiation effects: early (deterministic) and late (stochastic)

Early (deterministic) effects follow a sigmoidal curve



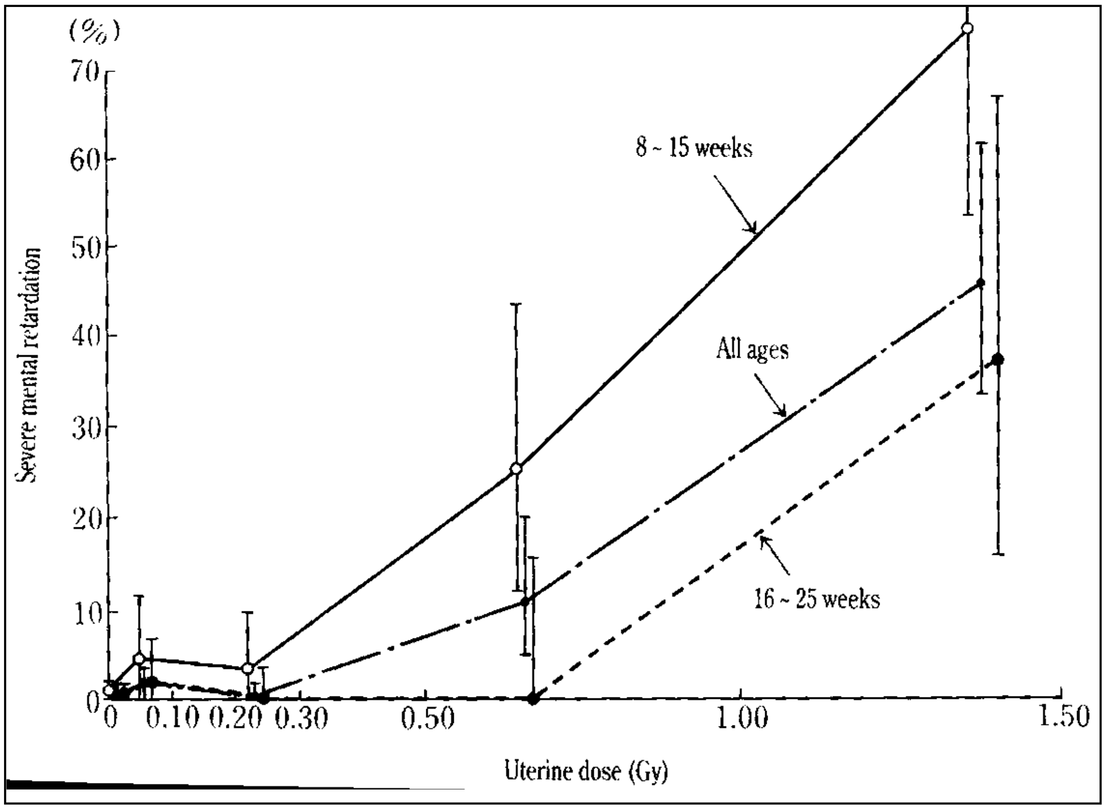
Late (stochastic) effects follow a linear or linear quadratic relationship



Opportunities provided by sheltering also contribute to confusion in dose assessment

Another example of stochastic effects: Birth defects*

Radiation-related mental retardation increases with increasing pre-natal dose

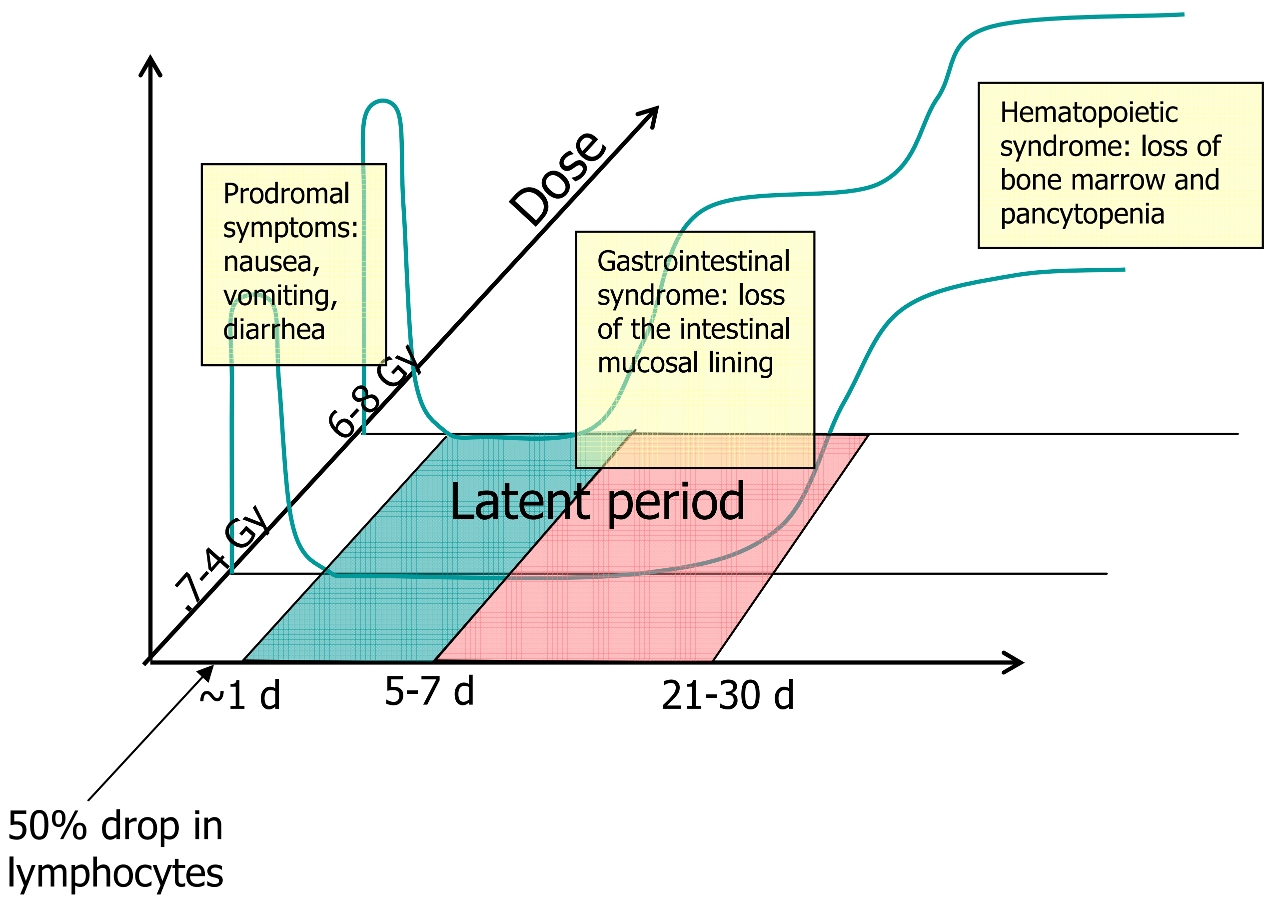


1 Gy = 1J/kg = 100 rad

1 rem = 1 rad for gamma rays, >1 rad for neutrons

*Otake M et al. *Cong Anom* 1989 29; 309-320.

Clinical symptoms of acute radiation sickness



Late effects:

Organ failure

Cancer

Birth defects

Current guidelines for radiation treatment

Variable	Proposed radiation dose range for treatment with cytokines	Proposed radiation dose range for treatment with antibiotics	Proposed radiation dose range for referral for stem-cell transplant consideration (SCT)
Small-volume scenario (≤100 casualties)			
Healthy person, no other injuries	3-10 Gy	2-10 Gy	7-10 for allogeneic SCT; 4-10 if previous autograft stored or syngeneic donor available
Multiple injuries or burns	2-6 Gy	2-6 Gy	
Mass casualty scenario (>100 casualties)			
Healthy person, no other injuries	3-7 Gy	2-7 Gy	7-10 for allogeneic SCT; 4-10 if previous autograft stored or syngeneic donor available
Multiple injuries or burns	2-6 Gy*	2-6 Gy*	NA

Waselenko, J.K. et al. 2004. Medical management of the acute radiation syndrome: Recommendations of the strategic national stockpile radiation working group. Ann Int Med 140 (12), 1037-1051.

Triage

Conventional Triage Categories for Injuries without Exposure to Radiation*	Changes in Expected Triage Categories after Whole-Body Radiation		
	<1.5 Gy	1.5 Š 4.5 Gy	>4.5 Gy, ≤ 10 Gy
Delayed	Delayed	Variable	Expectant
Immediate	Immediate	Immediate	Expectant
Minimal	Minimal	Minimal	Minimal
Expectant	Expectant	Expectant*	Expectant*
Absent	Ambulatory Monitoring	Ambulatory monitoring with routine care and hospitalization as needed	

Waselenko, J.K. et al. 2004. Medical management of the acute radiation syndrome: Recommendations of the strategic national stockpile radiation working group. Ann Int Med 140 (12), 1037-1051.

Problem: current methods of assessment do not lend themselves to fast, accurate triage

- **Direct measurement of radioactive emissions *in vivo*** is a practical solution for measurement of radioactive contamination, however high-throughput sample-processing systems and quick-reference guidance for converting contamination measurements do not exist.
- **Lymphocyte counts** do not dip below the normal range at doses less than 5 Gy within the first 24 hr, and lymphocyte kinetics will be logistically difficult to obtain within this time period and vary significantly from individual to individual.
- **Cytogenetics (chromosome aberrations)** becomes difficult below 1 Gy, and takes 48-72 hr for standard assays, while shorter-turnaround (24 hr) assays are not yet well benchmarked.
- **Time-to-vomiting** is limited in sensitivity (only 35% of victims vomit with a 2 Gy exposure) and is widely variable from individual to individual.
- **Prepositioned dosimeters** perform well for all criteria, however the most cost-effective and easy-to-read candidate, the SIRAD card, currently has limited distribution and shelf-life data available.

Summary

- It is difficult to detect nuclear and radiological threats in the sea of background and naturally occuring radioactive sources
- Substantial efforts are underway to meet the detection and interdiction challenge, using a multilayered defense architecture that reaches beyond our borders and covers all areas of the United States
- The stakes are high: with public fear and the cost of cleanup being most important for RDDs, and disastrous loss of life, property and infrastructure dominating for nuclear weapons
- Radiation effects are both short and long term
- Current technology offers some hope in identifying and treating radiation injury victims, but technology has a long way to go, and evacuation and shielding remain the most effective approaches for avoiding radiation sickness