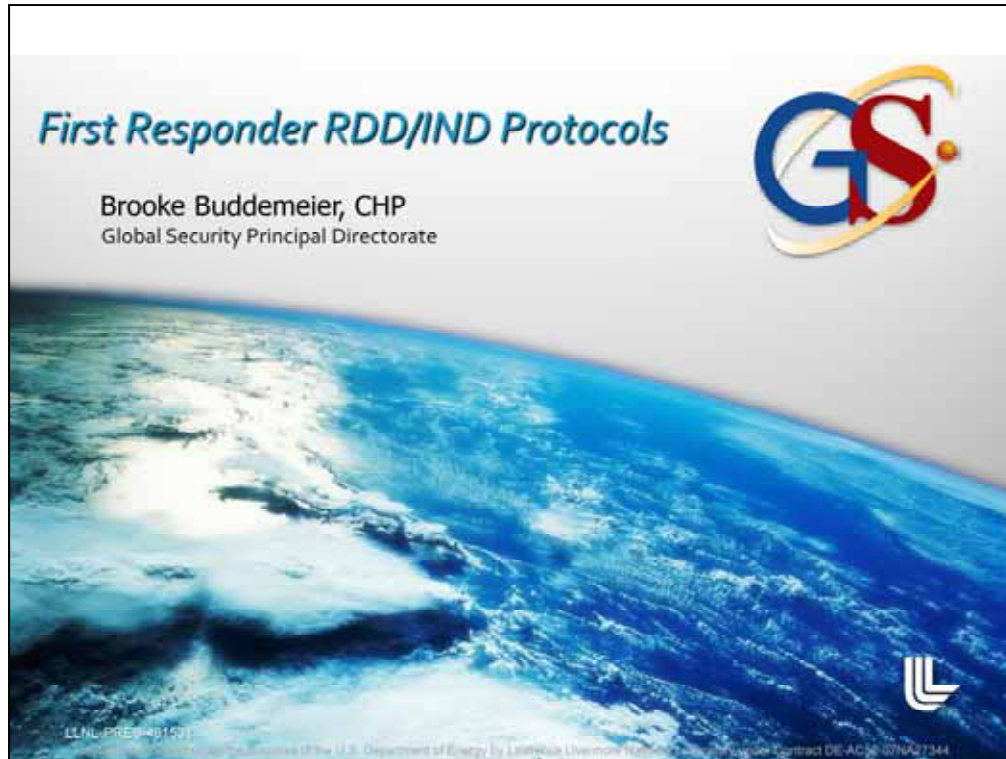


Radioactive Material Production,
Transportation, Use, and Possible Misuse



Brooke Buddemeier, CHP
Lawrence Livermore National Laboratory
Nuclear Counterterrorism Program

Radioactive Material Production, Transportation, and Use

- The creation, shipping, and use of radioactive material is **highly regulated** (IAEA, NRC, DOT, etc.).
- High Activity Sources can **only** be produced by sophisticated methods (e.g. reactors & accelerators).
- High activity sources can only be obtained after special licensing to ensure their safe use and their security.
- Similar regulations exist in other countries where radioactive material is produced or used.



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Emphasize that:

- 1) **High activity sources are difficult to obtain**
- 2) **Once obtained, measures are taken to ensure the safety and security of the source.**
- 3) **The Regulatory agencies continually check up on the users to make sure they follow the requirements.**
- 4) Pictured above is the Cherenkov radiation produced at [University of Missouri-Rolla](#) campus, the UMR Nuclear Reactor (UMRR)
- 5) Also picture is The Fast Flux Test Facility (FFTF) is a 400-megawatt (thermal) liquid-metal (sodium) cooled fast neutron flux nuclear test reactor owned by the U.S. Department of Energy (DOE). The facility is located in the 400 Area of DOE's Hanford Site in southeastern Washington State. Currently, the FFTF is being deactivated. This reactor produces many unique isotopes.

High Activity Radioactive Material



1 - 10
kiloCi
(when spent)

Fuel Assembly



TN-BRP Type B Storage/Transport
Spent Fuel Package

1 - 500
kiloCi
(when spent)



10 - 100
kiloCi

Sr-90 RTG at Barst Mountain, Alaska

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



0.01 - 0.2
kiloCi



1-10
kiloCi

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•Radioisotope Thermoelectric Generators (RTG)

The picture shown is of some Sr-90 RTGs up in Alaska, these range from 2 – 5 feet in height. RTGs use the heat generated by the decaying radioactive material to generate electricity. They make about 500watts (enough to light 5 100 watt light bulbs) but are extremely reliable and maintenance free for decades of operation in remote areas (like space or deep ocean). These generally have very radioactive sources of (4 to 500 kCi) in order to make the heat. The source resides at the center of the generator as is about the size of a large soup can. *Typically the radioactive material itself is in a chemically inert form (I.e. ceramic) and then placed in a double welled steel capsule. These sources undergo extensive testing (I.e. vibration, crushing, fire, cold, etc..) to ensure the don't break open in an accident.*

These sources are very robust and the RTG is designed to meet Type-B shipping container requirements, including surface dose rates below 200 mrem/hr on contact.

1 year after being removed, spent fuel activity is ~ 1Tbq/kg [27 ci/kg] (source Finland radiation and nuc authority)

•Nuclear fuels and Spent nuclear fuels. **Emphasize that unused nuclear reactor fuel is not highly radioactive. After use however, the fission products build up and make the waste very radioactive.** They are an external hazard and can not be handled directly. If dispersed they will be and internal and external hazard.

•Pressed into ceramic pellets and clad in special metals capable of withstanding the harsh conditions inside a reactor core. When spent fuel is transported, it is placed into shipping container that are able to withstand the most heinous accident conditions. ***If appropriate, show the shipping cask trials (locomotive hitting cask) video.***

CDC Emergency Preparedness & Response Radionuclides			
Radionuclide	Half Life (years)	Radiation	Information
Uranium	billions of years	α , + progeny	Natural uranium is comprised of several different isotopes. When enriched in the isotope of U-235, it's used to power nuclear reactor or nuclear weapons.
Americium-241	430 y	α	Am-241 is used for neutron generation (AmBe), in industrial devices that measure density and thickness, and in smoke detectors in small amounts.
Plutonium-238	88 y	α	Radionuclide thermoelectric generators and heat sources (primarily for space applications)
Cesium-137	30.2 y	β	Blood irradiators, tumor treatment through external exposure. Also used for industrial radiography.
Strontium-90	29 y	β	Radionuclide thermoelectric generators, industrial gauges and to treat bone tumors.
Cobalt-60	5.3 y	β	Tumor treatment through external exposure. Also used for industrial radiography.
Polonium-210	0.4 (140 d)	α	Anti-static devices and lightning detectors. Involved in U.K. Poisoning incident.
Iridium-192	0.2 (74 d)	β	Implants or "seeds" for treatment of cancer. Also used for industrial radiography.
Iodine-131	0.02 (8 d)	β	I-131 is used in medicine to diagnose and treat cancers of the thyroid gland. Also a concern for nuclear power plant accidents

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Source: <http://emergency.cdc.gov/radiation/>

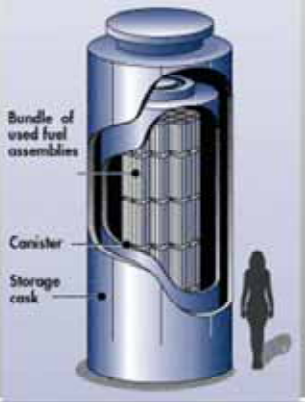

Narrative

Here are some examples of radioactive isotopes commonly used in industry.
{Read slide it time permits}

note: this slide can be removed for an overview

Spent Fuel

- Currently stored "onsite" at locations throughout the country.
- Spent Fuel containers extremely rugged and made to withstand extreme accident conditions.
- For thirty years, > 5,000 highly-radioactive fuel assemblies have been shipped without radiation release (despite several accidents).
- Security measures are taken.



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9/29/2011
Bullman

Source: **NUCLEAR TECHNOLOGY & INFORMATION ON REACTOR SAFETY**

<http://www.geocities.com/ntirs/index.html>

For over thirty years, spent fuel shipments have traversed our nation's highways and, over that time, over five thousand highly-radioactive fuel assemblies have been transported. Even with all of this experience and history, there has not been one single radiation release of any kind despite a few serious traffic accidents. This excellent safety record is due to the design, engineering, planning, and regulation related to the dry casks used for the transportation of spent fuel.

A variety of casks have been designed and tested and are being used. Lighter casks, from 25 to 40 tons are designed to hold up to 7 fuel assemblies. Heavier casks, up to 120 tons, are designed to carry up to 36 assemblies. These heavier casks may be transported by rail. In general, the casks are cylindrical with multiple walls and shields that give the casks their extreme strength and radiation shielding characteristics. In one such design, shown below, the spent fuel is sealed in a water-filled stainless steel cylinder with walls 1/2 inch thick and clad with 4 inches of a heavy metal (usually lead) for radiation shielding. This container is surrounded by 5 inches of water and encased in a corrugated stainless steel outer package. Another cask, designed by the Babcox & Wilcox Company and designation "BR-100" is also shown.

Source: **NRC** <http://www.nrc.gov/waste/spent-fuel-transp.html> **Safety Requirements**

Safety in the shipment of nuclear material is achieved by a combination of factors, including the physical properties of the nuclear material itself, the ruggedness of the container, and the operating procedures applicable to both the transportation package and the vehicle transporting the package.

Materials Shipping Requirements

NRC performs inspections to determine whether transportation package users have taken the appropriate package measurements to ensure radiation levels are not exceeded. NRC inspections also focus on whether casks have been properly inspected for certain specific criteria, such as leak-tightness, that bolts and other equipment are intact, and that the packages are safe for transport.

Safeguards (Security) Requirements

For transportation of spent fuel, NRC performs inspections to determine that the spent fuel is physically protected against radiological sabotage.

Radioisotope Thermoelectric Generators (RTG)



**Self heated
Plutonium 238**

²³⁸Pu Powers
Galileo Jupiter
Orbiter Probe

RTGAC
USAF

Sr-90 RTG at Summit Mountain, Alaska

- The heat generated by the radioactive decay is used to generate electricity
- Used when maintenance free power is need for decades (satellites, ocean bottom, and arctic applications)
- RTGs most often made from Sr-90 (0.46 kW/kg) or Pu-238 (0.54 kW/kg).

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Plutonium 238

Plutonium 238 is a non-fissile, alpha emitting isotope with a half life of 87 years. A sample of pure material would produce approximately 0.54 kilowatts/kilogram of thermal power. In some configurations, the surface temperature of a Pu-238 fuel element can reach 1050 degrees C.

These characteristics make Pu-238 the most capable heat generating isotope. It will outlast most customers; even after 20 years a Pu-238 based power source will produce 85% of its initial power output. It has a high energy density, allowing power system mass and volume to be minimized. It is also easy to shield and its emissions will not interfere with sensitive instrumentation.

Unfortunately, Pu-238 is difficult to manufacture, making it extremely expensive. An accurate price is difficult to determine because of the lack of an open market, but the recent estimates by experts in the field indicate that the material costs several thousand dollars per gram in kilogram sized lots if it is available at all. Since RTG conversion efficiency is on the order of six to eight percent, this puts the price of a 50 W power supply at close to a million dollars.

There is also the public relations problem associated with the word plutonium. Frequent readers of Atomic Energy Insights might understand that plutonium is not as dangerous as Ralph Nader says it is, but that realization has not yet permeated the general public's consciousness. Most political decision makers are also not knowledgeable enough about nuclear physics to understand that Pu-238 cannot be used to produce a nuclear weapon; it has the wrong number of nucleons to be a fissile isotope.

Strontium 90

Sr-90 is a beta emitter with a 28.1 year half life. A pure sample will supply 0.46 kilowatts/kilogram of thermal power when new, or about 15 percent less than a similar mass of Pu-238. Additionally, an Sr-90 based RTG will deteriorate about three times as fast as one based on Pu-238; a 20 year old power supply will produce only 61 percent of the initial power output.

Because of the lower energy density, a Sr-90 fuel rod will not get as hot as a Pu-238 rod. A new rod, depending on configuration, might be able to achieve a surface temperature of only 700 to 800 degrees C. This is important because a lower temperature available to the hot junction of a thermocouple will reduce the thermoelectric conversion efficiency of the RTG. Because of these characteristics, a Sr-90 RTG will be about 50 to 100 percent heavier than a Pu-238 RTG of the same power output. For space based applications, where every payload gram is carefully controlled, this mass difference makes it uneconomical to consider Sr-90.

Strontium, however, has some advantages over plutonium. It is a fission product with a high yield; about five percent of all fission reactions produce Sr-90. Since Sr-90 has a long half life compared to the time that reactor fuel spends in a core, it is quite feasible to mine Sr-90 from spent nuclear fuel. Sr-90 is considered by most of its current owners to be an expensive waste problem; perhaps some of them would pay to get rid of it.

Strontium is not associated with nuclear weapons and has never been called the most deadly element known to man. There is a precedence in the United States for widely licensing small quantities of sealed Sr-90; it is used in some aircraft ice detection systems.

There is also a precedent for its use in earth based RTGs; most of the Soviet ocean bottom and Arctic devices used Sr-90 heat sources. (Chmielewski)

Portable Radiography Sources

- “Top strength” industrial radiography sources can burn fingers and cause radiation sickness within a few minutes.
- Effects drop off dramatically with distance. Outside of 3 meters, acute effects rare even after hours of exposure.
- Sources are constructed to meet rigorous testing standards. A typical source is encapsulated in two (2) TIG welded Stainless Steel Capsules.
- Source Material itself is often metal (Cobalt or Iridium) or embedded on non-soluble ceramics or “microspheres” to prevent inhalation of radioactive material if the source encapsulation is breached.



Metals are difficult to disperse

“Top strength” industrial radiography sources can be ~100 Curies and produce ~ 2 R/min @ 1m

Strong Radiography Sources

~2 R/min @ 1 meter

Facility Sources:

Stronger sources exist in facility based system Produce 200 R/min at 1m

Co-60 Sources: 1.32 R/hr @ 1m per 1 Ci

Therefore: 13,200 R/hr (**200 R/min**) @ 1m per 10,000 Ci

or 150,000 R/hr (**2,000 R/min**) @ 1 ft per 10,000 Ci

or 20 R/hr @ **25 meter** per 10,000 Ci

Facility Based Irradiators

- These sources can have 10 to 100 times more radioactivity than radiography sources
- Found in food irradiators, medical sterilizers, etc.
- The shielded enclosures that hold the sources weigh more than a ton.
- Difficult to remove source from the facility or equipment.



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9/29/2011
Bullman

Irradiating blood is recognized as the most effective way of reducing the risk of Graft-Versus-Host Disease (GVHD). This disease most commonly occurs in patients with severely weakened immune systems, and is recognized as a risk associated with blood transfusions. Transfusion-Associated GVHD (TA-GVHD) has become a major concern in current transfusion practices for immunodeficient and immunosuppressed patients because of the associated high mortality rate. Immunosuppressive therapies have not proven effective for TA-GVHD.

The unit pictured above Weighs 1150 kg (2,535 lb.) or 1479 kg (3,260 lb.)
And uses a 650, 1450 or 2900 Ci Cs-137 Source.

High Activity Source Transportation

Containers that ship high activity sources are meant to withstand very punishing accident conditions.

 <p>FREE DROP</p> <p>A 30-foot free drop onto a flat, un-yielding surface so that the package's weakest point is struck.</p>	 <p>PUNCTURE</p> <p>A 40-inch free drop onto a 6-inch diameter steel rod at least 8 inches long, striking the package at it's most vulnerable spot.</p>	 <p>THERMAL</p> <p>Exposure of the entire package to 1475° for 30 minutes.</p>	 <p>IMMERSION</p> <p>Immersion of the package under 50 feet of water for at least 8 hours.</p>
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Buttressed

If time permits, the TEPP movie on source testing can be very valuable.

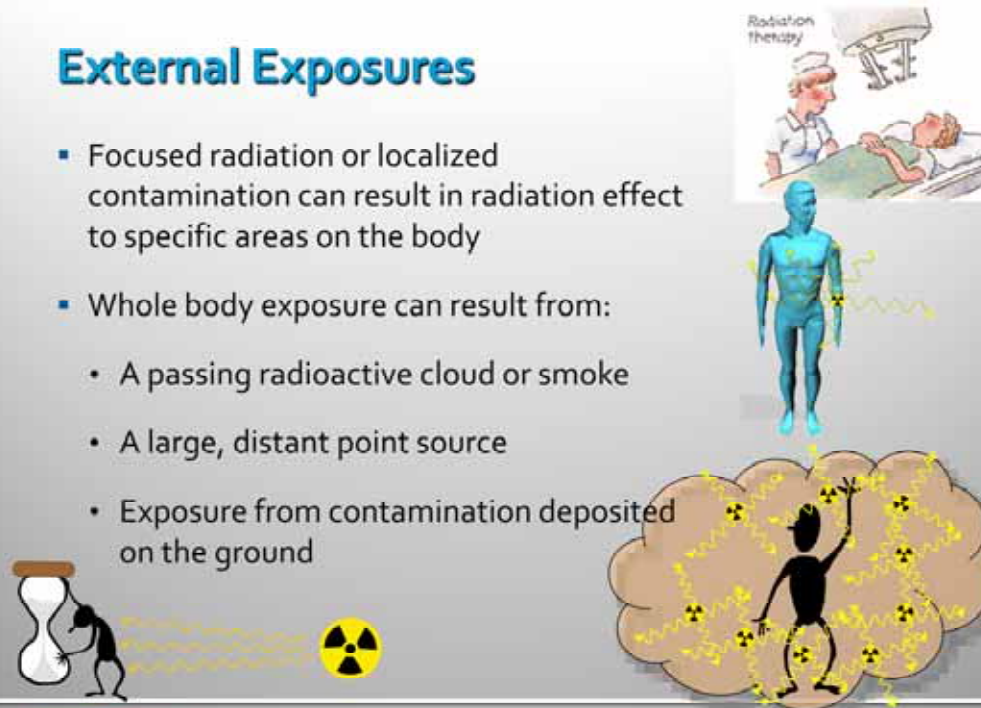
Conclusion:

Radioactive Material Production, Transportation, and Use

- High Activity Radioactive Material is highly regulated.
- Industrial Sources are very robust and made not to leak.
- When dangerous quantities are shipped, the material is in a container capable of withstanding harsh accident conditions.
- Very high activity industrial/medical sources are facility based and difficult to remove.

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



The slide includes three illustrations. In the top right, a cartoon shows a doctor in a white coat and cap performing 'Radiation therapy' on a patient lying in a hospital bed. In the center, a blue human figure stands with yellow wavy lines representing radiation passing through its body. In the bottom right, a black silhouette of a person stands inside a large, brown, cloud-like shape filled with yellow wavy lines and radiation symbols. In the bottom left, a black silhouette of a person stands next to a yellow radiation symbol on the ground, with yellow wavy lines emanating from it.

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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



Response to a Radiological Incident - Contamination -


- Monitor and isolate contaminated area
- Evacuate and “gross decon” victims (removal of outer clothing is an effective gross decontamination method)
- Avoid breathing in radioactive material
 - Shelter in place (close windows, turn off heating and A/C)
 - Evacuate, when safe to do so
 - Wear respiratory protection
- Radioactive material will not be uniformly distributed. Radiation “Hot Spots” near the source of the event will be a hazard.






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LAW ENFORCEMENT

Not all exploded sources will disintegrate. Responders should be careful to check that the intended RDD didn't simply bury a hot source in the ground or pavement. These sources can actually be more dangerous as their external dose rates could over expose responders that stay in the area.

Response to a Radiological Incident ~ Radiation ~



- Time: Limit the time spent in an areas of high radiation
- Distance: Exposure decreases dramatically as you increase your distance from the source.
- Shielding: Radiation is blocked by mass. When practical, operate behind objects (fire trucks, buildings, etc..)



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Not all exploded sources will disintegrate. Responders should be careful to check that the intended RDD didn't simply bury a hot source in the ground or pavement. These sources can actually be more dangerous as their external dose rates could over expose responders that stay in the area.

Internal Exposures



- Dose from internal depositions 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 effects
 - 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



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These slides were included in case the “BB1 Understanding Radiation” was not presented prior to these slides.

Early: Nausea & vomiting => Usually happens within a few hours of large (> 100 rad) exposures. The higher the dose, the sooner and more severe the symptom.

Burns and wounds heal slowly => For localized exposures, burns and tissue necrosis.

Hair loss, Fatigue, & medical complications =>

Dose (rads) Effects

25-50 First sign of physical effects
(drop in white blood cell count)

100 Threshold for vomiting
(within a few hours of exposure)

320 - 360 ~ 50% die within 60 days
(with minimal supportive care)

480 - 540 ~50 % die within 60 days
(with supportive medical care)




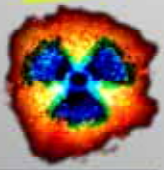

1,000 ~ 100% die within 30 days

A good example of this is the use of a large (> 1 Ci) Cs-137 or similar amounts of spent fuel.

Radiological injury or death is more likely to occur from an intact source as it irradiates nearby people. Once dispersed, the acute external radiation becomes less of a hazard and reducing the chronic exposure from internal deposition becomes the primary health concern. Of course the financial/civil burden of denial of facility/area use is also a significant factor.

Internal dose is Measured as CEDE = Committed Effective Dose Equivalent. This is equal to the total dose received by an individual over the next 50 years from an internal deposition. In addition to radiological decay, all radioactive material has a “biological half life” which describes how our bodies eliminate the radioactive material.

How Might High Activity Radioactive Material be Misused?

-   Expose people to an external source of radiation.
-  Disperse radioactive material using conventional means.
-  Explosively Disperse radioactive material [a "Dirty Bomb"].
-  Create a Nuclear Weapon (this requires special nuclear material)

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Expose people to an external source of radiation.

Sources could be placed in areas of high population (subways, stadiums, etc..) and expose passersby.

- * **Only a few individuals might be injured before the threat is discovered**
- * **medically detectable effects from available sources not likely (Time, Distance, Shielding)**
- * **Source easily found once threat is known**

Disperse radioactive material using conventional means.

- Requires putting the radioactive material in a dispersible form (i.e. fine powder or liquid)*
- If there is enough activity to be a threat once dispersed, then performing the prerequisite chemistry can be lethal to the chemist.*
- * Even without a lot of radioactivity, public hysteria to being "sprayed" can be a major issue. Remember the "med fly" spraying, (for those of us in California).*

Detonate a radioactive dispersal device (a 'dirty bomb')

Combining Radioactive sources with explosives

- **Satisfying "bang" to announce event**
- **Radiation Exposure unlikely to produce health effects, but..**
- **Contamination will greatly complicate emergency response effort.**
- * **Like above, commercial high activity sources may not easily be distributed, even with an explosion.**
- * **Source easily found once threat is known**

Detonate an improvised nuclear device
very hard to do...

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.




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If it comes up, the older (cold war) definition of a 'Dirty Bomb' was used for nuclear weapons that created an excessive amount of fallout. However, the term currently used in the news media is the slang term defined above.

But this is NOT the current definition

A Case Study: Goiania, Brazil 1987

- The 1.4 kiloCi (1,400 Ci) Cs-137 medical teletherapy source was breached by scrap metal recyclers.
- Everyone was impressed by "the glowing blue stones." Children & adults played with them.
- Serious radiological accident recognized 10 days later when Acute Radiation Syndrome symptoms were recognized by hospital staff.
- 112,000 people (10 % of Goiania's population) were surveyed at an Olympic Stadium. Significant psycho-social impacts.
- 4 deaths, 28 skin injuries, 50 internal depositions, significant contamination: 85 residences (41 demo-ed)

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11/10/2008 10:01:01 AM

Narrative:

In 1985, the Goiania Institute of Radiotherapy moved to a new location taking a Cobalt-60 teletherapy and discharging an obsolete Cesium-137 teletherapy unit in a partially demolished section of the old building in downtown Goiania

Two young men without permanent jobs looking for a way to make some money learned that there was a heavy equipment at an abandoned and partially demolished hospital building in downtown Goiania

Possibly on September 13, they forced the entrance of the building and decided to remove the shielding head of the teletherapy unit and sell it to a junk yard.

The two men, the owner of the junk yard and his two employees initiated attempts to dismantle the equipment

The rotating assembly and a capsule containing about 1400 Curies of Cesium-137 were dismantled presumably on September 18

The capsule was ruptured and the cesium released

Pieces of the source were distributed among the junk yard owner's relatives, neighbors and most close friends

Everyone was impressed with the "power of the stone" as it glowed blue in the dark.

Some of them scrubbed the material on the skin in order to appreciate its brightness

Residences about 100 miles from Goiania were found with cesium contamination

The owner's wife observed the occurrence of the first symptoms of acute radiation syndrome among her relatives and decided to look for medical assistance at the Hospital for Tropical Diseases

UCRL-PRES-149903, This work was

performed under the auspices of the U.S.
Department of Energy by the University of

California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-

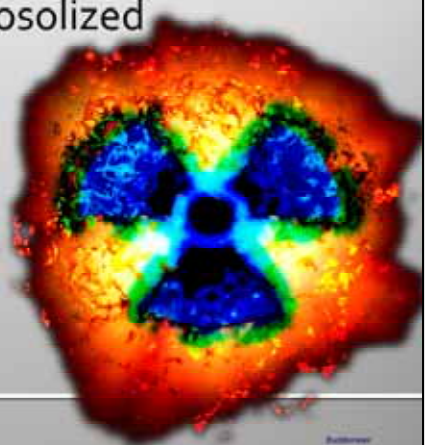
48.

Pieces of the source were put in a bag that she took along with her by bus to the hospital

On September 29, the Brazilian Nuclear Energy Commission was notified by a goianian physicist about the occurrence of a serious radiological accident

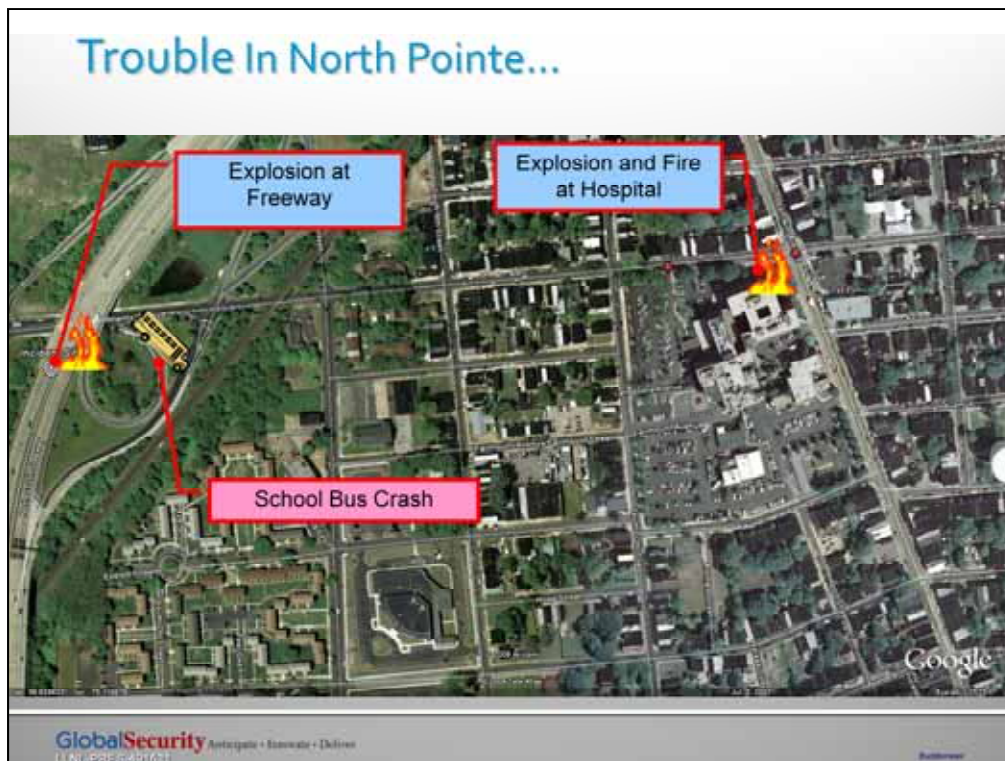
Example: Brazil's 1.37 kCi (1,370 Ci) Cs-137 Source Made Into a "Dirty Bomb"

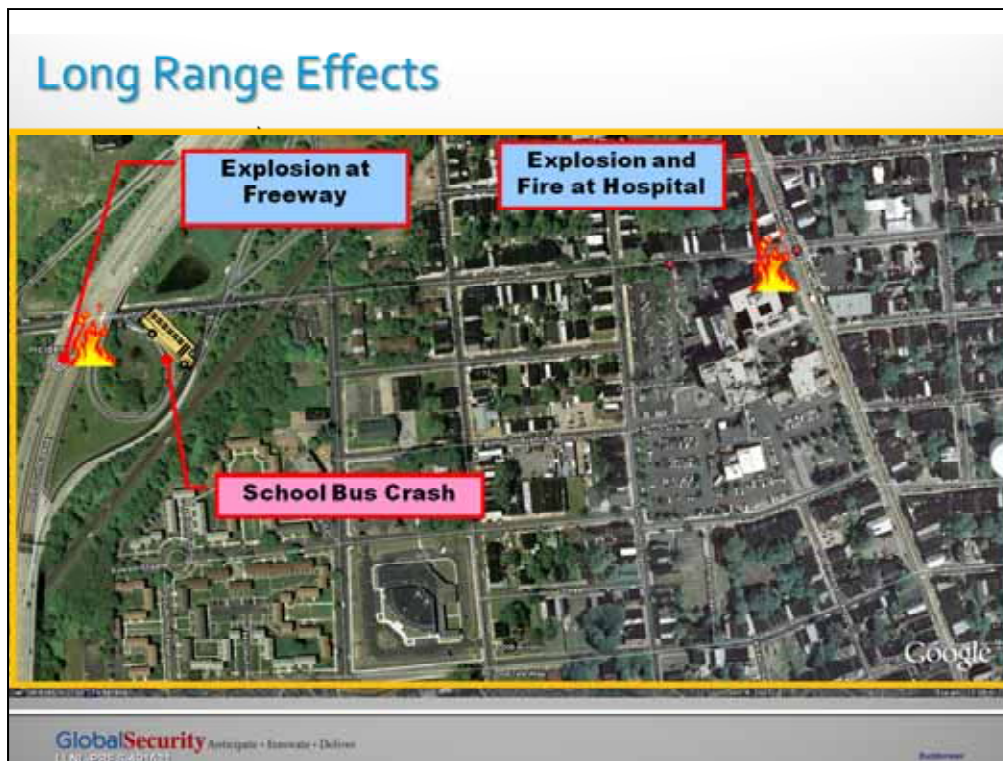
- Using Fictional "North Pointe" Example
- This model assumes "worse case" in that:
 - The source was 100% aerosolized (unrealistic)
 - Small explosive (~ 1 stick of dynamite)



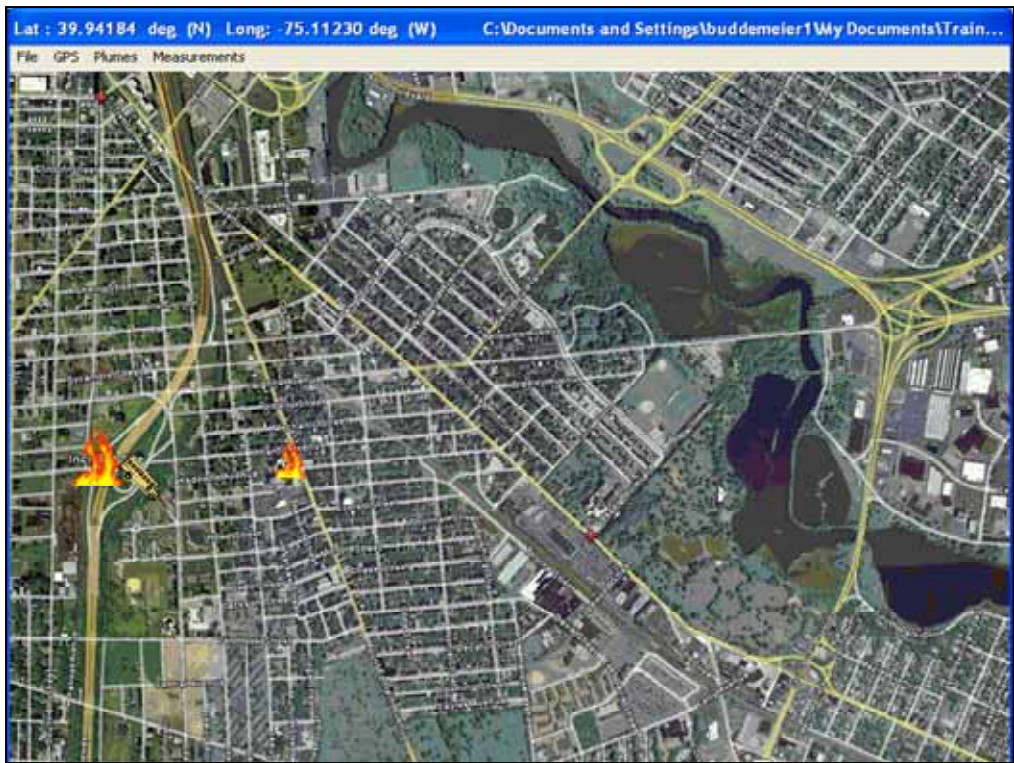
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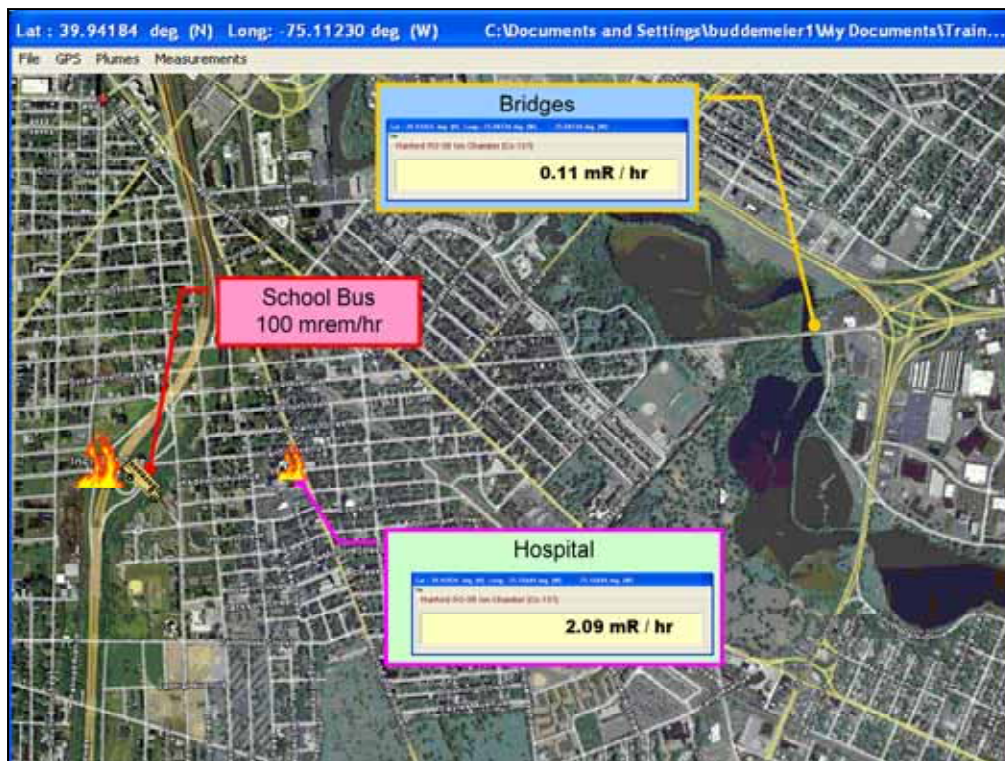
Very unrealistic scenario.... But it's just to provide you with a frame of reference.

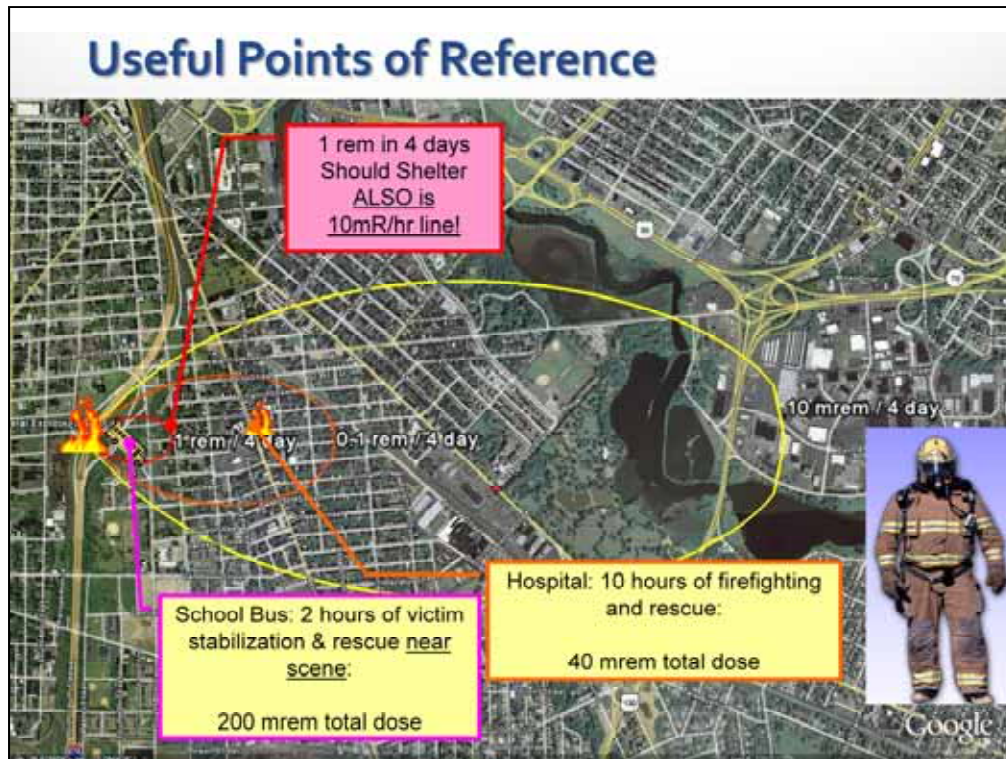




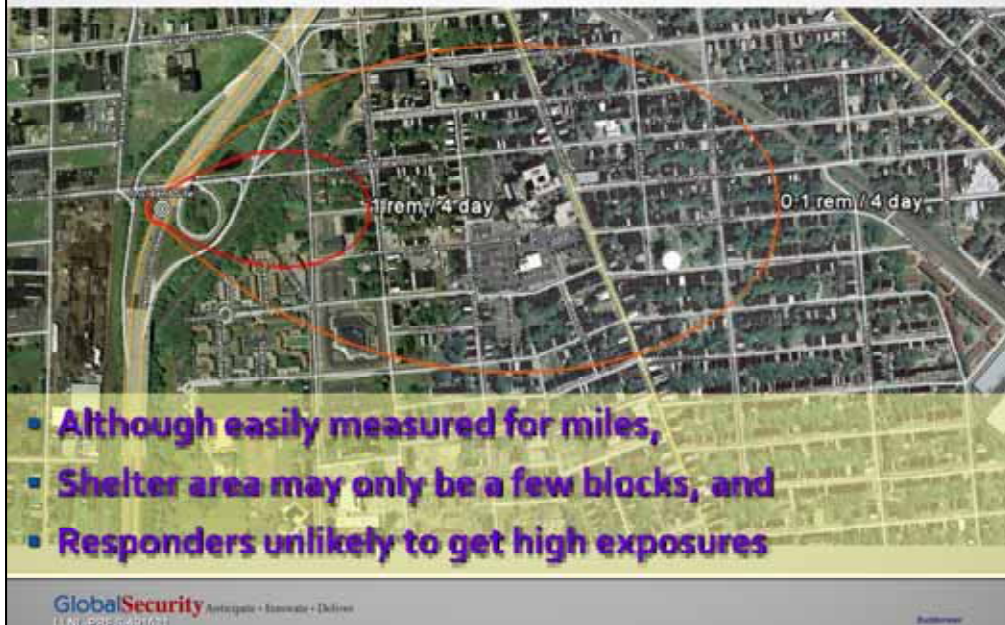








Putting It in Perspective



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.

I have been reviewing extensive materials on this subject and performing my own analysis. The general consensus about RDDs can be summed up by the following points.

1) The primary **radiological health** concern from an RDD is from dispersal and internal uptake of radioactive material. If there was enough to be of an external exposure concern for folks out of the "blast zone", then it would have been a very lethal point source to begin with and would have been difficult for the terrorist to set up & transport without keeling over before setting it off. However, it should be noted that a real exposure concern may be from source fragments at the scene.

2) Internal Exposures cause chronic long term doses that **generally** do not produce acute effects, even if they exceed dose levels that would have caused death or injury for an acute exposure. The primary concern for the internally exposed population is the long term increased risk of cancer. [The exception to this would be inhaling enough material to "burn" the inside of your lungs resulting in pulmonary edema, though this would require extended breathing of the "smoke"]

3) Increased risk of cancer is not an "injury." The definition of Injury should be limited to Acute Radiation Syndrome (ARS) and Acute Cutaneous Syndrome (ACS) (burns caused by high levels of skin contamination with high energy beta emitters).

4) The **primary** issues surrounding the radiological aspect of an RDD are not additional deaths or injuries, but:

a) Physically injured personnel receive a delay in treatment due to fear of contamination.

Some Federal Guidelines Do Exist...

But what does it mean to
these guys?



Dose Limit (rem)	Activity being performed	Limitations or conditions
5	Stay Times?	None
10	Protecting valuable property	None
25	Life saving or protection of large populations	None
100	Fight Fires... Rescue Victims... Decontaminate?	Persons fully aware of the risks involved use this limit only on a voluntary basis.


...or wait for the Experts?

*Taken from Table 2-2 of EPA 400-R-92-001 Manual of Protective Action Guides and Protective Actions for Nuclear Incidents.

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BSI/DOE/001

Current Guidance is Inconsistent and Hard to Implement.								
Turn-Back dose rate (lifesaving)			200 R/hr					
Turn-Back dose			10 rem					
Personnel Decontamination trigger level (beta, gamma β,γ)			2 times background					
Personnel Decontamination trigger level (alpha α)			Any constant, continuous clicks					
Personnel Equipment reuse contamination level (beta, gamma β,γ)			1 mR/hr on contact (above this decontaminate the equipment prior to reuse.)					
Gamma Ray Dose Rate			Stay Time to Receive This Dose					
Rate / hr	Rate / min	Rate / sec	1 rem	5 rem	10 rem	25 rem	100 rem	500 rem
5 mR/hr	83 μ R/min	1.4 μ R/sec	200 hrs	6 weeks	12 weeks	30 weeks	2 years	
100 mR/hr	1.7 mR/min	27 μ R/sec	10 hrs	50 hrs	100 hrs	250 hrs	6 weeks	30 weeks
1 R/hr	17 mR/min	270 μ R/sec	1 hr	5 hrs	10 hrs	25 hrs	100 hrs	500 hrs
10 R/hr	170 mR/min	2.7 mR/sec	6 minutes	30 minutes	1 hr	2.5 hrs	10 hrs	50 hrs
100 R/hr	1.7 R/min	27 mR/sec	36 seconds	3 minutes	6 minutes	15 minutes	1 hrs	5 hrs
500 R/hr	8.3 R/min	140 mR/sec	7 seconds	36 seconds	72 seconds	3 minutes	12 minutes	1 hrs
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This guidance was put together from various sources.

Notice the Turn-back dose is different than the life saving dose.

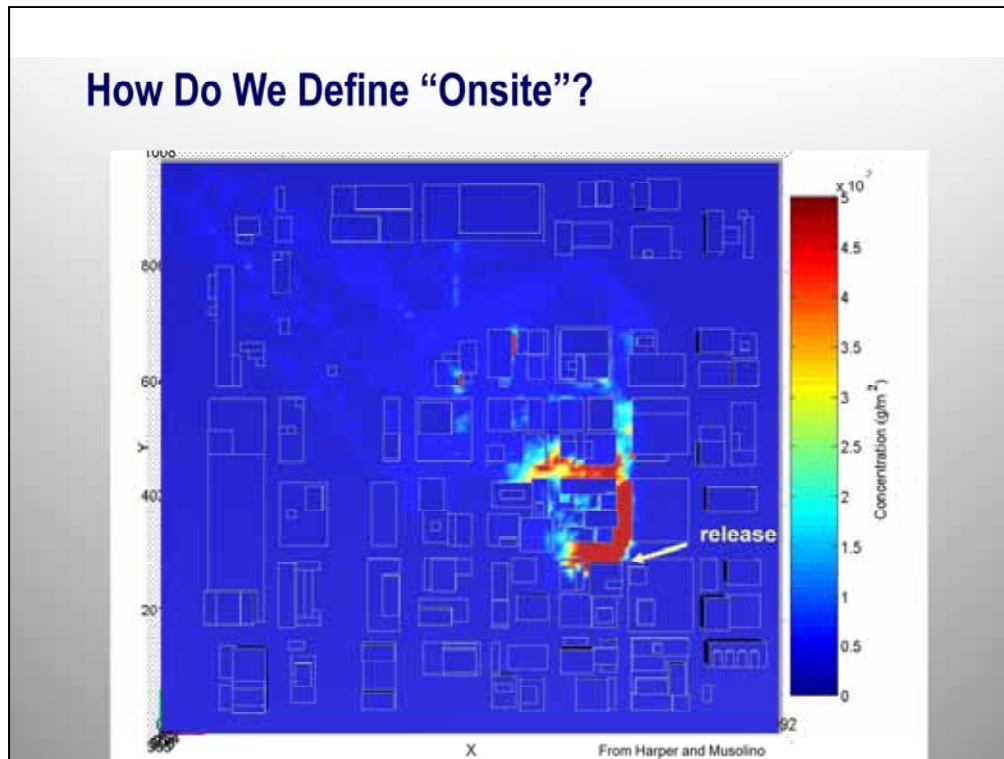
Notice that the decon guidance uses relative terms, but doesn't tell you what instrument to use. Many instruments can even detect alphas!

Equipment decon equipment is > 10 times background... try to do your 2x background survey with that!

[click]

Here is a typical Staytime table used in a Response Organization's Protocol. To use this you have to:

- 1) Know what dose is appropriate for you and your situation
- 2) **Know what the dose rate is in the area of concern**
 - This would mean that (1) someone has to go in and take a measurement and (2) the dose rate is fairly constant
 - Radiation fields are rarely consistent and in some cases decay will effect this significantly.



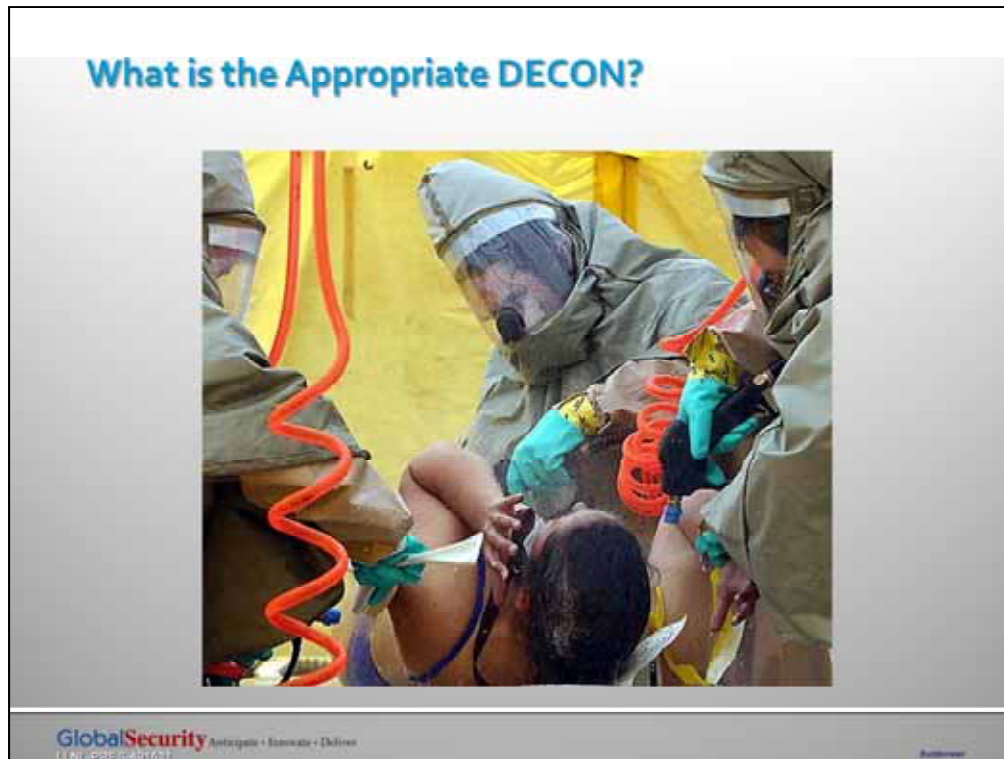
“Results can then be visualized in 2 or 3 dimensions quite readily. Wind patterns, as well as plume transport and dispersion can be readily visualized, as in these examples”



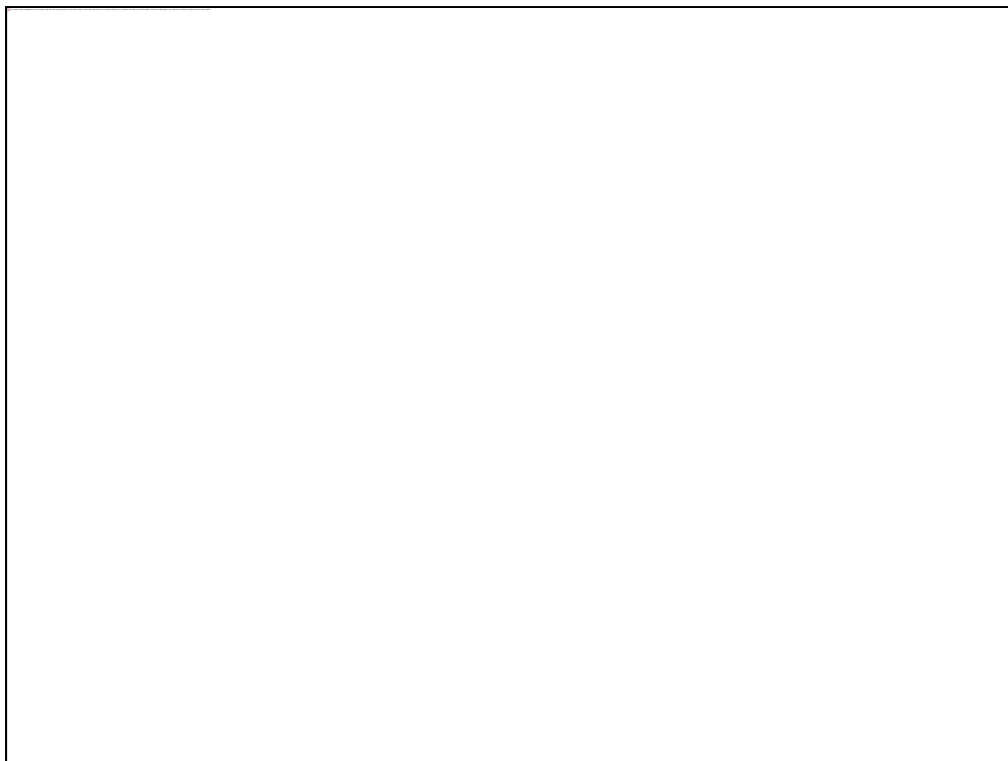
To be fair these photos were taken at different phases of the incident. (the guy in the blue helmet is a controller)

The Police officer on the left is one of the 1st on the scene and is wearing his uniform and a full face respirator. He is searching for, and helping evacuate, victims.

The EPA team on the right is wearing level A, they are doing surveys later in the day... though I understand that not all of the victims had been evacuated when they started.



That does not look like warm water and I doubt that is a soft bristle brush.



What is the Right Equipment?

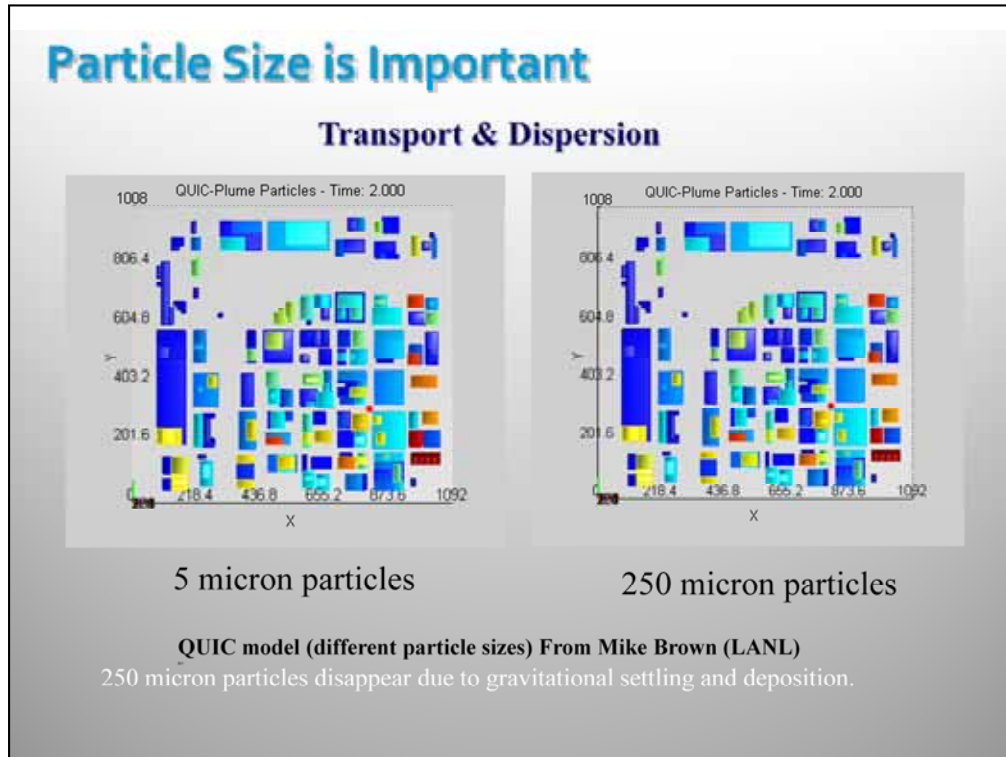


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Business

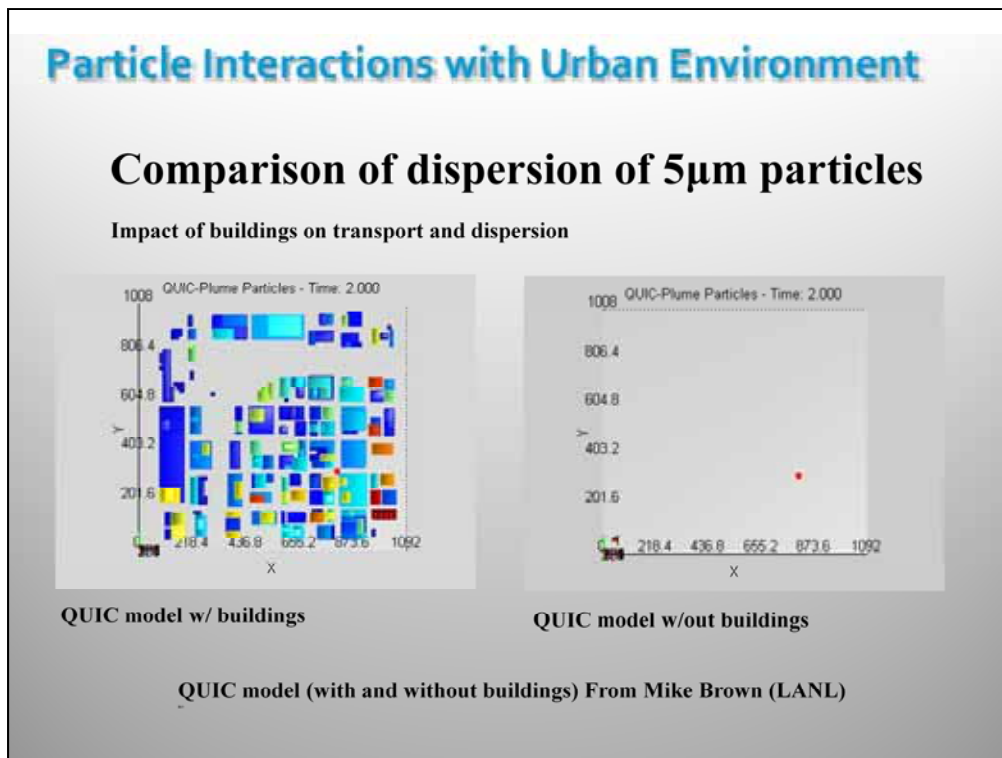
Solutions are Community Specific

- Every community balances the “risk / benefit” equation differently and has different needs.
- Most important to have a **scaleable approach**.
- Planning is often more important than the plan itself.
- A sound scientific basis is important

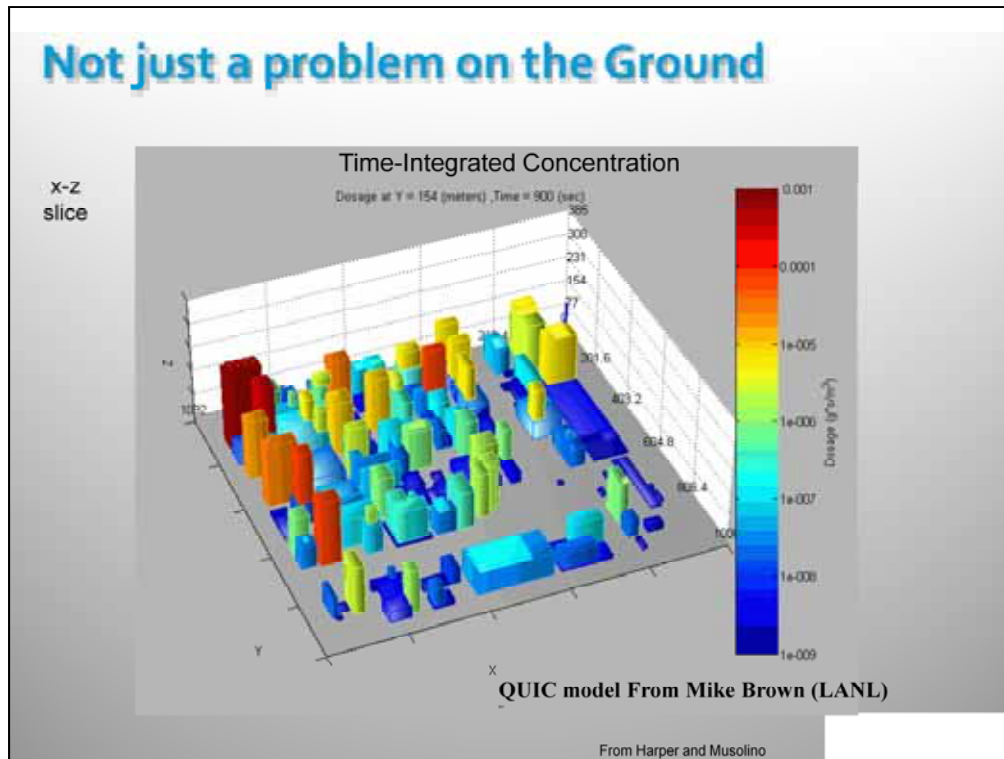


“Results can then be visualized in 2 or 3 dimensions quite readily. Wind patterns, as well as plume transport and dispersion can be readily visualized, as in these examples”

(this is an animated slide)




“Results can then be visualized in 2 or 3 dimensions quite readily. Wind patterns, as well as plume transport and dispersion can be readily visualized, as in these examples”




“Results can then be visualized in 2 or 3 dimensions quite readily. Wind patterns, as well as plume transport and dispersion can be readily visualized, as in these examples”

Initial Findings, Explosive RDD

- Primary concern is external exposure from the material deposited on the ground (a.k.a. groundshine)
- Inhalation dose is a very minor concern *except to those outdoors and near the explosion.* Responders will usually arrive after most the radiotoxic smoke has dissipated



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From Harper and Musolino

Buddemeier

Inhalation issues are only during the “plume passage.” although there will be some concern with resuspension of material (either by wind, equipment movement, or fires) this dose is small compared to the potential

ERG Equivalent for RDD

- Area of highest concern limited to 500 m (worse case)
- Within 500m, Primary inhalation hazard is gone within 10 minutes (prior to arrival of most responders)
- For likely scenarios, primary concerns of the early first responder are:
 - Protection from groundshine,
 - Provide guidance on how to handle contamination, &
 - Assess inhalation concern
- Although inhalation exposure not the primary focus, respiratory protection still advised

As Measurements are Made...

▪ Hazard Detection, Identification, & Control

Establish control zones consistent with NCRP and CRCPD

2 mrem/hour	Outer Exclusion Zone	Outer boundary for small incidents. No legal restrictions outside this area.
10 mrem/hour or Contamination above $\beta\gamma$ 1,000 Bq/cm ² α 100 Bq/cm ²	Hot Zone	Proceed for Emergency Operations (life saving, fire fighting, etc.). Shelter/Evacuate public, isolate area, and minimize responder time spent in the area.
10,000 mrem/hour (10 R/h)	High Radiation Hazard Zone	Proceed for time sensitive, mission critical emergency operations such as life saving
200,000 mrem/hour (200 R/h)	"Turn Back" Level	At this dose rate, the likelihood of successful rescue of victims is potentially outweighed by dose effects to the responders

Defining Outer Boundary & Exits/Triage/Monitoring Points

As additional resources arrive,* establish Hot Zone boundary and triage evacuees:

- a) Boundaries should be established based on urban landscape features (e.g., streets, parks, etc..). In the urban environment, turbulent wind conditions will make warm zone boundaries very irregular.
- b) Establish exit points, monitor to ensure < 10 mR/h
- c) If possible monitor at the exits to identify (triage) highly contaminated individuals
- d) If mass self-evacuation
 - Do not detain people in the contaminated area
 - Establish evacuation routes to channel self-evacuees away from Hot Zone

** The time sensitive, critical response operations (e.g., life saving, fire fighting) in the Hot Zone take precedent over warm zone activities.*

Shelter / Evacuation Considerations

Smoke and Dust from an explosive RDD may be contaminated. Immediately after a suspicious event, effort should be made to avoid breathing smoke and dust by seeking shelter and through respiratory protection, even ad-hoc protection.

- Sheltering is effective:
 - Respirable aerosol penetrates single residence buildings, even so...
 - Inhalation dose to those inside is a small fraction of outside dose
 - Larger buildings have more aerosol removal mechanisms than smaller buildings
- Effectiveness of turning off HVAC of modern high rise building needs further evaluation, buildings at risk should develop individualized emergency shelter in place (SIP) protocols.
- Ad-hoc Respirator: A dry cloth over the nose and mouth can reduce internal dose by 90%

Inhalation not a significant hazard after 10-30 minutes

Quotes from Harper and Musolino, "Realistic Radiological Dispersal Device Hazard Boundaries and Ramifications for Early Consequence Management Decisions"

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After 30 minutes, the inhalation hazard is greatly reduced as the particles settle out of the air.

One out of the smoke/dust area, Stop using ad-hoc protection.

Shelter / Evacuation Recommendations For and Outdoor, Urban "Dirty Bomb"

The best way to avoid or reduce exposure is to shelter, this means:

- If you are inside and your building is intact, stay inside.
- If you are outside, or in a significantly damaged or "smoky" building, move immediately in to the nearest robust, intact structure or out of the area if the event is small and there is a clear path out.

Evacuation is most effective if it can be accomplished *before* the radiological contamination arrives at the point of concern. For a no notice dispersal, this is generally not practical because;

- Those outdoors and in buildings near the event will not have time before the contaminates (smoke/particulate plume) reach them, and
- The radiological nature of the event may not be recognized until after responders arrive.

Immediate evacuation also carries a high degree of risk because:

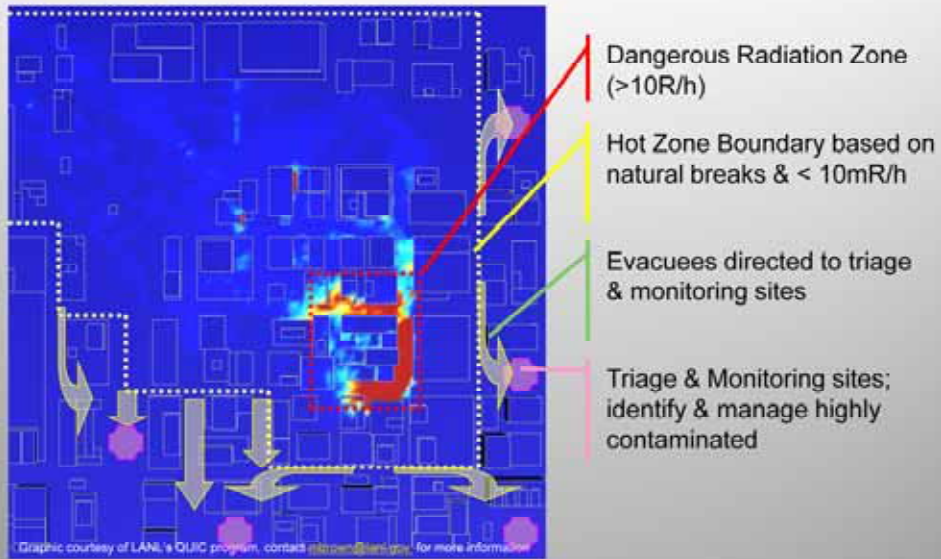
- In the initial confusion of the event, evacuees may inadvertently evacuate into more heavily contaminated areas, and
- Immediate evacuation tends to be rushed, increasing breathing rates (and therefore internal exposure to airborne contaminates) and the possibility of accidents (either running or driving erratically).

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After 30 minutes, the inhalation hazard is greatly reduced as the particles settle out of the air.

One out of the smoke/dust area, Stop using ad-hoc protection.

Use Natural boundaries for Warm Zone, Exits, and Monitoring sites



Medical Triage

- a) ***Medical emergencies (life threatening injury) take precedent over radiological monitoring or decontamination***
- b) Some may need medical assessment because of their exposure or radioactive material inhalation, A priority for decontamination and medical follow up are:
 - People with high levels of contamination on their clothes
 - People with wounds exhibiting high levels of radiation
 - People with upper body contamination (this is an indicator they were outside and close to the explosion)
- c) If the source is not ^{137}Cs , ^{60}Co , or ^{90}Sr , high doses and acute radiation effects are not possible with explosive RDD

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From Harper and Musolino

Buddemeier

life threatening injuries take precedent over radiological monitoring or decontamination. Contamination is not an immediate danger to the life of the victim or the responder.

There is the possibility of source fragments inside a wound, treatment (and source removal) of these victims should not be delayed.

You cannot get a significant lung dose (radioactive material uptake) without getting significant external contamination on the upper body

First Responder PPE

- a) Uniform
- b) Goggles
- c) Half-face APR
- d) Gloves



Level A and B protection are ineffective against a primary dose concern; groundshine radiation. Using level A or B may actually increase a responders dose as it limits functionality and communication which will increase their working time in the radiation field.


Public Decontamination Considerations

▪ Contaminated Public, 2 Possibilities:

- A few individuals close (within few hundred meters) to the release may require prompt decontamination for their safety and safety of others. These highly contaminated individuals also warrant medical follow-up.
- Majority of those contaminated do not need decontamination on an urgent basis and are **not** a danger to themselves or others.

▪ Radiological Decontamination requirements far less difficult than chemical or biological decontamination:

- Removal of outer layer of clothing
- Gentle washing with soap & warm water on exposed skin & hair
- Decon staff needs only minor respiratory protection



Decontamination: Scalable Approach

- For **Small Events**:
 - Full wet decontamination techniques can reduce anxiety of the victim and clean-up costs from cross-contamination
- However, as the **number of victims grow large**, decontamination capacity can be quickly overwhelmed, Consider:
 - Screening to identify decontamination priorities
 - Dry decontamination techniques
 - Self decontamination
 - Pre-established reception centers throughout a community with supplies rapid set-up can facilitate decontamination of population

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Decontamination strategies must consider:

Self decontamination strategies, and

Decontamination of special needs population

Pre-established reception centers throughout a community with supplies rapid set-up can facilitate decontamination of population.

Decontamination Priorities

“Initial personnel monitoring and decontamination efforts at the scene should primarily focus on preventing acute radiation effects to the affected individual. Cross contamination issues are a secondary concern.”

~ NCRP 2005

- Screening: Individuals with spot contamination greater than 2.2×10^6 dpm (37,000 Bq)* should be a priority for decontamination
- Post decontamination monitoring should look for 2.2×10^5 dpm (3,700 Bq) spot contamination

*This spot contamination can cause Acute Exudative Radiodermatitis if not removed within 36 hours. (FEMA-REP-22)

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Acute Exudative Radiodermatitis is characterized by inflamed skin with redness, pain, and oozing body fluids. Medical care may be needed. This is the deterministic **health effect** of greatest concern because it occurs at the lowest level of concentrated surface contamination.

Based on information in Appendix B of Reference 2, the threshold dose to the skin for acute exudative radiodermatitis is in the range of 1,200 to 2,000 rad (as used here, 1 rad = 1 rem). The lower end of the range (1,200 rem) is conservatively assumed.

Based on dose conversion factors in Appendix B of EPA 520/1-89-016 *Evaluation of Skin and Ingestion Exposure Pathways* (Reference 4) for the mix of radionuclides assumed to be associated with a major reactor accident, the factor to convert skin contamination to skin dose at a skin depth of 7 mg/cm², is about 7 rem/h per $\mu\text{Ci}/\text{cm}^2$ (may also be expressed as 7 rem per $\mu\text{Ci h}/\text{cm}^2$). Therefore, if the activity is concentrated in a 0.2 cm² area, then the threshold MDL of activity on the spot to **avoid** acute exudative radiodermatitis is **34 $\mu\text{Ci h}$** (i.e., 1,200 rem / 7 rem per $\mu\text{Ci h}/\text{cm}^2 \times 0.2 \text{ cm}^2$). Dividing 34 $\mu\text{Ci h}$ by 36 h and 336 h of exposure yields **0.95 μCi** and **0.10 μCi** for loose and fixed contamination respectively.

**Twice Background Not Realistic...
and Impossible to Measure**

Instrument/ Detector Combination	Fixed Contamination (0.1 μ Ci Threshold)				Loose-Plus-Fixed Contamination (1.0 μ Ci Threshold)			
	2.2 x 10 ⁵ dpm (3,700 Bq)			Time Needed to Monitor an Adult ^b (minutes)	2.2 x 10 ⁶ dpm (37,000 Bq)			Time Needed to Monitor an Adult ^b (minutes)
	Probe Speed (inches/s)	Height Of Probe (inches)	Path Width (inches)		Probe Speed (inches/s)	Height of Probe (inches)	Path Width (Inches)	
CD V-700 with side window detector	4	0.25 to 0.5	0.6 ^c	19	6	1 to 2	2	3.9
CD V-718 with end window detector	3	0.5 to 1	1	16	6	1 to 4	3	2.6
All tested instruments with pancake detector except the Victoreen 190	6	1 to 3	2	3.9	24	2 to 6	7	0.28
Victoreen 190 with pancake detector	6	1 to 4	3 ^c	2.6	24	2 to 6	8 ^c	0.24

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Background Information on Contamination Monitoring Guidance for Portable Instruments Used for Radiological Emergency Response to Nuclear Power Plant Accidents, dated October 3, 2002. FEMA REP-22

- a. The values shown were derived with the detector protected by two layers of plastic vegetable wrap and in the presence of 0.1 mR/h gamma radiation background, except as noted.
- b. These are calculated values assuming a skin area of 18,000 cm² = 2790 in².
- c. Audible detection was not possible in the presence of 0.1 mR/h background. This value was derived in the presence of 0.02 mR/h background.

What is the Right Equipment?										
Mission	Alarming Dosimeters & Personal Emergency Radiation Detectors (PERDs) ¹	Non-alarming Personal Emergency Radiation Detectors (PERDs) ¹	Survey Meter ²	PRND Detection Systems ³	Contamination monitors ⁴	Dosimeters	Aerial System	Portal Monitor	Sensor Networks	Medical Instrumentation ⁵
Confirmation of Nuclear Yield	●	○	●	○	—	—	●	○	○	—
Yield Estimation	—	○	●	—	—	○	●	—	●	—
Dangerous Fallout Zone Activities (use instruments that can function in exposure rates up to 1,000 R/hour)										
Location of Ground Zero	○	—	—	—	—	—	●	—	○	—
Worker Dose Assessment	—	○	—	—	—	●	—	—	—	—
Worker Safety for DFZ Missions	●	○	○	—	—	—	—	—	—	—
Survey of Dangerous Fallout Zone	●	—	●	—	—	—	●	—	○	—
Establishing Evacuation Routes	●	—	●	—	—	—	●	—	○	—
Hot Zone Activities (use instruments that can function in exposure rates up to 10 R/hour)										
Worker Dose Assessment	○	○	—	—	—	●	—	—	—	—
Worker Safety for Hot Zone Missions ⁶	●	○	○	—	—	—	—	—	—	—
Survey of Hot Zone	●	—	●	—	—	—	●	—	○	—
Establishing Evacuation Routes	●	—	●	—	—	—	●	—	○	—
Activities Outside of Hot Zone (use instruments that can function in exposure rates up to 0.01 R/hour)										
Worker Dose Assessment	○	○	—	—	—	●	—	—	—	—
Worker Safety Outside Hot Zone	●	○	○	○	○	—	—	—	—	—
Locating Hot Zone Boundary	●	—	●	○	○	—	●	—	○	—
Monitoring Medical Care Locations	●	—	●	○	●	—	—	○	—	○
Monitoring at Shelters (Radiation Levels)	○	—	●	○	●	—	—	○	—	—
External Contamination Detection (Personnel)	○	—	○	—	●	—	—	—	—	○
Internal Contamination Detection (Personnel)	—	—	○	—	○	—	—	—	—	●
Equipment & Facility Contamination Monitoring	○	—	○	○	●	—	○	—	—	○

Notes:

¹ The American National Standards Institute is developing performance criteria for Personal Emergency Radiation Detectors (PERDs). There are two standards, ANSI N42.49A and ANSI N42.49B, which will be published by the Fall of 2010; Alarming Electronic Personal Emergency Radiation Detectors (PERDs) for Exposure Control (ANSI N42.49A) are alarming electronic radiation measurement instruments used to manage exposure by alerting the emergency responders when they are exposed to photon radiation. The instruments provide rapid and clear indication of the level of radiation exposure and/or exposure rate and readily recognizable alarms. The alarms are both audible and visual, and distinguishable between exposure rate and exposure. Non-alarming Personal Emergency Radiation Detectors (PERDs) for Exposure Control (ANSI N42.49B) are ionizing photon radiation measuring detectors that provide a visual indication of the exposure to the user, and are designed to be worn or carried on the body of the user. These detectors do not have audible or visual alarm. These detectors provide indications that decision levels based on recommended DHS Protective Action Guides have been reached or exceeded. These detectors include carbon fiber detectors (a.k.a., pocket ionization chamber or Direct Reading Pocket Dosimeter), electronic exposure indicating detectors and self-developing photochemical detectors (i.e., color changing cards).

² ANSI N42.33 and ANSI N323 describe performance criteria for instruments used for detection and measurement of photon emitting radioactive substances for the purposes of detection and interdiction and hazard assessment. **Survey Meter** is generally considered an ANSI N42.33 Type II instrument, the figure below provides information on the applicable exposure rate ranges for these instruments.

³ Radiation detection systems deployed in support of preventive radiological nuclear detection (PRND) missions are generally too sensitive to be used within the DFZ or Hot Zone, however they can be of great use outside the Hot Zone for the activities noted above. This includes instruments such as the Personal Radiation Detectors (defined by ANSI N42.32), survey equipment (defined by ANSI N42.33 Type I instruments noted above), Radioisotope Identification Devices (defined by ANSI N42.34), Backpack, and Mobile systems.

⁴ Contamination monitors are count rate meters designed to measure activity (alpha, beta, photon, or alpha-beta) per unit surface area or activity of a localized source associated with the contamination of the examined object. These detectors include thin window detectors such as thin-window Geiger-Mueller (GM) (either "pancake," or end-window) hand-held survey meter and would be acceptable to monitor for either area or personal contamination. Performance criteria are described in ANSI N323, American National Standard Radiation Protection Instrumentation Test and Calibration, Portable Survey Instruments.

⁵ Includes nuclear medicine diagnostics, gamma imaging cameras, etc.

⁶ Missions within the DFZ should be restricted to time-sensitive, mission-critical activities justified under the worker safety section of this document. Examples may include investigation of underground evacuation routes, fire control, supporting a controlled evacuation, and restoration of critical infrastructure required for life saving activities.

⁷ Common missions within the Hot Zone include: fire fighting, direct public notification of protective recommendations, USAR activities, life saving sustaining activities, supporting a controlled evacuation, road clearing, and restoration of critical infrastructure. Worker exposures should be justified as per the Response Worker Safety section of this chapter.

⁸ Includes monitoring of vehicles and material being evacuated from the contaminated region.

⁹ Facilities include infrastructure and open air structures.

¹⁰ Definitions of the Legend categories:

Useful - This is a device that can effectively perform the designated mission or task without modification of the device or of its normal mode of employment. In a sense, the device was designed or intended for that mission or task.

Marginal - The device can provide useful and relevant data in support of the designated mission or task, but with modification to the normal mode of employment. In addition, its use may create a potentially unsafe condition to the user of the device. This implies a need for care in the interpretation of the data produced by such a device under the circumstances.

Not Useful - While the device is capable of detecting nuclear radiation, its technical performance characteristics or conditions of use are such that it is unlikely to be able to provide useful information in support of the designated mission or task. In addition, its use may create a grossly unsafe condition to the user of the device.

References of Interest for Equipment Selection

ANSI N13.11 (2001) "Criteria for Testing Personnel Dosimetry Performance"
ANSI N323A (1997) "Radiation Protection Instrumentation: Test and Calibration, Portable Survey Instruments"
ANSI N42.17A (1989) "Performance Specifications for Health Physics Instrumentation- Portable Instrumentation for Use in Normal Environmental Conditions"
ANSI N42.17C (1989) "Performance Specifications for Health Physics Instrumentation-Portable Instrumentation for Use in Extreme Environmental Conditions"
ANSI N42.20 (2003) "Radiation Protection Instrumentation: Performance Criteria for Active Personnel Radiation Monitors"
ANSI N42.32 (2006), "American National Standard for Performance Criteria for Alarming Personal Radiation Detectors for Homeland Security"
ANSI N42.33 (2006), "American National Standard for Portable Radiation Detection Instrumentation for Homeland Security"
ANSI N42.37 (2006), "American National Standard for Training Requirements for Homeland Security Purposes Using Radiation Detection Instrumentation for Interdiction and Prevention"
ANSI N42.42 (2007) "American National Standard Data Format Standard for Radiation Detectors Used for Homeland Security"
DHS 2006 Preparedness Directorate; Protective Action Guides for Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents; Notice 71FR174
IAEA EPR - FIRST RESPONDERS 2006 "Manual for First Responders to a Radiological Emergency"
IAEA-TECDOC-1432 (2005) "Development of an Extended Framework for Emergency Response Criteria"
ICRP Publication 96 (2006) "Protecting People Against Radiation Exposure in the Event of a Radiological Attack"
NCRP Commentary No. 19 (2005) "Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism"
NCRP Report No. 138 (2001) "Management of Terrorist Events Involving Radioactive Material"
NFPA 472: (2008) Standard for Competence of Responders to Hazardous Materials/Weapons of Mass Destruction Incidents

Equipment Characteristics

There are three primary characteristics to consider when selecting Instruments

Sensitivity.

- ⇒ Sensitive detectors can measure very low levels of radiation.

Selectivity.

- ⇒ There are different types of Radiation, the type of radiation and it's energy "signature" can help distinguish common natural, medical, or commercial sources from potential threats.

Portability.

- ⇒ Portability can be a critical element depending on how the detection system is being used.

Sensitivity

- As a general rule, equipment sensitivity is proportional to size: larger detectors are more sensitive.
- Highly sensitive instruments may be helpful for detecting low levels of radiation, but can also be easily “overwhelmed” by levels that could easily be encountered in an emergency response.



Selectivity

Homeland Defense Equipment Reuse Program

Instrument Selection

COMMONLY USED CONTAMINATION SURVEY INSTRUMENT PRIOR SELECTION

DETECTION ABILITY:  NONE  SOME  GOOD

PRIME	SEC. RADIATION	ALPHA	BETA	GAMMA
 Thin window	50 - 100 CPM			
 Medium window	20 - 50 CPM			
 Thick window	100 - 1000 CPM			
 Thin window	20 - 50 CPM			
 Thin window	20 - 50 CPM			
 Thin window	0 - 1 CPM			

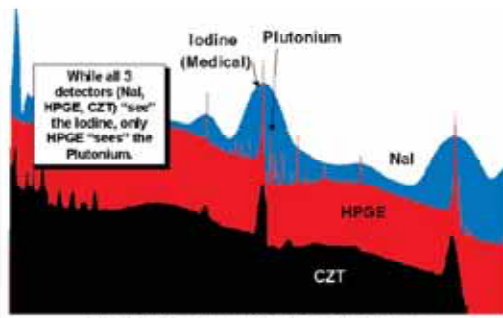


Figure 2. HPGe in comparison to NaI and CZT detectors.

- Alpha and Beta radiation require thin window detectors
- Gamma spectroscopy systems (RIIDs) use the energy "signature" to identify the radionuclide, however most hand-held RIIDs have poor resolution and can incorrectly identify complex signatures.

Detection Equipment Portability

- **Human-portable** – equipment that is small enough to be carried easily by a single person either as a handheld device or in a backpack.
- **Mobile** – vehicle mounted detection systems. These systems contain the largest detectors of all five types, and are therefore the most sensitive
- **Aerial** – detection equipment is carried by a helicopter. It is used for operations in large areas that are not easily covered with other mobile systems
- **Re-locatable** – detection equipment that can be moved from place to place. It differs from mobile types in the sense that it can be temporarily fixed to a certain area, but has the ability to be moved if needed
- **Fixed** – these are (typically) **portal** radiation monitors. This type of equipment is usually applied to choke points used by pedestrian, vehicle, and commercial traffic


Tools: *Electronic Dosimeters*

The Pros

- Alarms in hazardous situations.
- Can identify a significant radiological event.
- Records dose.
- Long battery life.
- Small Size.
- Simple operation and often very rugged

The Cons

- Not necessarily sensitive enough to detect low levels of radiation.
- Won't detect alpha or low energy beta radiation



Although the perfect tool does not currently exist, there are a few different types of instruments that have some of the right properties. One example would be the one of the numerous electronic dosimeters that are currently on the market.

The Pros

These devices are becoming more common in the industry today. In addition to their small size & ruggedness, they track the exposure received by the wearer and can even alert them to hazardous situations by an audible alarm. The user simply needs to turn the unit on and wear it. Many units have low power consumption and the batteries can last for months while on.

[Click to Display Cons]

•The Cons

Although some of these devices have beta radiation detectors, when used passively, these devices won't alert the user to alpha and beta radiation from contamination unless there was an accompanying deep dose field. Many of the units are not sensitive enough to detect low levels of radiation that may be associated with contraband concerns (microSv or fractions of a mrem)

[Click]

Tools: *Electronic Dosimeters*

Description:


About the size of a pager, these electronic devices track the total radiation dose received by the wearer. They often use low power silicon chips or small Geiger-Müller (GM) tubes to measure dose. Most have the ability to alarm at certain dose rates or total dose. Although these devices are not sensitive enough to necessarily find fugitive radioactive material, they can quickly detect significant events and **protect the wearer from overexposure.**

Application:

Well suited for emergency responders who may need to quickly enter a scene, these devices can help ensure responder safety by alerting them to potentially hazardous radiation levels without any user activation or operation. The units can also alert the wearer when unusual radiation levels are present, though they may not be sensitive enough to find low levels, i.e., $< 5 \mu\text{Sv/hr}$ ($< 0.5 \text{ mrem/hr}$).

Examples:

Canberra Industries: <http://www.canberra.com/Products/Products.asp?ID=1137>
 Far West Technology, Inc.: <http://www.farwesttech.com/Products.asp>
 MGP Instruments: <http://www.mgp-instruments.com/Products.asp>
 POLIMASTER, Ltd.: <http://www.polimaster.com/Products.asp>
 Science Applications International Corporation (SAIC): <http://www.sai.com/products/radiation.asp>
 Siemens Environmental Systems - UK: <http://www.siemens.com/pressroom/pressroom.asp?cid=2237&cid2=2237&cid3=2237>
 Thermo Electron Corp: <http://www.thermo.com/Products/Products.asp>



This does not
represent an
endorsement

{Note to readers, only the yellow application section is initially displayed}

In summary, the issues associated with electronic Dosimeters are

Well suited for emergency responders who may need to quickly enter a scene, these devices can help ensure responder safety by alerting them when radiation is present, but they may not be sensitive enough to identify the radiological nature of events involving small quantities or alpha emitting isotopes.

Units with more than 1 alarm levels preferred, one alarm used for radiation proximity “alert” ($1 \mu\text{Sv/hr}$) and one used to indicate hazardous “turn back” levels (0.1 Sv/hr or 0.1 Sv).

Training must be provided to ensure that the user continues to perform rescue and first aid efforts even with “alert” alarms. Additional victim casualties could result from ill trained responders who leave the scene at alert levels.

Typical costs are several hundred dollars per unit, but models that detect beta or neutron radiation, or those with external probes can be more expensive.

[click]

I’ve summarized the description and some EXAMPLE units on this slide. Don’t try to read this eye-chart, it is there to complete your hand out. This does not represent an endorsement!


Tools: *Personal Radiation Detectors (PRDs)*

Pros

- Very sensitive. Alerts the user of any statistically significant changes to the natural background radiation levels.
- Useful for finding contraband radioactive material.
- Good battery life
- Small Size
- Simple operation

Cons

- Will alarm in the presence of legitimate commercial, medical, or naturally occurring sources of radiation.
- Does not accurately measure (or work in) high dose rates which would be of concern to emergency responders performing rescue operations.
- Won't detect alpha or low energy beta contamination (other than by any associated dose field)
- Expensive (\$800 – \$2,000)



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[1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] [17] [18] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30] [31] [32] [33] [34] [35] [36] [37] [38] [39] [40] [41] [42] [43] [44] [45] [46] [47] [48] [49] [50] [51] [52] [53] [54] [55] [56] [57] [58] [59] [60] [61] [62] [63] [64] [65] [66] [67] [68] [69] [70] [71] [72] [73] [74] [75] [76] [77] [78] [79] [80] [81] [82] [83] [84] [85] [86] [87] [88] [89] [90] [91] [92] [93] [94] [95] [96] [97] [98] [99] [100]

Although it looks similar to a electronic dosimeter, there is a very different kind of detector out there which I call “Personnel Radiation Proximity Alert Systems.”

The Pros

- Very sensitive. Alerts the user of any statistically significant changes to the natural background radiation levels.
- Useful for finding contraband radioactive material.
- Good battery life (often weeks of continuous operation)
- Small Size (pager or notebook sized)
- Simple operation (requires no user action, simply wear the unit)

[Click Display Cons]

•Cons




- Will alarm in the presence of legitimate commercial, medical, or naturally occurring sources of radiation.
- Does not accurately measure (or work in) high dose rates which would be of concern to emergency responders performing rescue operations.
- Won't detect alpha or low energy beta contamination (other than by associated dose fields)
- Expensive (\$800 – \$2,000)

Tools: Personal Radiation Detectors (PRDs)




Description: Often called “Radiation Pagers,” and similar in appearance to the electronic dosimeters, these units have the very different function of finding low levels of radiation using very sensitive crystal or plastic scintillators. Although good for finding contraband radioactive material, these units do not have the range necessary for personnel protection (i.e., high dose rates).

Application: Well suited for law enforcement or inspectors, these devices can alert the wearer to any unusual radiation in their proximity. These devices are best used when there is an opportunity for a measured response, as most alerts will occur from legitimate commercial, medical, or natural radioactive material. Training and protocols need to be provided to properly resolve any alarms.

Examples: POLIMASTER, Ltd: <http://www.polimaster.com/en/products/ratemeters.htm>
 Sensor Technology Engineering, Inc <http://www.nttc.edu/ertProgram/radpagers.asp>
 T, TECHNICAL ASSOCIATES: <http://www.tech-associates.com/dept/sales/product-info/vski-2.html>

This does not represent an endorsement

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In summary

Well suited for law enforcement or inspectors, these devices can alert the wearer to any unusual radiation in their proximity. These devices are best used when there is an opportunity for a measured response, Training must be provided to ensure that the user realizes that the alarms do not necessarily indicate a hazardous situation. As in all of these cases, additional victim casualties could result from ill trained responders who leave the scene because of the proximity alarms. Training must also be provided on how to resolve the many alarms that will occur from legitimate radioactive material uses.

click]

I've summarized the description and some EXAMPLE units on this slide. Don't try to read this eye-chart, it is there to to complete your hand out.


Tools: *Simplified Contamination Survey Instruments*

Pros

- "Open window" GM for alpha and beta contamination.
- Most have Good Sensitivity.
- Digital models can have set alarm levels
- Small Size
- Simple operation
- Rugged, simple technology.

Cons

- Sensitive enough alarm in the presence of legitimate commercial, medical, or naturally occurring sources of radiation.
- Many models can not be used in high dose rates which would be of concern to emergency responders performing rescue operations (>0.1 Sv/hr | >10 R/hr).
- Low accuracy (i.e., uses pancake GM for dose measurement)



Industry Standard Radiation / Contamination Survey instruments are those commonly used by health physicists and radiation control technicians at nuclear power plants, hospitals, and research laboratories. These instruments use a variety of detector technology (GM, Ion chamber, scintillator, proportional counter, etc..) to measure dose rates and contamination. Although well suited for the experienced user, they may not be appropriate for the occasional user like an emergency responder. In order to meet the needs of the occasional, novice user, manufacturers have tried to create sub-genre of instruments that are smaller and easier to use. I have labeled this category *Simplified Contamination Survey Instruments*

Pros

- Most have Good Sensitivity.
- Digital models can have set alarm levels
- "Open window" GM for alpha and beta contamination.
- Small Size (cell phone or notebook sized)
- Simple operation (user action required, but usually only one or two switches)
- Rugged, simple technology.

[Click to show Cons]


Cons

Sensitive enough alarm in the presence of legitimate commercial, medical, or naturally occurring sources of radiation.


Many models can not be used in high dose rates which would be of concern to emergency responders performing rescue operations (>0.1 Sv/hr | >10 R/hr).

Low accuracy (i.e., uses pancake GM for dose measurement)

Tools: Simplified Contamination Survey Instruments

Description:	These simplified meters use thin window (GM) detectors to measure alpha & beta surface contamination as well as dose rates. Although often <i>more sensitive than the electronic dosimeter</i> , these devices are not as sensitive as the radiation proximity alert systems. Although they have a <i>higher range than the personal radiation proximity alert systems</i> , many models will still not function well in the emergency response dose rate ranges (0.1 Sv/hr or 0.1 Sv). Their simplified operation is designed for the occasional user.	
Application:	Well suited for emergency responders and hospital staff who may need to quickly determine if radioactive <u>contamination</u> is present. The units can also alert the wearer when unusual radiation levels are present. Training must be provided on their use as successful contamination monitoring requires specific techniques.	
Examples:	<p>Canberra Industries: http://www2.canberra.com/PCatalog.nsf/allRPL_PDF/55e1e1a9e04.pdf</p> <p>T₁ TECHNICAL ASSOCIATES http://www.tech-associates.com/dept/sales/product-info/thin-3.html</p> <p>Berkeley Nuclonics Corp: http://www.berkeley-nuclonics.com/Telnet/AM/</p> <p>Health Physics Instruments: http://www.hpi.com/hpi_hpi_41266.htm</p> <p>Radiation Alert Instruments: http://www.scint.com/mon3.htm, http://www.scint.com/imp3.htm, http://www.scint.com/imp_exp.htm</p>	

This does not represent an endorsement



In Summary

Smaller, simpler, and often cheaper than commercial equipment, these devices are well suited for the emergency responders. There is a large variety of capabilities in this class of instrument to the appropriate features must be considered for the task and the user. Training must be provided to ensure that the user understands how to interpret readings. Using the instrument to detect contamination will require also require special training.

Typical costs are \$300 - \$600 dollars per unit. For the occasional user, choose the more expensive digital models as they will have alarms and are easier to operate.

[click]

I've summarized the description and some EXAMPLE units on this slide. Don't try to read this eye-chart, it is there to to complete your hand out.

Tools: Isotope Identification Equipment (Gamma Spectroscopy)

Pros

- Very sensitive. Alerts the user of any statistically significant changes to the natural background radiation levels.
- Useful for finding contraband radioactive material.
- Often tracks dose rates and total dose of user while on.
- Can identify many common isotopes

Cons

- Although fairly good at identifying common isotopes with simple spectra, these units can not identify all possible isotopes of concern and can also mis-identify isotopes.
- Will alarm in the presence of legitimate commercial, medical, or naturally occurring sources of radiation (though the analysis capability can often help resolve this)
- Expensive (\$8,000 - \$12,000)
- Won't detect alpha or low energy beta contamination.
- Requires extensive training or support to use properly



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[1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] [17] [18] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30] [31] [32] [33] [34] [35] [36] [37] [38] [39] [40] [41] [42] [43] [44] [45] [46] [47] [48] [49] [50] [51] [52] [53] [54] [55] [56] [57] [58] [59] [60] [61] [62] [63] [64] [65] [66] [67] [68] [69] [70] [71] [72] [73] [74] [75] [76] [77] [78] [79] [80] [81] [82] [83] [84] [85] [86] [87] [88] [89] [90] [91] [92] [93] [94] [95] [96] [97] [98] [99] [100]

Commercially available handheld NaI gamma spectroscopy has seen great improvements in the last 5 years. Mostly in the form of better analysis algorithms and easier interfaces.

Pros

- Very sensitive. Alerts the user of any statistically significant changes to the natural background radiation levels.
- Useful for finding contraband radioactive material.
- Often tracks dose rates and total dose of user while on.
- Can identify many common isotopes

[Click to Display Cons]

Cons

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- Expensive (\$8,000 - \$12,000)
- Won't detect alpha or low energy beta contamination.
- Requires extensive training or support to use properly

Tools: Isotope Identification Equipment (Gamma Spectroscopy)

Description: These expensive and sophisticated units use the different gamma ray “signatures” given off by the radioactive material to identify the originating isotope(s). Proper identification of the isotope is important for determining the appropriate response actions. Although the analysis being performed is complicated, these units offer a simple interface to help non technical users make a measurement. Many of the units have modes of operations similar to the proximity alert and electronic dosimeters.


Application: Best suited for experienced users or well trained and practiced responders, these units will help identify the radioactive material involved at a scene or in contraband. Good for follow-on radiological emergency response teams or inspectors.

Examples: Berkeley Nucleonics Corp <http://www.berkeley-nucleonics.com/radiation/index.htm>
Bicron/Thermo Electron: <http://www.thermo.com.sg/usa/tnp/>
Exploranium Radiation Detection Systems: <http://www.exploranium.com/pr125ag1.htm>
Perkin Elmer (Ortec): <http://www.ortec-online.com/safeguards.htm>
Quantrac Sensor: <http://www.quantracsensor.com/>
Radiation Alert: <http://www.seintl.com/usa.htm>
XRF Corporation: <http://www.xrfcorp.com/products/ics.htm>

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[11/01/2006/01/01]

SURVEILLANCE AND MEASUREMENT SYSTEM

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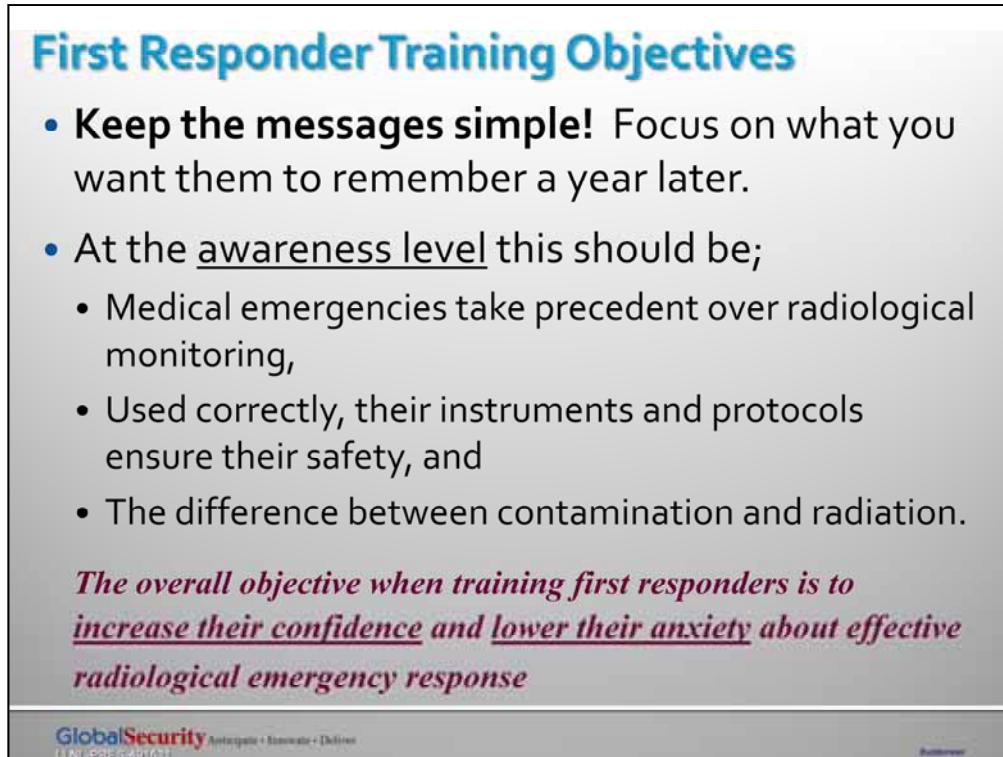
In Summary,

Their expensive prohibits them from being in every first responder's back pocket, but they can be a valuable tool in the hands of a well trained regional responder. Although most units have been ruggedized, the technology is inherently shock sensitive and the automated analysis is not 100% effective.

Accurate assessment often requires an experienced spectroscopist to assess data. Fortunately, many of the units have the ability to download the spectrum for remote analysis by an expert. However, even with an expert the limited resolution or efficiency of room temperature spectroscopy systems may be insufficient to accurately identify an isotope and higher resolution, liquid nitrogen cooled detectors would need to be used (\$30,000+)

[click]

I've summarized the description and some EXAMPLE units on this slide. Don't try to read this eye-chart, it is there to to complete your hand out.



First Responder Training Objectives

- **Keep the messages simple!** Focus on what you want them to remember a year later.
- At the awareness level this should be;
 - Medical emergencies take precedent over radiological monitoring,
 - Used correctly, their instruments and protocols ensure their safety, and
 - The difference between contamination and radiation.

The overall objective when training first responders is to increase their confidence and lower their anxiety about effective radiological emergency response

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Narrative:

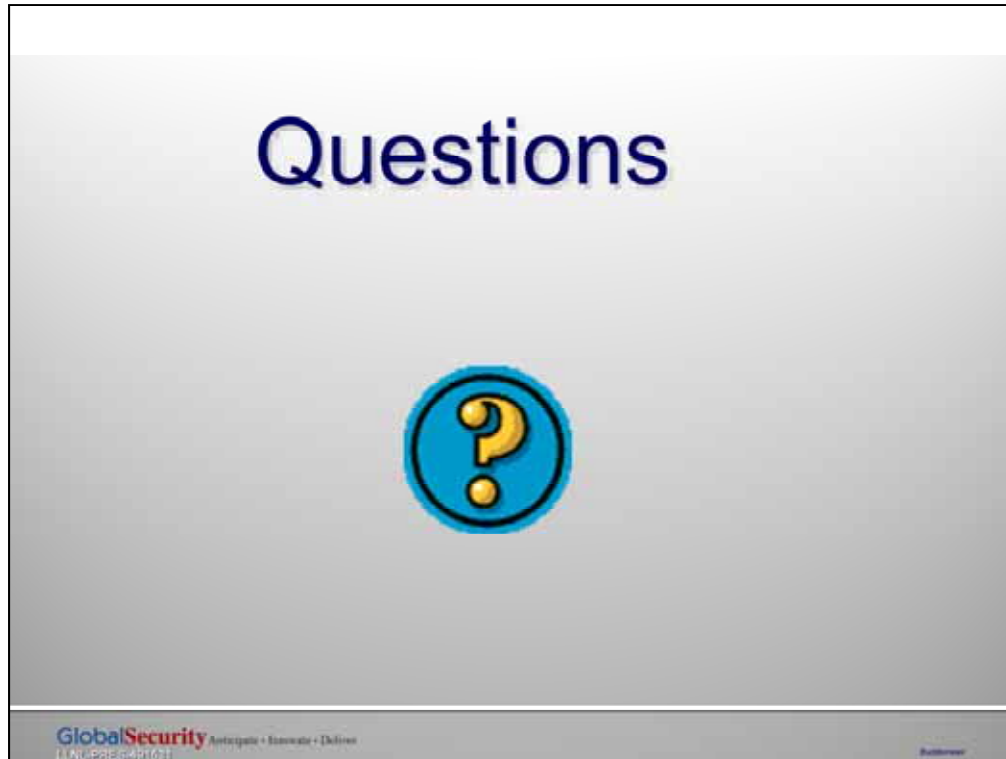
When training first responders in radiological safety, it's important to clearly understand your objectives.

Lets face it, most first responders will never have to use the information you are providing them... and they know it. You can't expect them to retain the details of radiation science, but you can let them walk away with several impressions that will serve them well if they ever do have to respond to a radiological emergency.

Unfortunately most untrained responders see the radiation symbol and stop dead in their tracks or tend to over-respond.

Often what is needed at the awareness level is to improve their understanding about radiation and their instrumentation. Through this understanding will come the confidence to effectively respond to a radiological emergency. The responder should walk away with

- Medical emergencies take precedent over radiological monitoring,
- Used correctly, your instruments and protocols ensure responder safety, and
- They should understand the difference between contamination and radiation.



Exposure & Contamination

Penetrating Radiation Exposure
PPE does not protect against this

Internal Contamination
PPE protects against this



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BioWatch

References

- National and International regulations, recommendations, and guides evaluated:
 - OSHA Regulations
 - DHS Protective Action Guides for Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND)," Federal Register, Vol. 71, No. 1, Notices, January 3 (2006)
 - "Handbook for Responding to a Radiological Dispersal Device – First Responder's Guide – The First 12 Hours," Conference of Radiation Control Program Directors, September (2006).
 - U.S. Federal Emergency Management Agency, "Contamination Monitoring Guidance for Portable Instruments Used for Radiological Emergency Response to Nuclear Power Plant Accidents," FEMA-REP-22, Washington, DC (2002).
 - International Atomic Energy Agency, "Development of an Extended Framework for Emergency Response Criteria," TECDOC-1432 (2005).
 - National Council on Radiation Protection and Measurements, "NCRP Commentary No. 19: Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism," Bethesda, Maryland, December (2005).
 - Other professional society and research recommendations.

References

The devices pictured and web pages referenced in this presentation were chosen as examples and in no way represent an endorsement of any manufacturer or product.

Compendium of Weapons of Mass Destruction Training produced by the federal government" [online]. Available at <http://www.fema.gov/compendium/index.jsp>

The Department of Energy, Transportation Emergency Preparedness Program (TEPP) [information available online] <http://www.em.doe.gov/otem/program.html>

A Practical Guide To Incident Response, ARSCE 2002; WPM-A.4 James G. Barnes, CHP Rocketdyne/Boeing

The Department of Energy's "Partners in Emergency Response" Publication. [information available online] <http://www.doeal.gov/opa/Freedom.htm>

The Department of Energy, Emergency Operations Training Academy (EOTA), Computer Based Training (CBT) for the response to Weapons of Mass Destruction CDs can be copied and have been distributed to each state's FEMA representative who can be found at www.fema.gov/contacts/contacts.cfm or by contacting DOE's Emergency Operation Training Academy at www.eota.doe.gov or call (505) 845-5170 ext.172

Equipment Supplement: Radiation Detection Equipment for the PRND Mission



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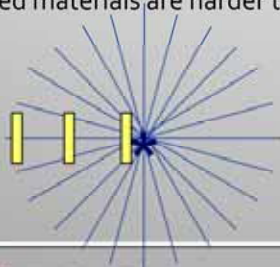
Need to Add some window dressing, pics of instrumentation and operators...

Detecting Weak Sources of Radiation

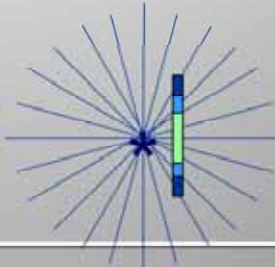
Time, Distance, and Shielding also apply to the probability of detection, though the principal is reversed

- **Maximize the time** the detection equipment is close to the source to increase the probability of detection.
- **Minimize the distance** between the detector and a suspected source of radiation to increase the probability of detection.
- **Reduce shielding** between the detector and the source. Remember, shielded materials are harder to detect.

**Effect of
Detector
Distance
from
Source;
 $1/r^2$ drop**



**Effect of
Detector
Size**



Human Portable Detection Equipment

Human-portable equipment is carried easily by a single person. This category include:

- **Personal Radiation Detectors (PRD)**
- **Backpack detectors**
- **Radioisotope Identification Devices (RIID)**
- **Advanced Radioisotope Identification Devices (ARIID)**

Equipment Selection Issues

- **Targeted Material** – determines the kind of radiation detection equipment needed (gamma or gamma and neutron)
- **Operation Type**
 - **Static operation** - stays in place, detecting objects as they approach the vicinity (at choke points or fixed sites)
 - **Mobile operation** – can be conducted in different places (sweeps), *Covert vs. Overt*
- **Source Identification**
 - Detect radiation only
 - Detect and identify radioisotopes
- **Detection Period**
 - **Constant** – operation which is conducted continuously
 - **Intermittent** – operation conducted at certain intervals
 - **Event specific** – detection conducted at significant events

When selecting equipment one should consider the following issues

Targeted material – improvised nuclear device, radiological dispersal device, radiation exposure device

Static operation example – screening of commercial vehicles at a highway weigh station

Constant operation example – screening cargo crossing a border into the United States

Intermittent operation example – screening commercial vehicles on given days, but not on a constant basis

Event specific operation example – at political party conventions, Super Bowl

TYPES OF PRND EQUIPMENT

(USE OF PRODUCT IMAGES DOES NOT INDICATE AN ENDORSEMENT)

Personal Radiation Detectors (PRDs)

Description:

Often called "Radiation Pagers," and similar in appearance to the electronic dosimeters, these units have the function of finding low levels of radiation using very sensitive crystal or plastic scintillators. Although good for finding contraband radioactive material, these units do not have the range necessary for personnel protection (i.e., high dose rates) or distant detection.

Application:

Well suited for law enforcement or inspectors, these devices can alert the wearer to any unusual radiation in their proximity. These devices are best used when there is an opportunity for a measured response, as most alerts will occur from legitimate commercial, medical, or natural radioactive material. Training and protocols need to be provided to properly resolve any alarms.



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LAW ENFORCEMENT

Bullseye

In summary

Well suited for law enforcement or inspectors, these devices can alert the wearer to any unusual radiation in their proximity. These devices are best used when there is an opportunity for a measured response, Training must be provided to ensure that the user realizes that the alarms do not necessarily indicate a hazardous situation. As in all of these cases, additional victim casualties could result from ill trained responders who leave the scene because of the proximity alarms. Training must also be provided on how to resolve the many alarms that will occur from legitimate radioactive material uses.







Personal Radiation Detectors (PRDs)

Pros

- Very sensitive. Alerts the user of any significant changes to the natural background radiation levels.
- Useful for finding contraband radioactive material
- Good battery life
- Small Size

Cons

- Will alarm in the presence of legitimate commercial, medical, or naturally occurring sources of radiation.
- Does not accurately measure (or work in) high dose rates, due to signal overload, which would be of concern to emergency responders performing rescue operations.
- Won't detect alpha or low energy beta contamination (other than by any associated exposure field)
- Relatively Expensive (\$800 – \$2,000)

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Although it looks similar to a electronic dosimeter, there is a very different kind of detector out there which I call “Personnel Radiation Proximity Alert Systems.”

The Pros

- Very sensitive. Alerts the user of any statistically significant changes to the natural background radiation levels.
- Useful for finding contraband radioactive material.
- Good battery life (often weeks of continuous operation)
- Small Size (pager or notebook sized)
- Simple operation (requires no user action, simply wear the unit)

[Click Display Cons]

•Cons

- Will alarm in the presence of legitimate commercial, medical, or naturally occurring sources of radiation.
- Does not accurately measure (or work in) high dose rates which would be of concern to emergency responders performing rescue operations.
- Won't detect alpha or low energy beta contamination (other than by associated dose fields)
- Expensive (\$800 – \$2,000)

- examples



mini rad-D
Personal
Radiation
Detector

Personal Radiation Detectors - examples (cont'd)

UltraRadiac MRAD-TRN, Ludlum PRM



Polimaster 1401GNA/GNB



This does not
represent an
endorsement

Polimaster 1703 GN/GNA/GNB



BNC 1703 MO-1











Polimaster 1401MA



Personal Radiation Detectors -

examples (cont'd)
some newer models have radioisotope identification capabilities

Thermo Scientific RadEye 	RAE Neutron ROE 	Thermo Scientific Interceptor 
Flir Raider 	BNC 915 PalmRAD II 	STE Radiation Pager 5 
		Polimaster 1704 GN 


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1704 is spectroscopic PRD like Thermo Scientific Interceptor above

Flir bought ICx, the manufacturer of IndetiFinder and other detection instruments. ICx products had several sellers in US like Laurus (100% women owned company), Thermo Scientific.

What are the limitations of the spectroscopic PRD's versus hand-held RRID? – In general PRDs are smaller in size, so smaller detectors, less sensitive than hand-helds. PRDs screens usually are smaller, so details in the graphical spectrum are less clear.

PRDs Specifications



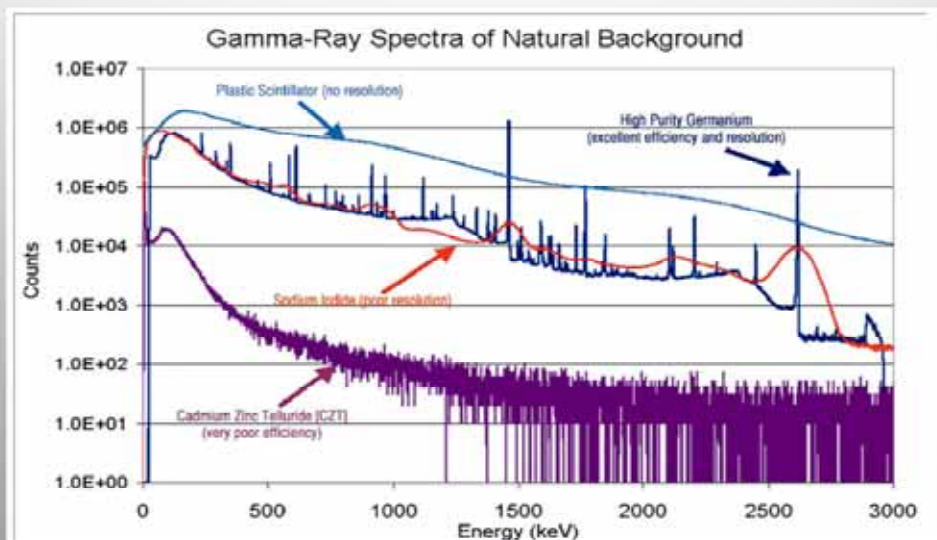
	Thermo RadEye	Polimaster 1703 GNB	STE Radiation Pager	Thermo Sci. Interceptor	Ludlum Personal R.M.
Gamma Det'n	Yes	Yes	Yes	Yes	Yes
Neutron Det'n	Opt	Yes	No	Yes (He-3)	No
Weight (oz)	5.6	8.5	6.0	13.8	5.1
LxWxH (in)	1.25x2.4x3.78	3.38x1.25x2.88	4.1x0.9x2.4	4.4x2.4x1	3.0x0.69x5.4
Temp. (deg. F)	-22 to 141	-22 to 122	-13 to 122	-4 to 122	-40 to 150
I.D. Capability	Yes (NBR)	Yes	No	Yes	No
Battery Type	AAA	AA	AA	Li-Ion	Li-Ion
Detector Type	NaI(Tl)	CsI(Tl)	1/2x1 1/2 CsI(Tl)	CZT	E comp GM
Sensitivity	1.5 cps / μ R/h (17 cps/mR/hr)	1 cps / uR/hr	Not advert.	1.5 cps / uR/hr	0.0003 cps/uR/hr
Range	1uR/hr - 25 mR/hr	0 - 7 mR/hr	X - 3.8 mR/hr		0.1 - mR/hr - 1000 R/hr

PRDs are advertised as being 5000 to 100000 more sensitive than electronic dosimeters

While dosimeters' range 1 million times higher than most PRDs'

PagerS up to ~12 mR/hr

Quick detector resolution comparison



Quick detector resolution comparison

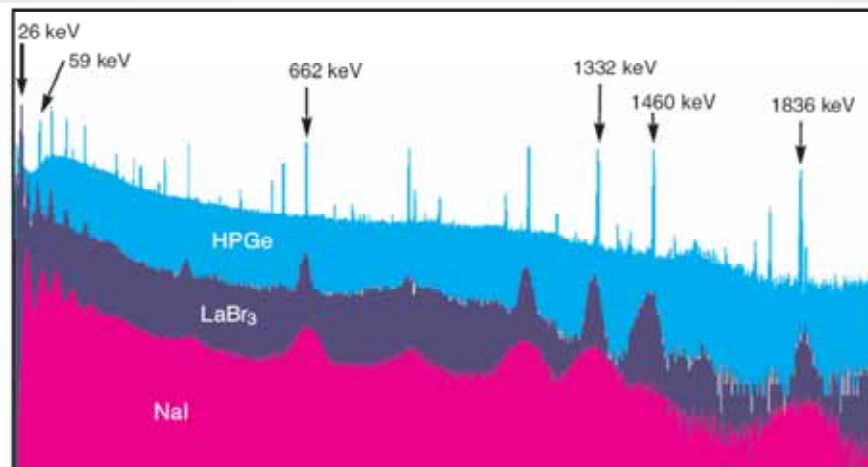


Figure 1. Comparison for LaBr₃(Ce), NaI(Tl), and HPGe spectra.

Quick detector resolution comparison

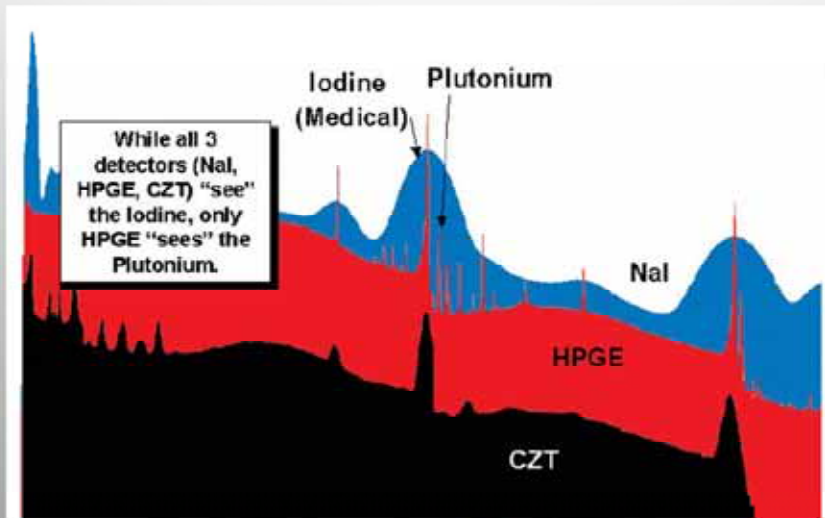





Figure 2. HPGe in comparison to NaI and CZT detectors.

High Resolution Detection Systems for Interdiction of Nuclear Material Trafficking
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U.S. Department of Homeland Security

Bullseye

Backpacks (larger, typically more sensitive devices carried in a

Description:	<p>Backpack radiation detectors are designed for operators who need to quickly detect and locate a radiation threat in an unpredictable radiation background. The unit's detectors and associated electronics are hidden inside a backpack (or vest), allowing the operator to inconspicuously search public areas. They can incorporate larger gamma (plastic, NaI, CsI, LaBr) and neutron (^3H, ^6Li glass) detectors and even can have radioisotope identification capabilities. Some models are equipped with GPS and can communicate and transmit data to a command center.</p>	
Application:	<p>Backpack radiation detector systems provide portable, mobile detection and identification of radioactive material. These are ideal for use in large event venues such as political conventions, Super Bowl football and sporting events. Useful for emergency response, law enforcement, border security, non-proliferation enforcement, environmental waste monitoring, radiation safety. Can be used also for search and recovery of radioactive material. Configurations with radioisotope identification capabilities and GPS require more experienced users or well trained and practiced responders.</p>	
		

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Detectors can be NaI, CsI or LaBr or other exotic scintillators.

Backpacks, Pros & Cons

Pros

- Can incorporate larger and multiple detectors. Various sizes, sensors and configurations can be accommodated
- Very sensitive. Alerts the user of any significant changes to the natural background radiation levels.
- Useful for clandestine monitoring of radiation levels.

Cons

- Requires one person to carry only one unit.
- Suitable mostly for outdoor applications; indoors use is suspicious
- More sensitive units are bulkier and heavier
- Expensive (\$10,000 - \$20,000)
- Won't detect alpha or low energy beta



Backpacks - examples

Thermo Scientific Packeye Backpack



BNC RD-100



Nucsafe backpack/vest



Nucsafe backpack




Radio-Isotope Identification Devices (RIIDs)

Description:

These expensive and sophisticated units use the different gamma ray “signatures” given off by the radioactive material to identify the originating isotope(s). Proper identification of the isotope is important for determining the appropriate response actions. Although the analysis being performed is complicated, these units offer a simple interface to help non technical users make a measurement. Many of the units have modes of operations similar to the proximity alert and electronic dosimeters.

Application:

Best suited for experienced users or well trained and practiced responders, these units will help identify the radioactive material involved at a scene or in contraband. Good for follow-on radiological emergency response teams or inspectors.



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1-800-895-6100

In Summary,

Their cost prohibits them from being in every first responder’s back pocket, but they can be a valuable tool in the hands of a well trained regional responder.

Although most units have been ruggedized, the technology is inherently shock sensitive and the automated analysis is not 100% effective.

Accurate assessment often requires an experienced spectroscopist to assess data. Fortunately, many of the units have the ability to download the spectrum for remote analysis by an expert. However, even with an expert the limited resolution or efficiency of room temperature spectroscopy systems may be insufficient to accurately identify an isotope and higher resolution, mechanically cooled detectors would need to be used (\$80,000+)

[click]

I’ve summarized the description and some EXAMPLE units on this slide. Don’t try to read this eye-chart, it is there to complete your hand out.


Radio-Isotope Identification Devices (RIIDs)

Pros

- Very sensitive. Alerts the user of any significant changes to the natural background radiation levels.
- Useful for finding contraband radioactive material.
- Often tracks dose rates and total dose of user while on.

Cons

- Although fairly good at identifying common isotopes with simple spectra, these units can not identify all possible isotopes of concern and can also mis-identify isotopes.
- Will alarm in the presence of legitimate commercial, medical, or naturally occurring sources of radiation (though the analysis capability can often help resolve this)
- Expensive (\$10,000 - \$20,000)
- Won't detect alpha or low energy beta contamination.
- Requires extensive training or support to use properly



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Commercially available handheld NaI gamma spectroscopy has seen great improvements in the last 5 years. Mostly in the form of better analysis algorithms and easier interfaces.

Pros

- Very sensitive. Alerts the user of any statistically significant changes to the natural background radiation levels.
- Useful for finding contraband radioactive material.
- Often tracks dose rates and total dose of user while on.
- Can identify many common isotopes

[Click to Display Cons]

Cons

Although fairly good at identifying common isotopes with simple spectra, these units can not identify all possible isotopes of concern and can mis-identify isotopes.

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- Expensive (\$10,000 - \$12,000)
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- Requires extensive training or support to use properly

Radio-Isotope Identification Devices (RIIDs) – examples

Canberra InSpector-1000



Smith Detection RadSeeker



XRF ICS-4000



Thermo Scientific
identiFinder-U, identiFinder-2



BNC SAM 935



Some models like Canberra InSpector, IdentiFinder, BNC SAM 935, BNC 940 have options with different detectors: NaI, CsI, LaBr, and other exotic crystals, He-3 tubes for neutrons

Radio-Isotope Identification Devices (RIIDs) - examples (cont'd)

BNC SAM 940



Thermo Scientific FH 40 NBR



Polimaster
PM1401K



Ludlum Model 703
Isotope Identifier



RIIDs Specifications



	identifFinder-U	BNC SAM 940	Polimaster PM1401K	Thermo Sci. FH 40 NBR	Ludlum Model 703
Gamma Det'n	Yes	Yes	Yes	Yes	Yes
Neutron Det'n (optional)	Yes	Yes	Yes	Yes	Yes
Weight (oz)	2.95	4.5	1.5	1.0	4.5
Length (in)	9 x 2.75 x 3.5	12 x 5 x 4	9.5 x 2.2 x 2.2	8 x 1.4 x 2	12 x 5 x 4
Detector	1.4 x 2 NaI	2 x 2 NaI (1.5 x 1.5 LaBr)	CsI(Tl)	NaI + Org. Scint	2 x 2 NaI (3 x 3)
Sensitivity	>10cps per uR/hr		2 cps per uR/hr	28 cps per uR/hr	15 cps per uR/hr (38)
Resolution	≤8%	7% (2.8%)			7%
Temp. (deg. F)	4 to 131	4 to 131	-22 to 122	4 to 122	4 to 131
Battery Type	AA	AA	AA	AA	NiMH AA

identifFinder-U

BNC SAM 940

Advanced Radio-Isotope Identification Devices (ARIIDs)

Application: Description:

These expensive and sophisticated RIID use mechanically cooled germanium detectors to identify the originating isotope(s). They must be plugged in at times. ARIID produce very high laboratory quality data and analysis. They are also capable of localizing the radiation source and providing dose rate information.


Best suited for experienced users or well trained and practiced responders. Good for follow-on radiological emergency response teams or inspectors.

Pros

- Have superb radioisotope identification capabilities.
- Can have large source signature databases and can be used in the field or in the lab.

Cons

- Expensive (\$75,000 - \$90,000)
- Heavy for long hand-held operation; more fragile than the rest
- Require extensive training and support to use advantageously



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In Summary,

Their cost/price prohibits them from being in every first responder's back pocket, but they can be a valuable tool in the hands of a well trained regional responder.

Although most units have been ruggedized, the technology is inherently shock sensitive and the automated analysis is not 100% effective.

Accurate assessment often requires an experienced spectroscopist to assess data. Fortunately, many of the units have the ability to download the spectrum for remote analysis by an expert. ~~However, even with an expert the limited resolution or efficiency of room temperature spectroscopy systems may be insufficient to accurately identify an isotope and higher resolution, mechanically-cooled detectors would need to be used (\$80,000+)~~

Advanced Radio-Isotope Identification Devices (ARIIDs) - examples

ORTEC Detective



ORTEC Micro-Detective-HX



CANBERRA Falcon 5000



ORTEC Micro-Detective







ARIIDs Specifications



	ORTEC Detective	ORTEC micro-Detective	CANBERRA Falcon 5000	ORTEC micro-Detective-HX
Detectors	HPGe (γ), GM, optional He-3 (n)	HPGe (γ), GM, optional He-3 (n)	HPGe (γ), GM, optional He-3 (n)	HPGe (γ), GM, optional He-3 (n)
Weight (oz)	26.3	15.2	34.1 (with 2 batteries)	15.2
Length (in)	15.5 x 7 x 14	14.7 x 6 x 11	17 x 7 x 17	14.7 x 5.8 x 11
Temp. (°F)	32 - 104	14 - 104	(- 4) - 122	14 - 104
Time to cool	< 12 hours	< 12 hours	3- 4 hours	< 12 hours
Battery life	>3 hours	3 hours	8 hours	3 hours

Mobile devices (mounted on a vehicle)

Description:	<p>Mobile detection equipment are vehicle-mounted detection systems which contain the largest detectors and are therefore the most sensitive. They can consist of multiple detectors, both gamma and neutron. Most of these systems are capable of both detection and radioisotope identification. They usually display alarms and analysis on laptops which interface with the detection system. Some are equipped with additional features as data transmission, GPS, image camera.</p>	<p>This does not represent an endorsement</p> 
Application:	<p>Vehicle-mounted detectors are generally used for operations that need to cover large areas quickly. They are adaptable for clandestine monitoring and searching for radiation sources. Vehicle driving speed must be within the capabilities of the detection system.</p>	

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These are usually built to meet the requirements of the customer and can have various configurations. They can have large and multiple detectors with high overall sensitivity, gamma and neutron detectors, often radioisotope identification capabilities, GPS positioning and data transmission capabilities. All kinds of detectors are possible – NaI, LaBr, HPGe, He-3, plastic scintillators, gas filled detectors (GM), etc.

Mobile devices

Pros

- Very sensitive; can incorporate large and multiple detectors
- Useful for covering large areas.
- Can be tailored towards specific requirements.
- Often have additional capabilities – radioisotope identification, GPS, data transmission, computer analysis, take images
- Can be used for clandestine monitoring of radiation levels.

Cons

- Can be very expensive (\$15,000 -50,000 or more)
- Won't detect alpha or beta contamination (sources)
- Requires training.

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represent an
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Mobile devices - examples

Thermo Scientific Mobile ARIS



TSA MDS134A



Mirion SPIR-Ident-mobile






BNC Textron IST RadTruck




SAIC Exploranium GR-460



Portal monitors

Description:	Radiation portal monitors are stand-alone units designed to automatically scan pedestrian, vehicle or rail traffic. The system comprises two or more detector panels that detect gamma-ray and often neutron radiation. All of the essential components are contained in the panels: radiation detectors, electronics, controller, and occupancy detector. Their gamma detectors are usually plastic but NaI and mechanically cooled HPGe detectors may be used for radioisotope identification.	  
Application:	The portal monitors may be designed and configured for overt or inconspicuous monitoring of traffic. They can be used at the entrance or exit of many different sites: Nuclear Power Plants, research centres, scrap & steel industries, waste disposals & waste incinerators, hospitals, border crossing points. These systems are often placed on both sides of a monitored lane, allowing the vehicle/object to pass through. Simpler units produce just an alarm, while more sophisticated systems can discriminate medical, industrial and natural radioactive sources and transmit the data to a command or monitoring center for further analysis.	

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There is a wide variety of portal monitors: pedestrian, vehicle, rail, cargo containers; large and small, one sided, two sided or multiple sides (left, right, above and even below), simple alarm producing or spectroscopic with radioisotope identification and data transmission capabilities. The more sophisticated the portal monitor is the more experienced personnel is required and more maintenance is generally needed.

Portal monitors

Pros

- Can incorporate large and multiple detectors both for gamma and neutron emitting sources
- Very sensitive
- Most are maintenance free and do not require frequent calibration
- Can be set up for unattended and/or covert operation.
- More sophisticated systems have radioisotope identification capabilities.
- Optional vehicle speed alarm, video monitor, license plate image

Cons

- Simpler, non-spectroscopic systems produce false alarms due to legitimate radioactive material traffic (industrial and medical sources, natural radioactive materials)
- More sophisticated spectroscopic systems are expensive and require experienced or trained personnel
- Could be very expensive (\$50,000 - \$ 500,000)



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Portal monitors - examples

Canberra MiniSentry



Thermo Scientific TPM 903B



Mirion SPIR-Ident-Pedestrian G



Ludlum 52-1-1



Mirion Stride-200



TSA PM700AG-AGN



BNC ARAM



Portal monitors – examples (cont'd)

SAIC/Exploranium ST-20



TSA VM 250 AG/AGN



SAIC/Exploranium SRM 980



Transportable portal monitor



Portal monitors - examples

WF Portal monitor RCVL



Detectors inside a panel



Polimaster 5000A



SAIC/Exploranium AT 980



Polimaster 5000A



Canberra GPS Portal SS



Integrating Detection Equipment into PRND Mission

- **Mission planning:** Appropriate equipment selection
- **Primary Screening:** Detect and locate the presence of radioactive material
- **Secondary Screening**
 - After receiving alarm, identify and distinguish between:
 - False alarms
 - Background radiation alarms
 - Legitimate sources alarms
 - Illicit radiological material alarms
 - Measure approximate radiation level
- **Alarm Adjudication & Resolution**
 - Use radiological material recognition factors and measurement information to assist in assessing the situation

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Initiate organizational protocols to ensure the health and safety of Business

Talk through how this maps to ConOps, mention CTOS for equipment training, DNDO for mission planning, etc. (more to follow from Sean on this topic)

Radiation safety instruments for the safety of personnel

- **Main purpose – provide safety for the user**
 - Measure radiation dose (in mrem or μSv) or dose rate (mrem/hr or $\mu\text{Sv/hr}$)
 - Alarm (often multiple alarms available) if radiation is above certain dose (rate) threshold
 - Usually smaller and less sensitive than PRDs (pagers)
 - No radioisotope identification capabilities
 - Often employs different type detectors – e.g. ion chamber
- **Examples**
 - Dosimeters
 - Dose rate meters

More likely to come into play during secondary screening activities or response to actual release/exposure incident

Personnel Safety: Electronic Dosimeters & Survey Instruments

Siemens MK-2



ALOKA PDM-122



RAE DoseRAE-2



Graetz X5 CEx



Atomtex AT 3509



Canberra Dosecard



EkoTest card



EkoTest DGC-Tera



Innovision 451 P



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1-800-880-0000

BSI/HSR/001

Electronic dosimeters are not designed for search, location or identification of radioactive material, although in some cases they can be used for limited search. Some models allow dose (rate) information to be downloaded. Other models have different levels for several alarms (alarm 1, alarm2, for gamma, for neutron, for dose, for dose rate).


Tools: *Simplified Contamination Survey Instruments*

Pros

- "Open window" GM for alpha and beta contamination.
- Most have Good Sensitivity.
- Digital models can have set alarm levels
- Small Size
- Simple operation
- Rugged, simple technology.

Cons

- Sensitive enough alarm in the presence of legitimate commercial, medical, or naturally occurring sources of radiation.
- Many models can not be used in high dose rates which would be of concern to emergency responders performing rescue operations (>0.1 Sv/hr | >10 R/hr).
- Low accuracy (i.e., uses pancake GM for dose measurement)



Industry Standard Radiation / Contamination Survey instruments are those commonly used by health physicists and radiation control technicians at nuclear power plants, hospitals, and research laboratories. These instruments use a variety of detector technology (GM, Ion chamber, scintillator, proportional counter, etc..) to measure dose rates and contamination. Although well suited for the experienced user, they may not be appropriate for the occasional user like an emergency responder. In order to meet the needs of the occasional, novice user, manufacturers have tried to create sub-genre of instruments that are smaller and easier to use. I have labeled this category *Simplified Contamination Survey Instruments*

Pros

- Most have Good Sensitivity.
- Digital models can have set alarm levels
- "Open window" GM for alpha and beta contamination.
- Small Size (cell phone or notebook sized)
- Simple operation (user action required, but usually only one or two switches)
- Rugged, simple technology.

[Click to show Cons]

Cons

Sensitive enough alarm in the presence of legitimate commercial, medical, or naturally occurring sources of radiation.

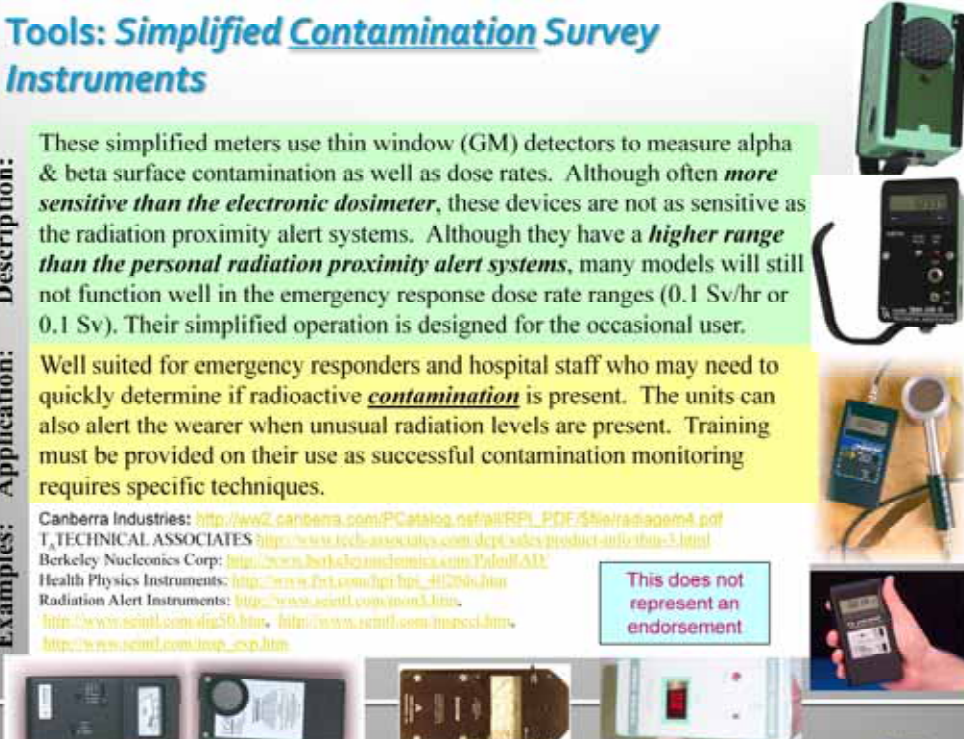
Many models can not be used in high dose rates which would be of concern to emergency responders performing rescue operations (>0.1 Sv/hr | >10 R/hr).

Low accuracy (i.e., uses pancake GM for dose measurement)

Tools: Simplified Contamination Survey Instruments

Description:	These simplified meters use thin window (GM) detectors to measure alpha & beta surface contamination as well as dose rates. Although often <i>more sensitive than the electronic dosimeter</i> , these devices are not as sensitive as the radiation proximity alert systems. Although they have a <i>higher range than the personal radiation proximity alert systems</i> , many models will still not function well in the emergency response dose rate ranges (0.1 Sv/hr or 0.1 Sv). Their simplified operation is designed for the occasional user.
Application:	Well suited for emergency responders and hospital staff who may need to quickly determine if radioactive <u>contamination</u> is present. The units can also alert the wearer when unusual radiation levels are present. Training must be provided on their use as successful contamination monitoring requires specific techniques.
Examples:	<p>Canberra Industries: http://www2.canberra.com/PCatalog.nsf/allRPL_PDF/55e1e1a9e04.pdf</p> <p>T₁ TECHNICAL ASSOCIATES http://www.tech-associates.com/dept/sales/product-info/thin-3.html</p> <p>Berkeley Nuclonics Corp: http://www.berkeley-nuclonics.com/Telnet/AM/</p> <p>Health Physics Instruments: http://www.hpi.com/hpi_hpi_41266.htm</p> <p>Radiation Alert Instruments: http://www.scint.com/mon3.htm, http://www.scint.com/imp3.htm, http://www.scint.com/imp_exp.htm</p>

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In Summary

Smaller, simpler, and often cheaper than commercial equipment, these devices are well suited for the emergency responders. There is a large variety of capabilities in this class of instrument to the appropriate features must be considered for the task and the user. Training must be provided to ensure that the user understands how to interpret readings. Using the instrument to detect contamination will require also require special training.

Typical costs are \$300 - \$600 dollars per unit. For the occasional user, choose the more expensive digital models as they will have alarms and are easier to operate.

[click]

I've summarized the description and some EXAMPLE units on this slide. Don't try to read this eye-chart, it is there to to complete your hand out.