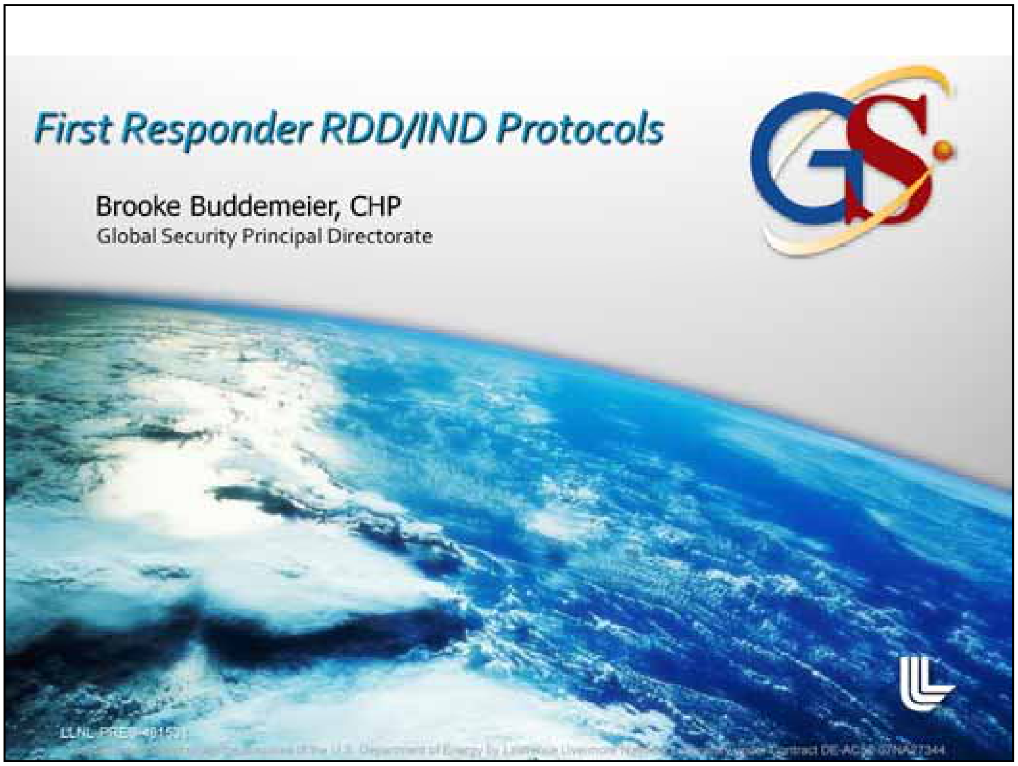
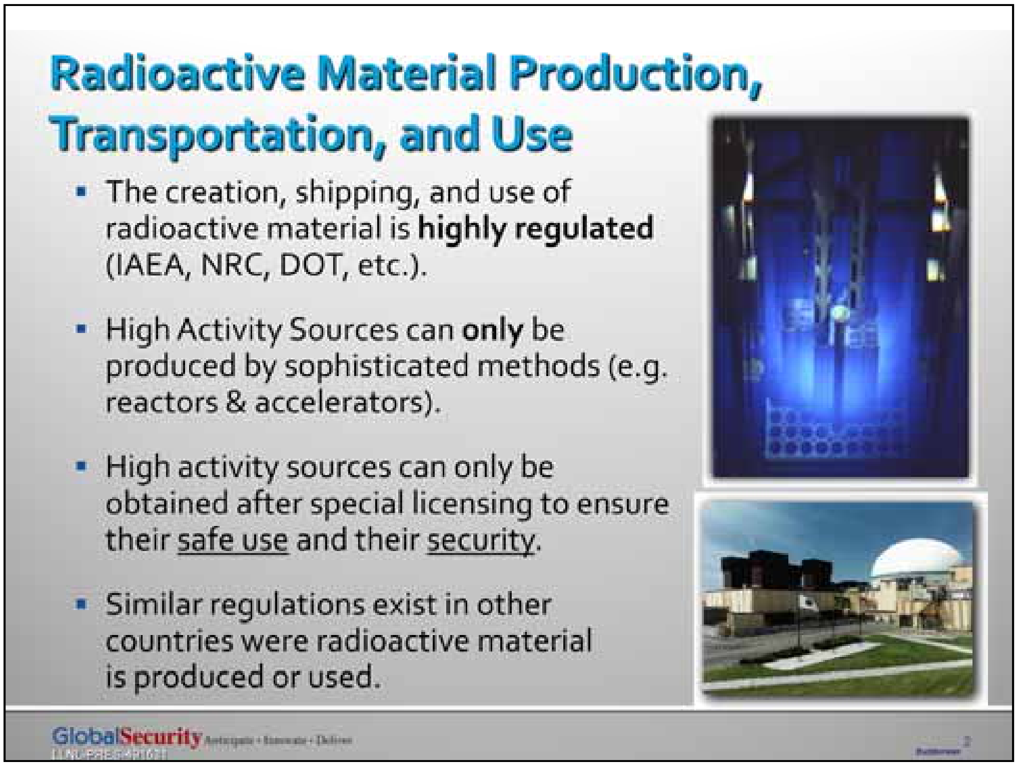


Brooke Buddemeier, CHP
Lawrence Livermore National Laboratory
Nuclear Counterterrorism Program



Emphasize that:

1) High activity sources are difficult to obtain

2) Once obtained, measures are taken to ensure the <u>safety</u> and <u>security</u> 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.

•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.
Irridium-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

GlobalSecurity Source: http://emergency.cdc.gov/radiation/

Narrative

Here are some examples of radioactive isotopes commonly used in industry.

{Read slide it time permits}

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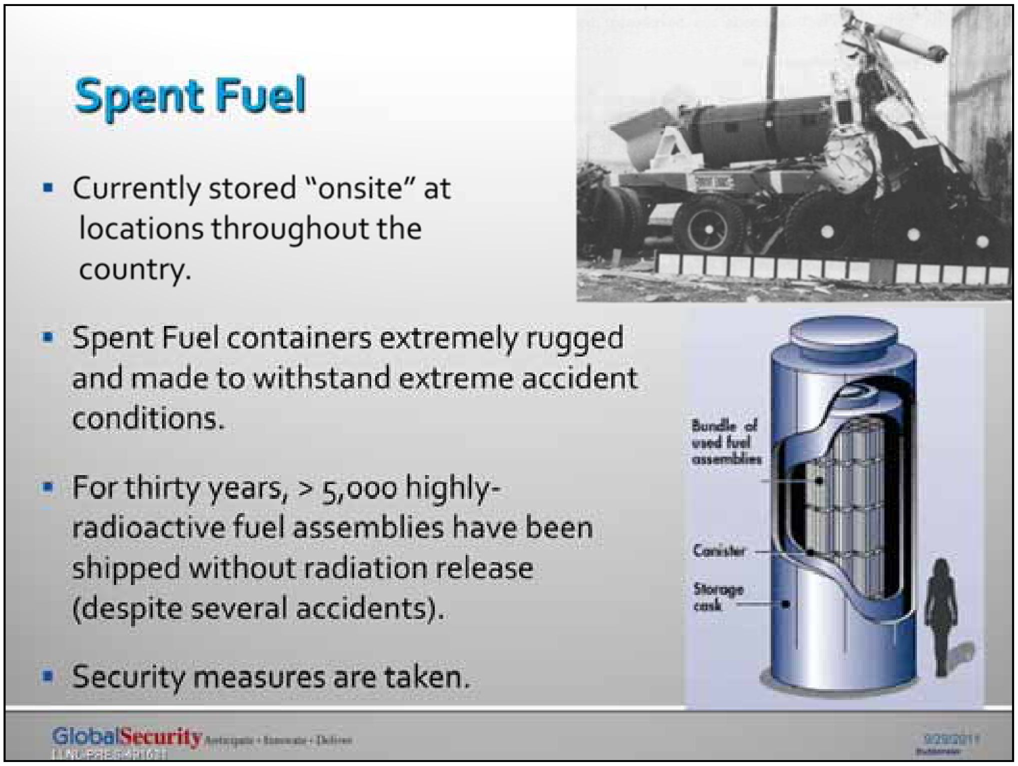
note: this slide can be removed for an overview

*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.



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***

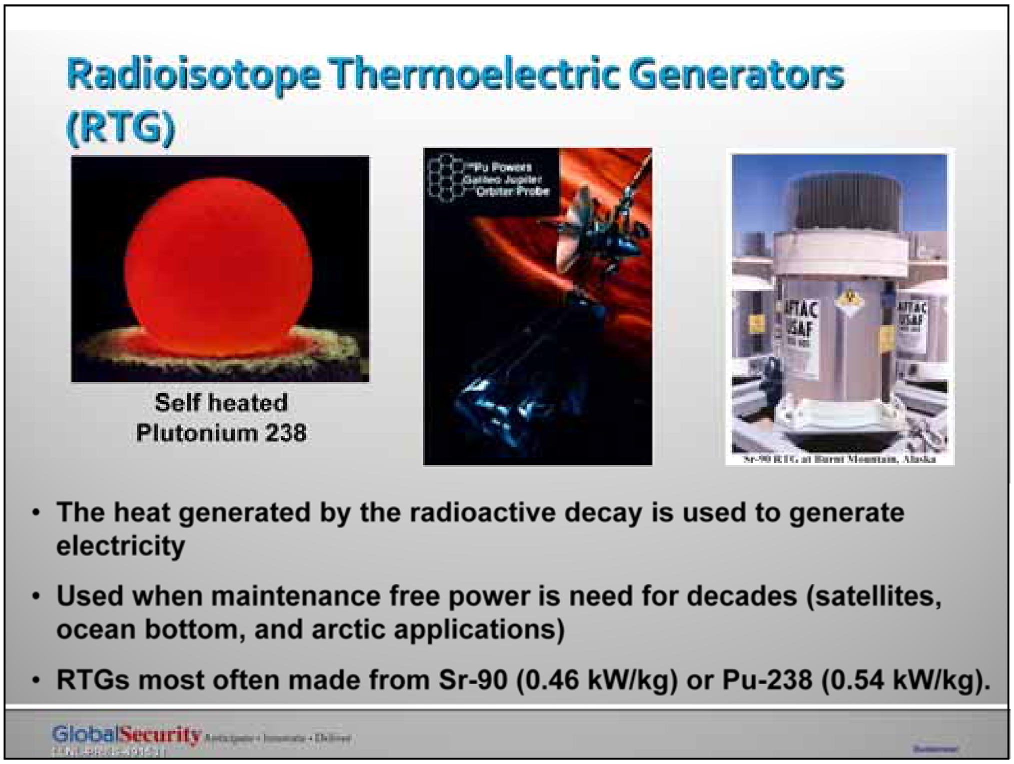
Safety in the shipment of nuclear material is achieved by a combination of factors, including the physical properties of the nuclear material itself, the ruggedness of the container, and the operating procedures applicable to both the transportation package and the vehicle transporting the package.

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.



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 Ð 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

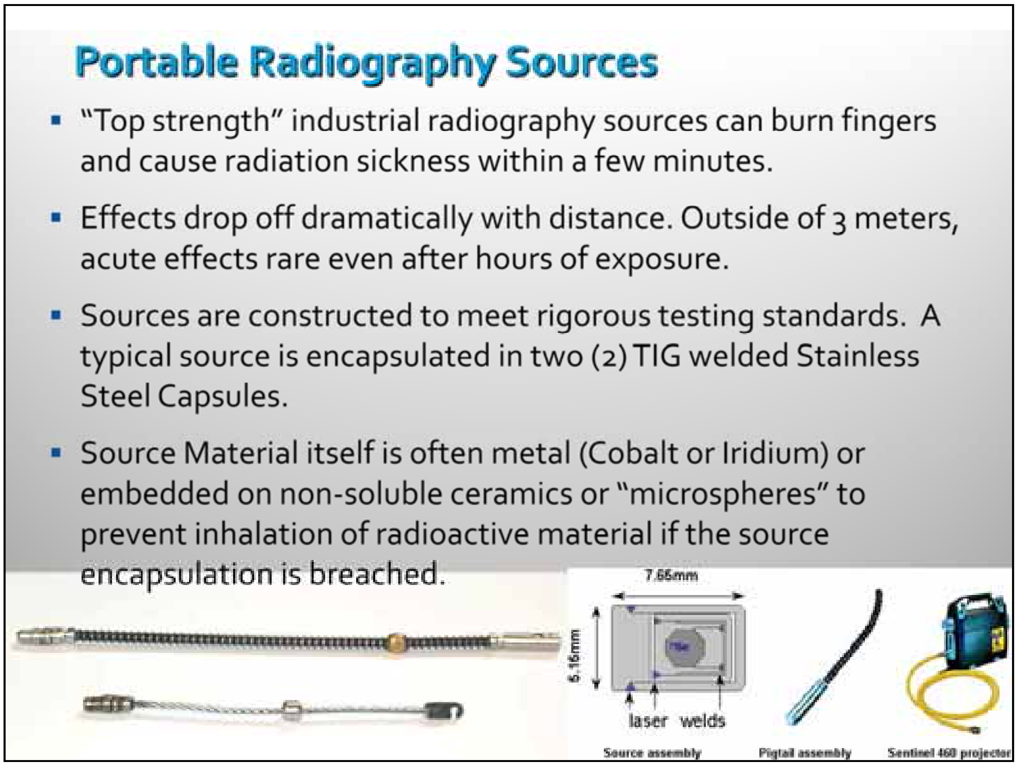
Sr-90 is a beta emitter with a 28.1 year half life. A pure sample will supply 0.46 kilowatts/kilogram of thermal power when new, or about 15 percent less than a similar mass of Pu-238. Additionally, an Sr-90 based RTG will deteriorate about three times as fast as one based on Pu-238; a 20 year old power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



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

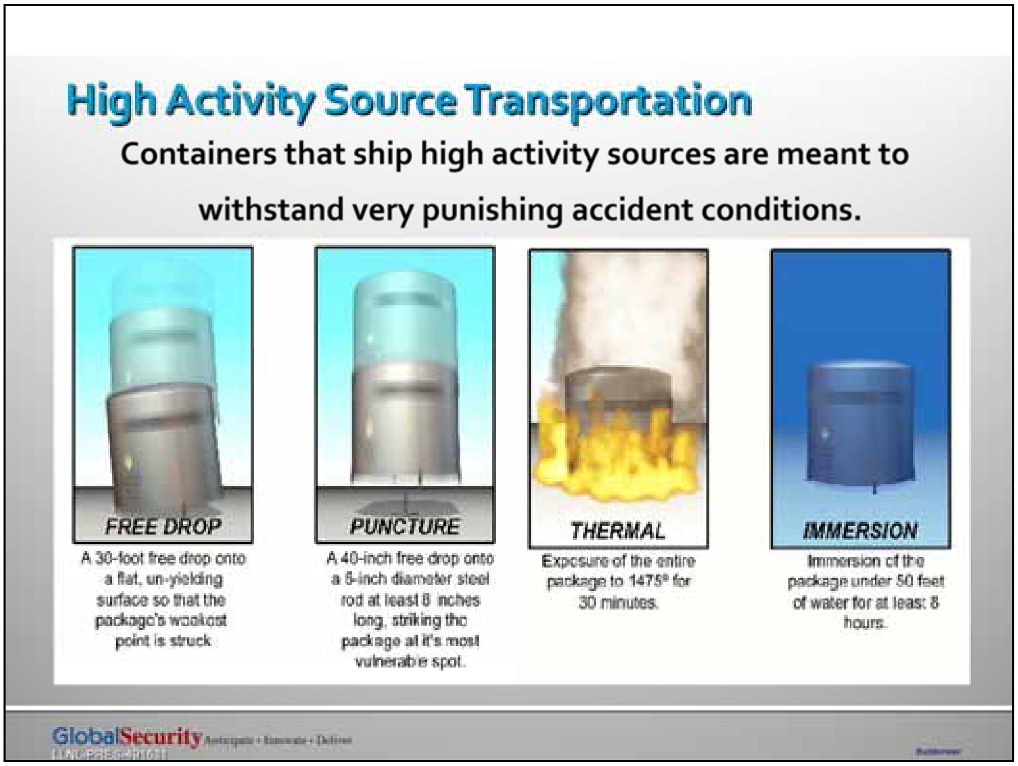
Therefore: 13,200 R/hr **(200 R/min**) @ 1m per 10,000 Ci

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

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.



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.

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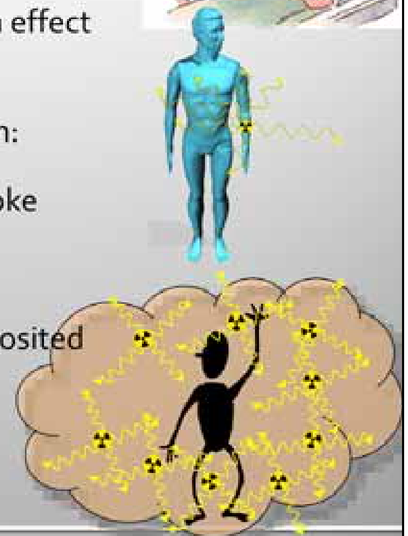
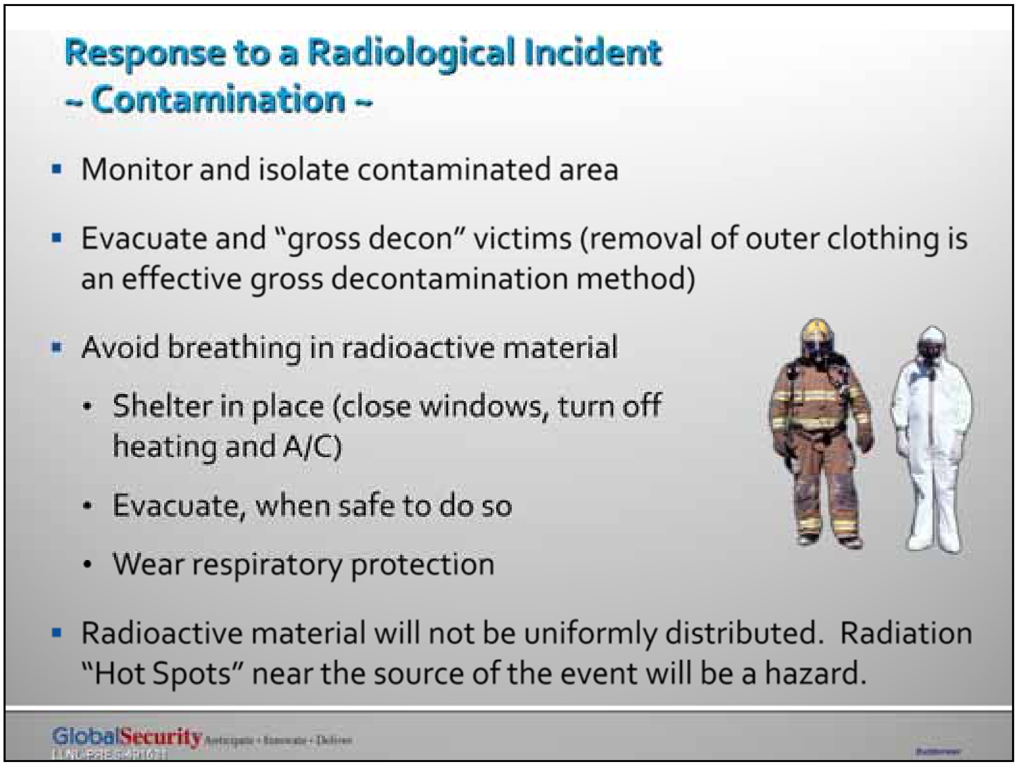
External Exposures

- Focused radiation or localized contamination can result in radiation effect to specific areas on the body
- Whole body exposure can result from:
  - A passing radioactive cloud or smoke
  - A large, distant point source
  - Exposure from contamination deposited on the ground



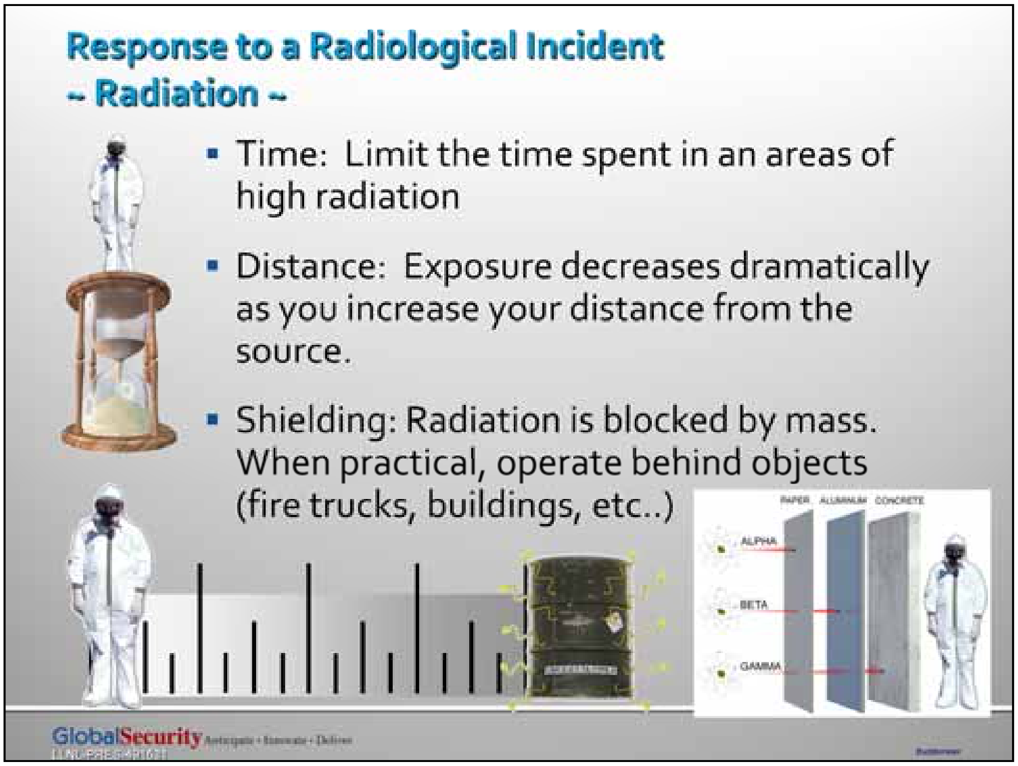
Internal Exposures

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



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 exposure responders that stay in the area.



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These sources can actually be more dangerous as their external dose rates could over expose responders that stay in the area.

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.

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.

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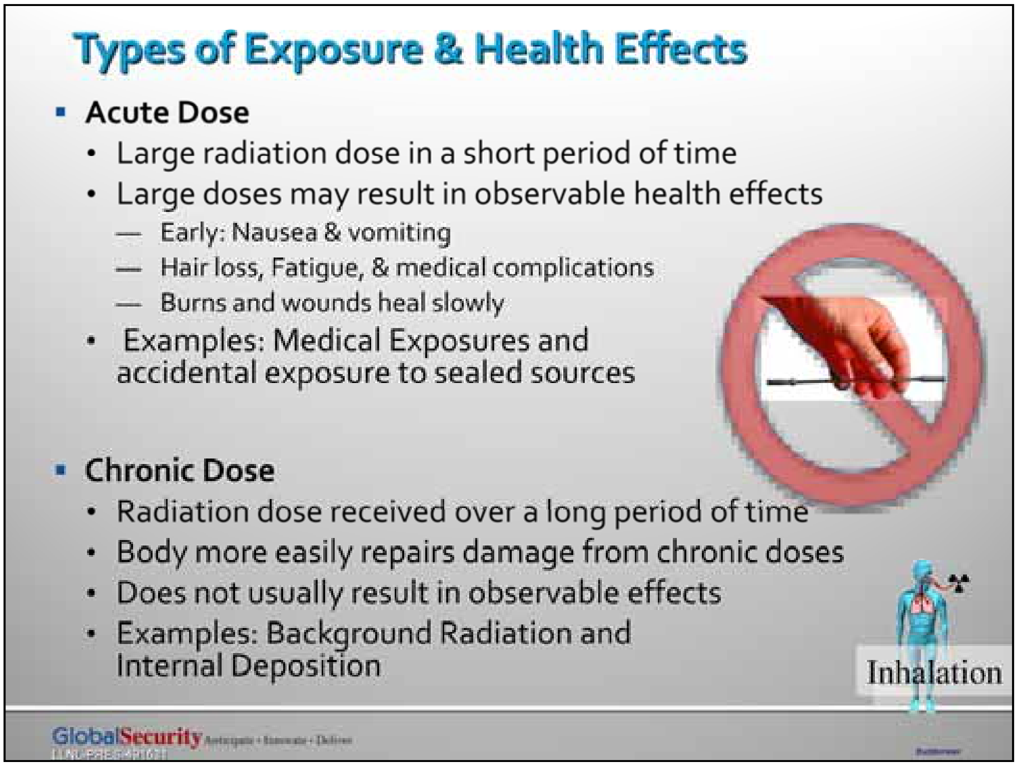


These slides were included in case the "BB1 Understanding Radiation" was not presented prior to these slides.

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.

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 one 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

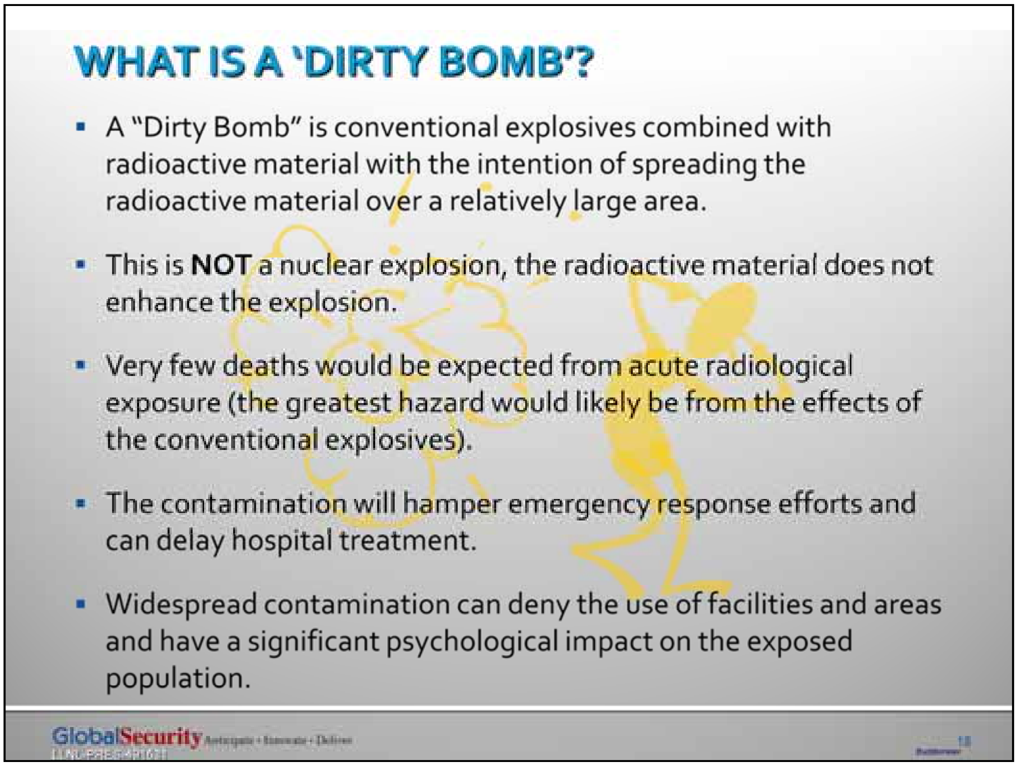
•Radiation Exposure unlikely to produce health effects, but..

•Contamination will greatly complicate emergency response effort.

*** Like above, commercial high activity sources may not easily be distributed, even with an explosion.**

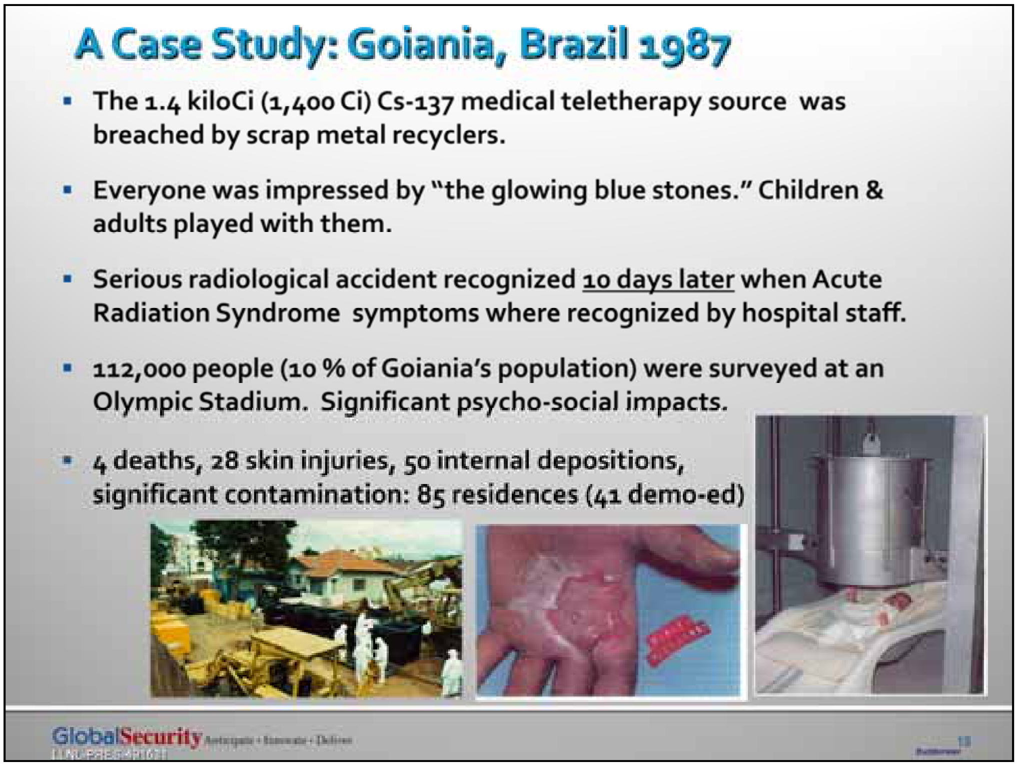
*** Source easily found once threat is known**

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



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



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 session 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.

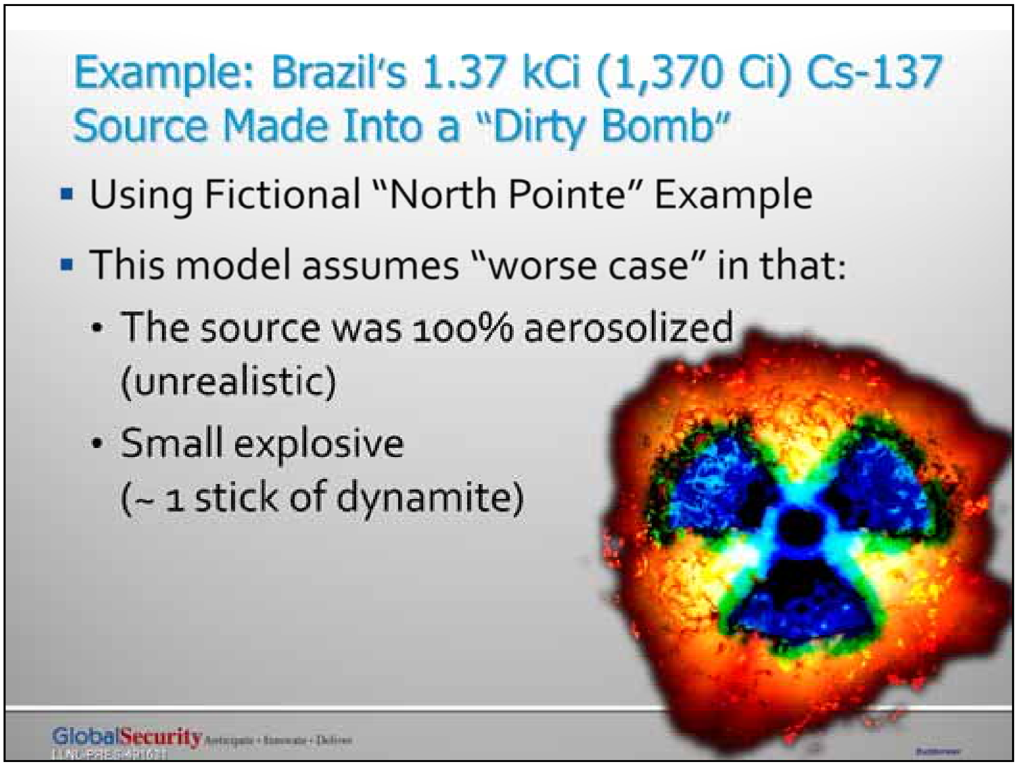
Some of them scrubbed the material on the skin in order to appreciate its brightness

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

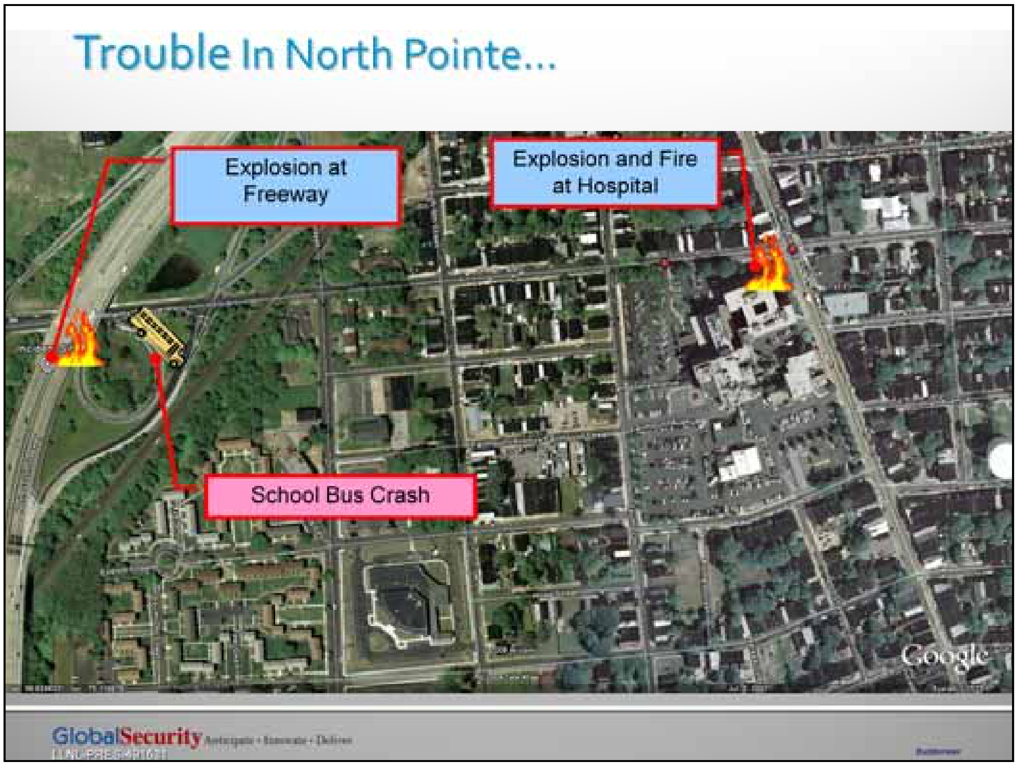
Pieces of the source were put in a bag that she took along with her by bus to the hospital

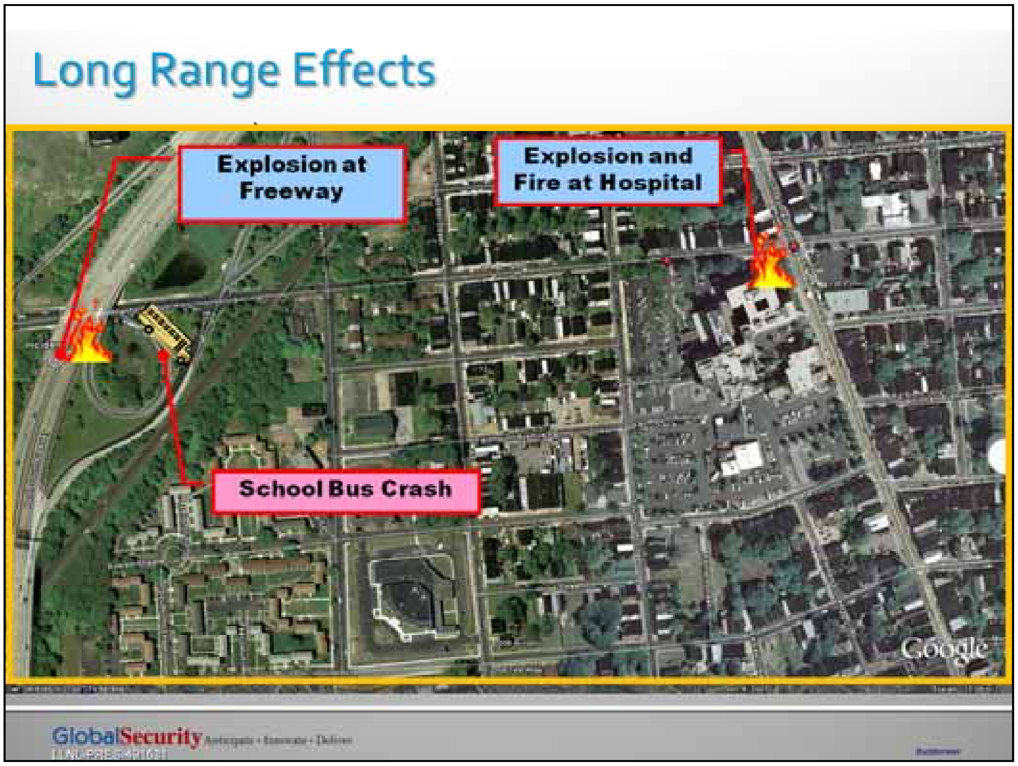
On September 29, the Brazilian Nuclear Energy Commission was notified by a goianian physicist about the occurrence of a serious radiological accident

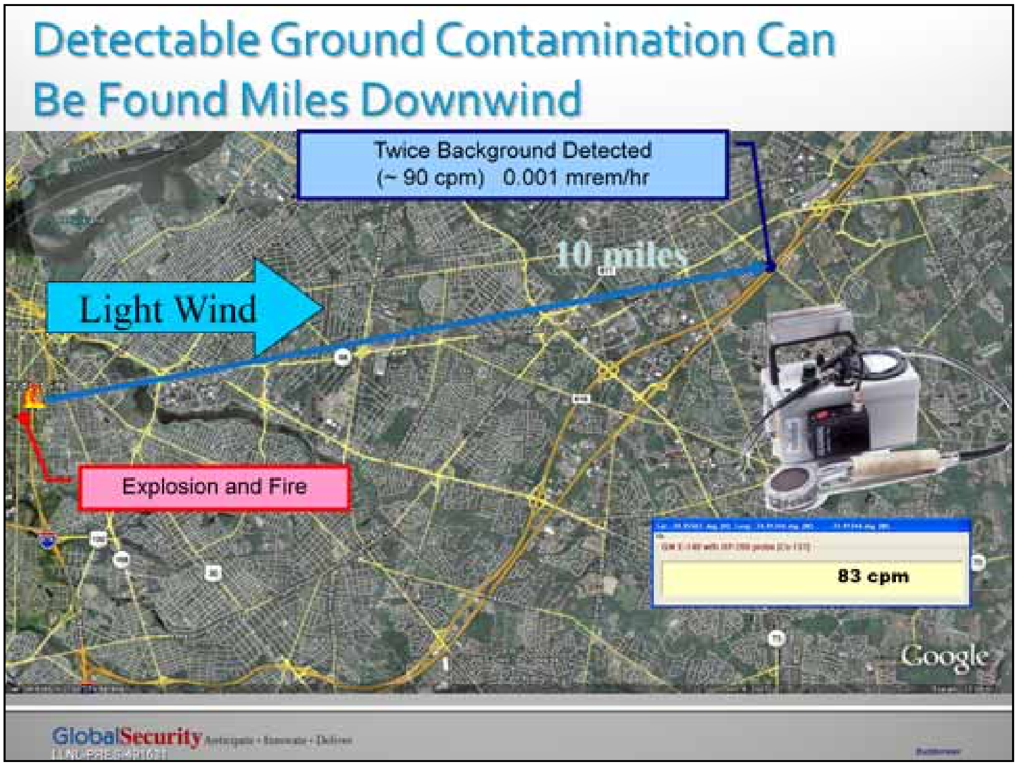


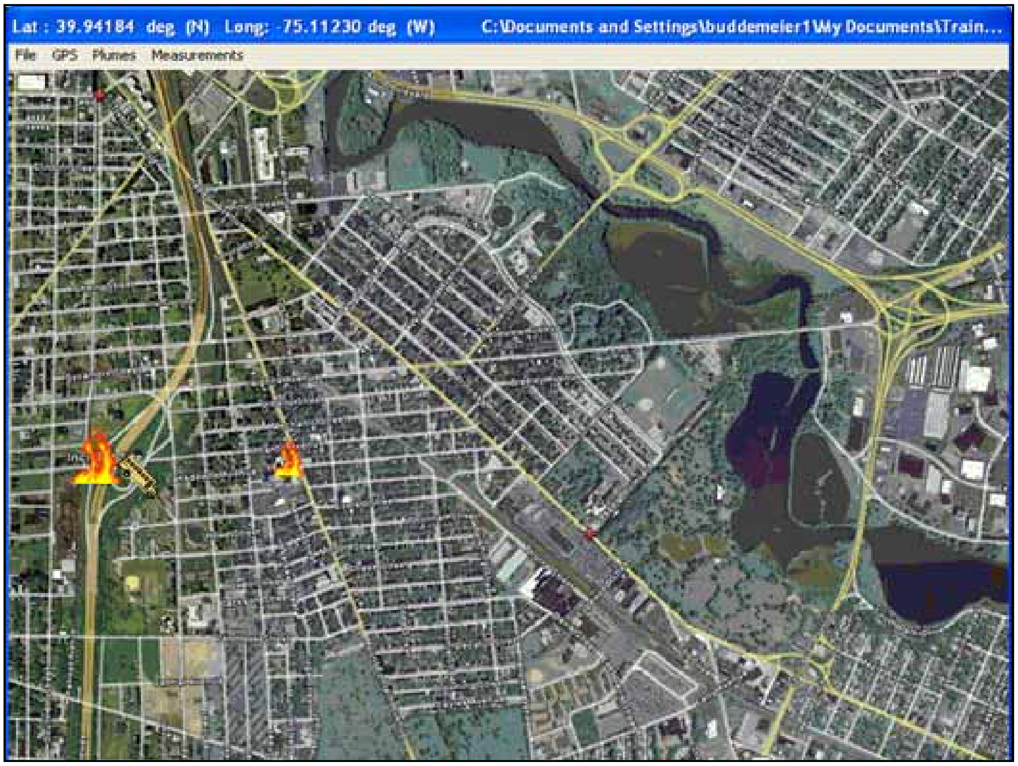
Very unrealistic scenario…. But it's just to provide you with a frame of reference.

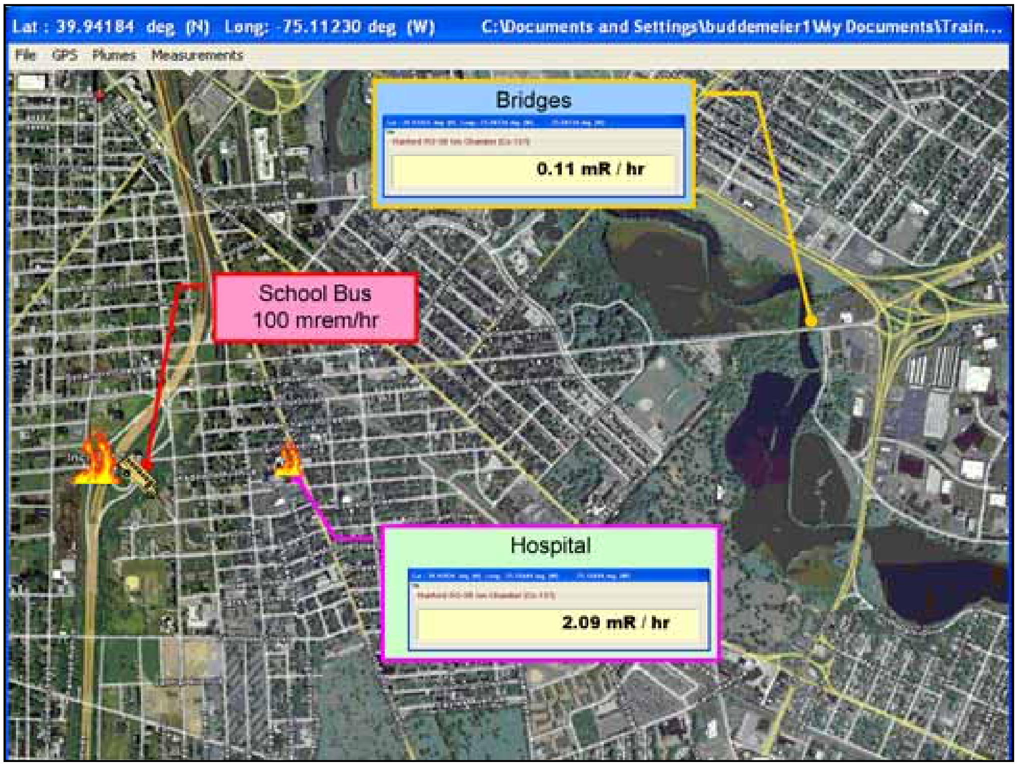
UCRL-PRES-149903; This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

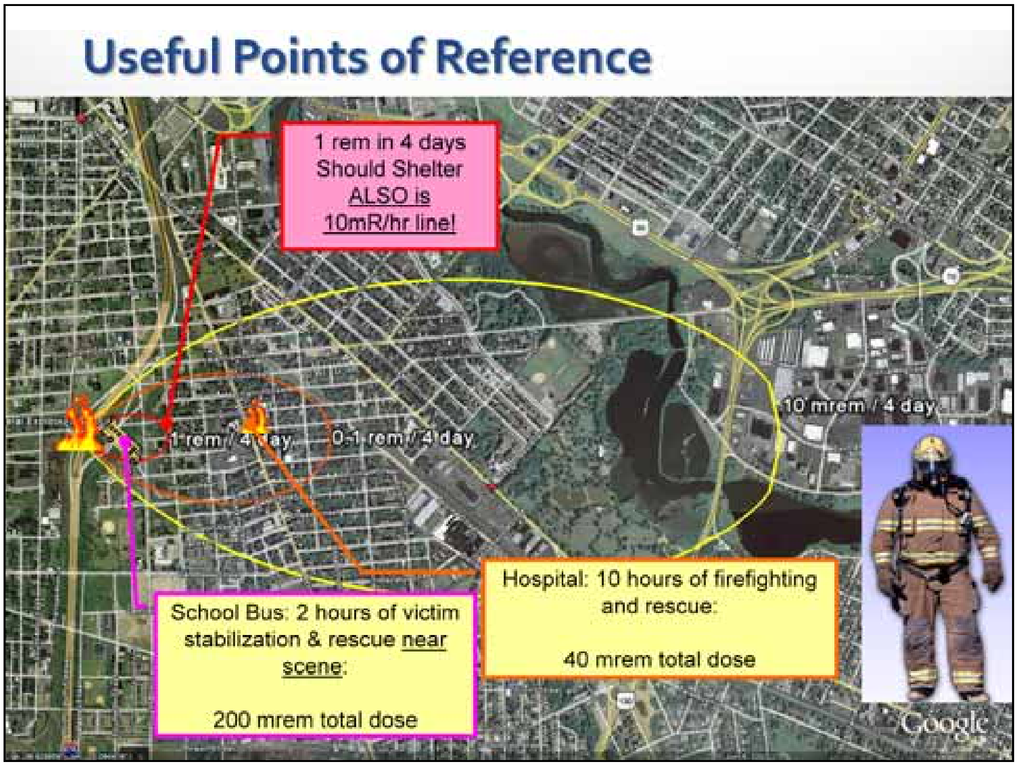

Trouble In North Pointe…
Explosion at Freeway
Explosion and Fire at Hospital
School Bus Crash
Google
GlobalSecurity Anticipate · Innovate · Deliver


Long Range Effects
Explosion at Freeway
Explosion and Fire at Hospital
School Bus Crash
Google
GlobalSecurity Anticipate • Innovate • Deliver


Detectable Ground Contamination Can Be Found Miles Downwind
Twice Background Detected
(~ 90 cpm) 0.001 mrem/hr
10 miles
Light Wind
Explosion and Fire
83 cpm
Google
GlobalSecurity

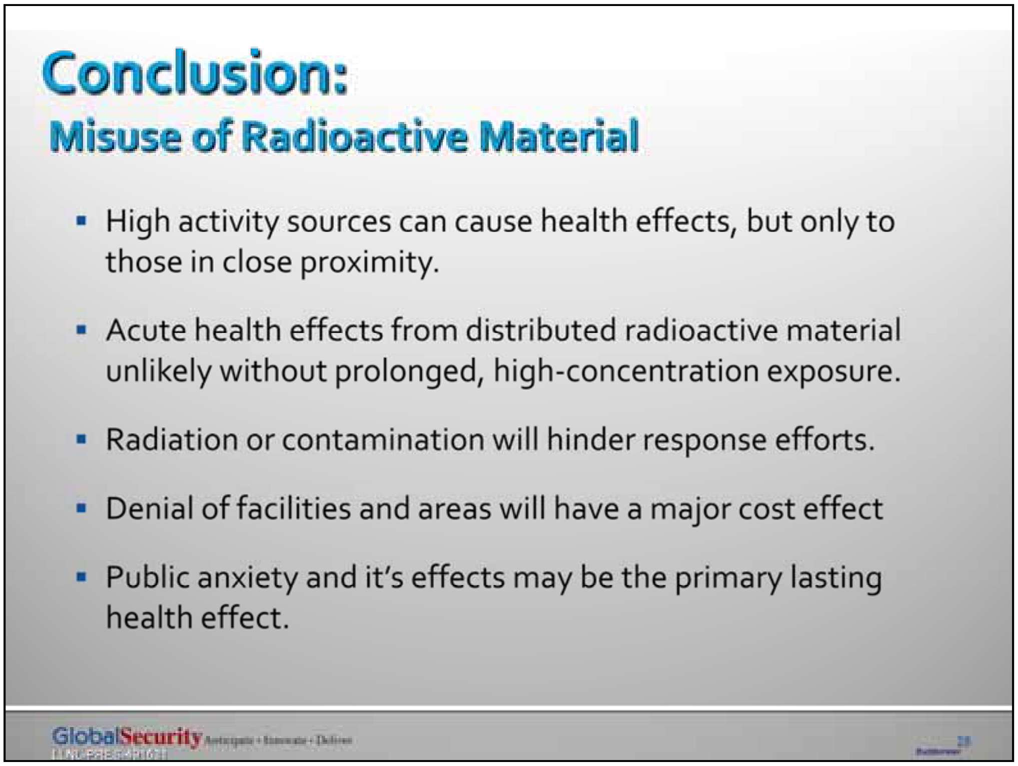

Lat : 39.94184 deg (N) Long: -75.11230 deg (W) C:\Documents and Settings\buddemeier1\My Documents\Train...
File GPS Plumes Measurements


Lat : 39.94184 deg (N) Long: -75.11230 deg (W) C:\Documents and Settings\buddemeier1\My Documents\Train...
File GPS Plumes Measurements
Bridges
0.11 mR / hr
School Bus
100 mrem/hr
Hospital
2.09 mR / hr


Useful Points of Reference
1 rem in 4 days Should Shelter ALSO is 10mR/hr line!
10 mrem / 4 day
1 rem / 4 day
0-1 rem / 4 day
Hospital: 10 hours of firefighting and rescue:
40 mrem total dose
School Bus: 2 hours of victim stabilization & rescue near scene:
200 mrem total dose
Google

Putting It in Perspective

- Although easily measured for miles,
- Shelter area may only be a few blocks, and
- Responders unlikely to get high exposures



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 <u>health</u>*** 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 rick of cancer. [The exception to this would 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 (ACS) 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	[illegible]y	None
10	[illegible]g valuable property	None
25	Life saving or protection of large populations	None
[illegible]	[illegible]g or protection of large populations	Persons fully aware of the risks involved use this limit only on a voluntary basis.

Stay Times?

Turn Back Dose?

Fight Fires…

Decontaminate?

Rescue Victims…

…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.*

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 μR/min	1.4 μR/min	200 hrs	6 weeks	12 weeks	30 weeks	2 years	
00 mR/hr	1.7 mR/min	27 μR/sec	10 hrs	50 hrs	100 hrs	250 hrs	6 weeks	30 weeks
1R/hr	17 mR/min	270 μR/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
00 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.

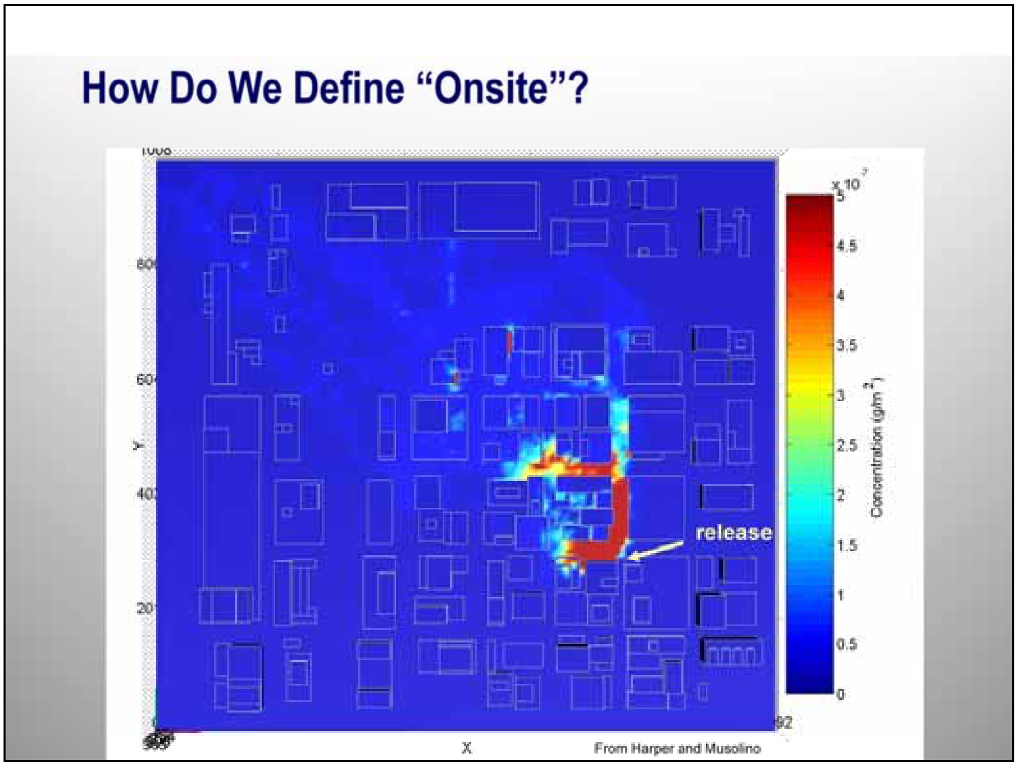
Notice that the decon guidance uses relative terms, but doesn't tell you what instrument to use. Many instruments can even detect alphas!

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 ant 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.**

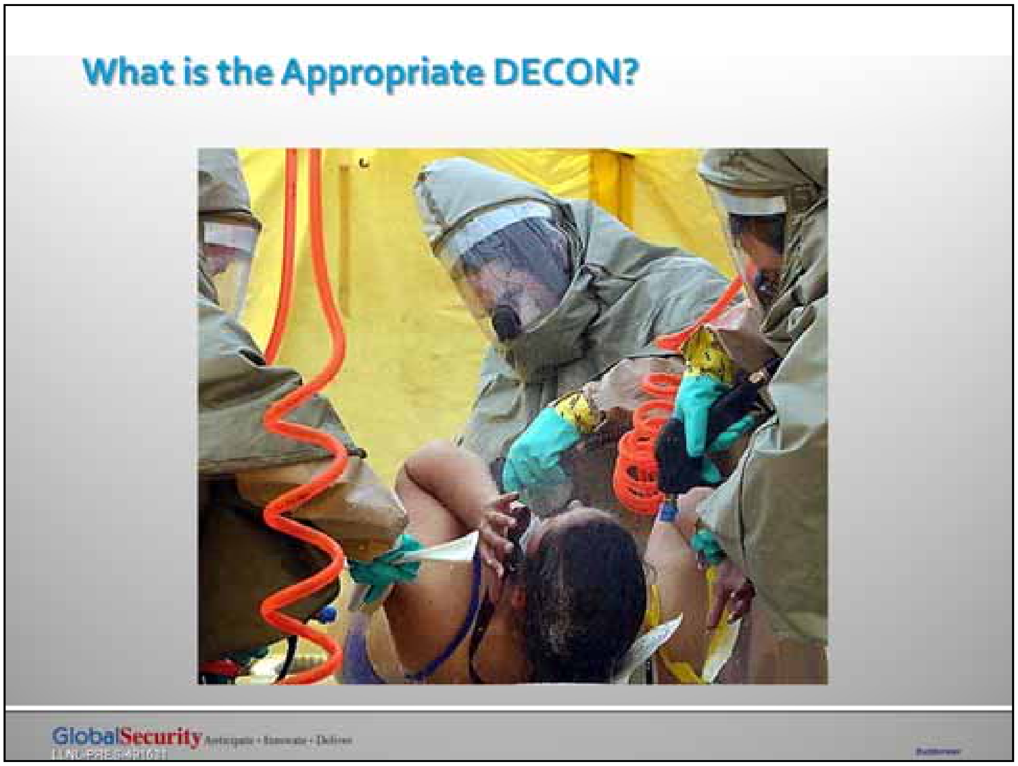


"Results can then be visualized in 2 or 3 dimensions quite readily. Wind patterns, as well as plume transport and dispersion can be readily visualized, as in these examples"

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.



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

The image cannot be displayed. Your computer may not have enough memory to open the image, or the image may have been corrupted. Restart your computer, and then open the file again. If the red x still appears, you may have to delete the image and then insert it again.

What is the Right Equipment?

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

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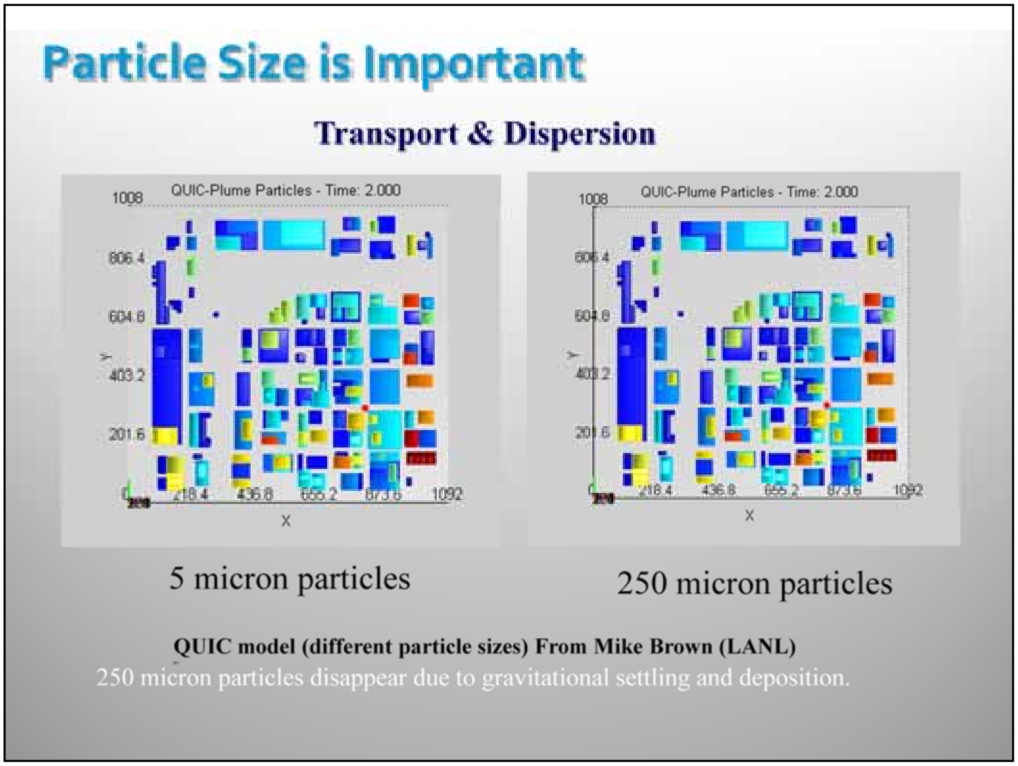
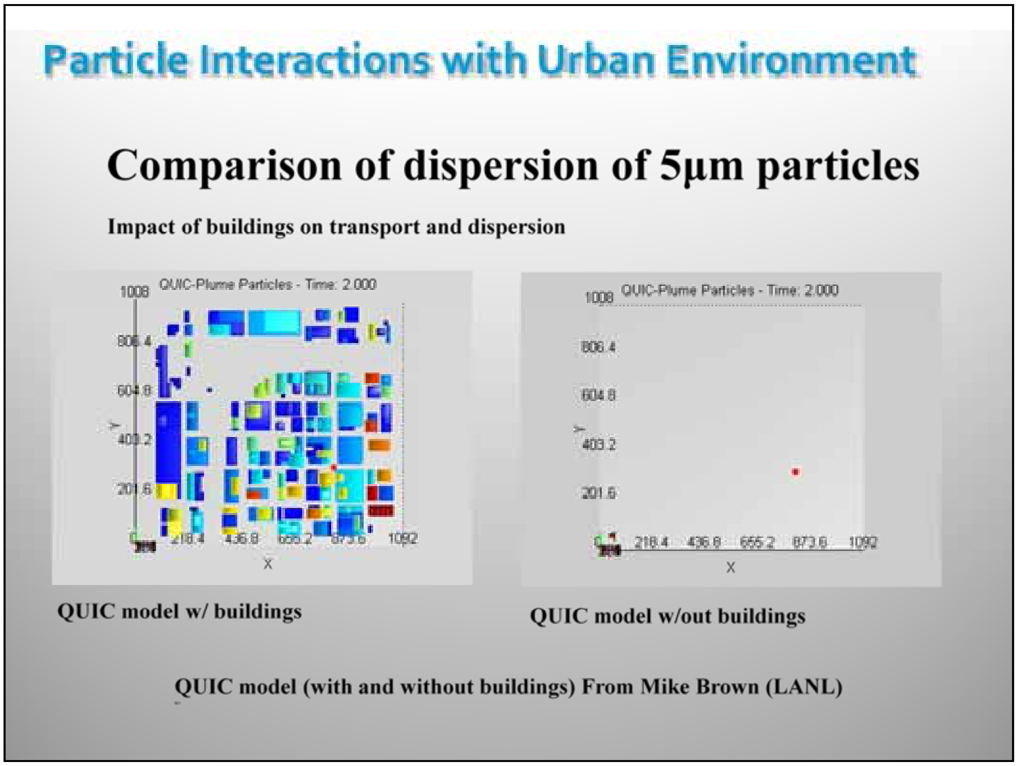


"Results can then be visualized in 2 or 3 dimensions quite readily. Wind patterns, as well as plume transport and dispersion can be readily visualized, as in these examples"

(this is an animated slide)



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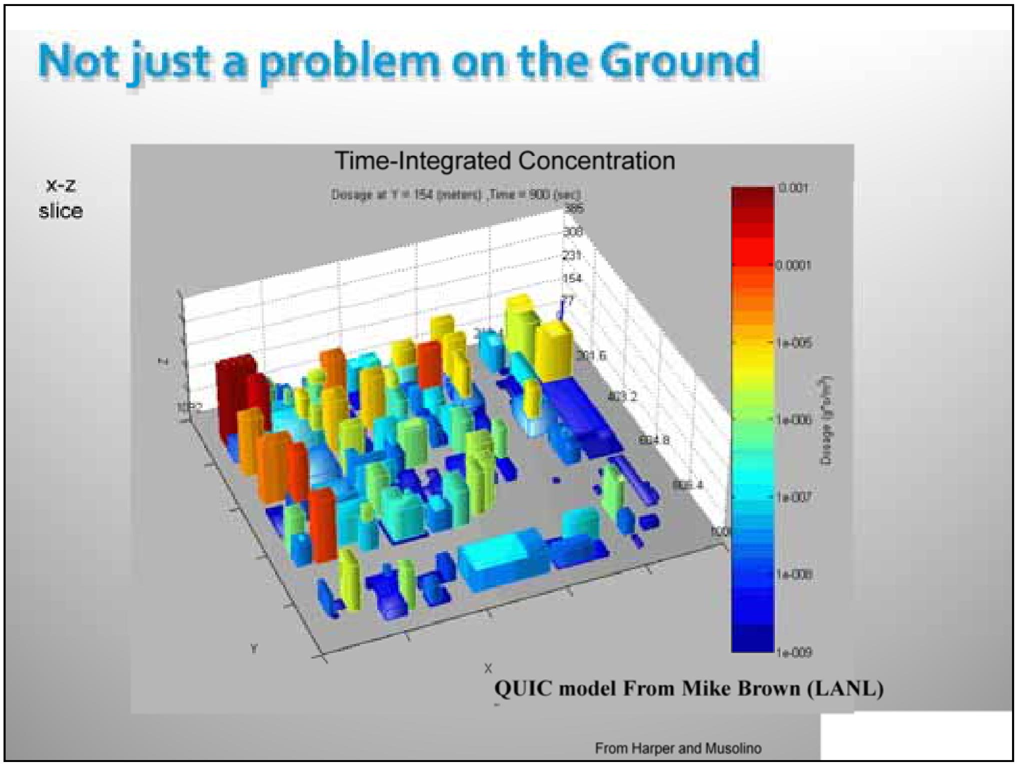
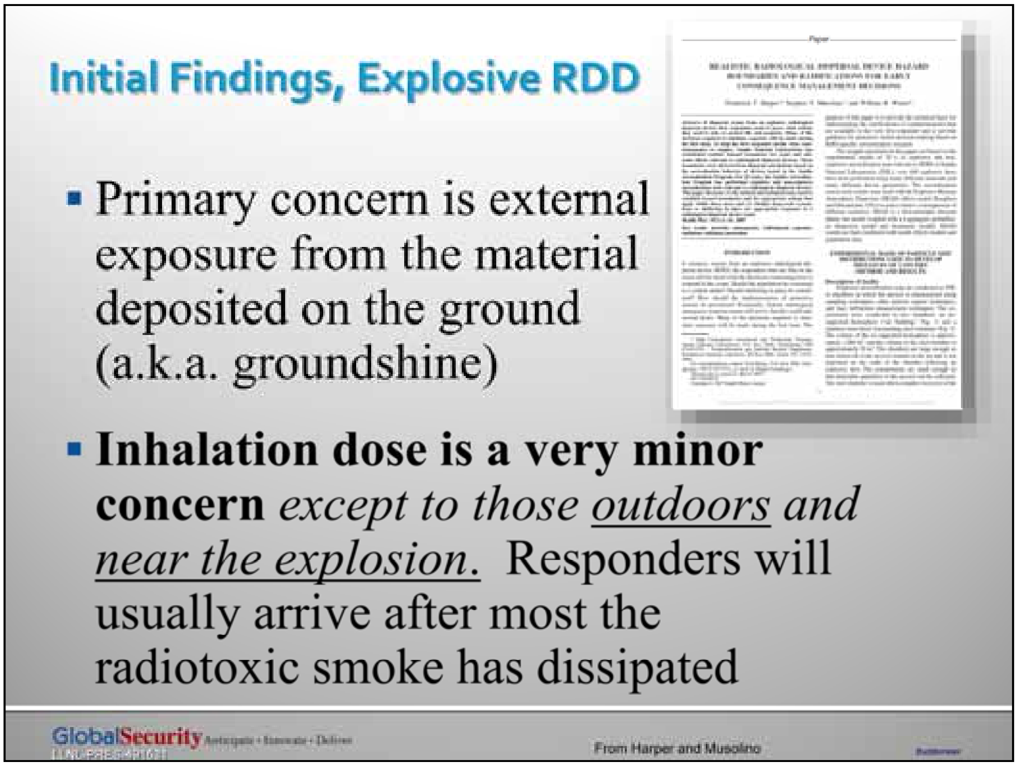


"Results can then be visualized in 2 or 3 dimensions quite readily. Wind patterns, as well as plume transport and dispersion can be readily visualized, as in these examples"



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 ßγ 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

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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

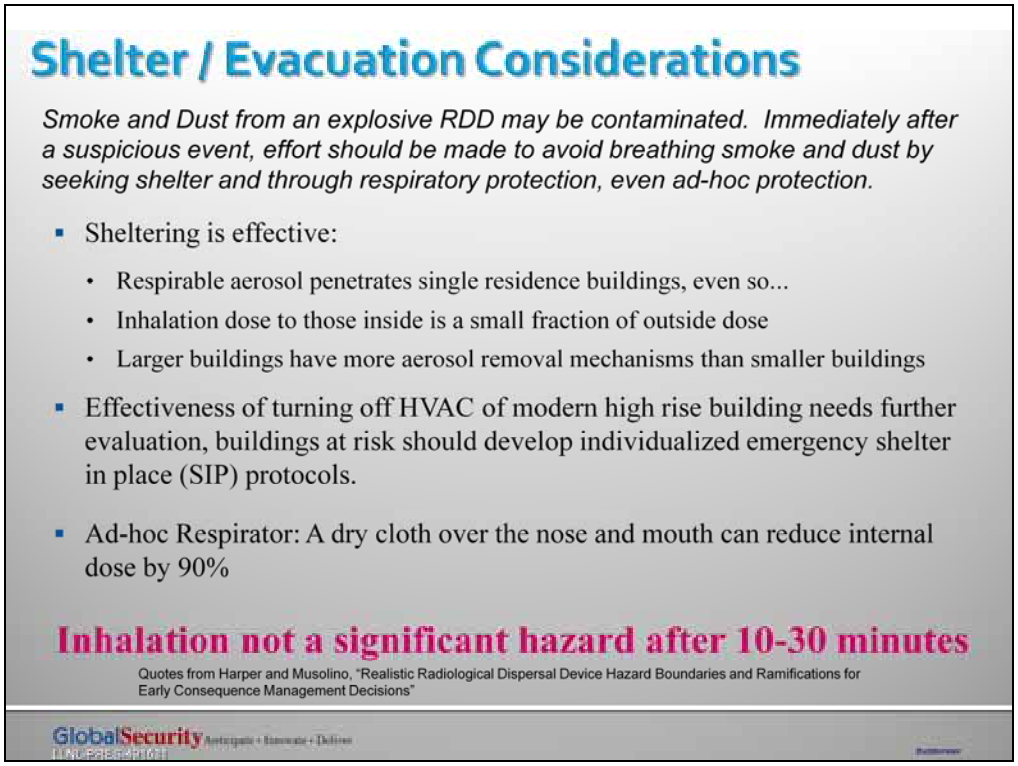
c) If possible monitor at the exits to identify (triage) highly contaminated individuals

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.***

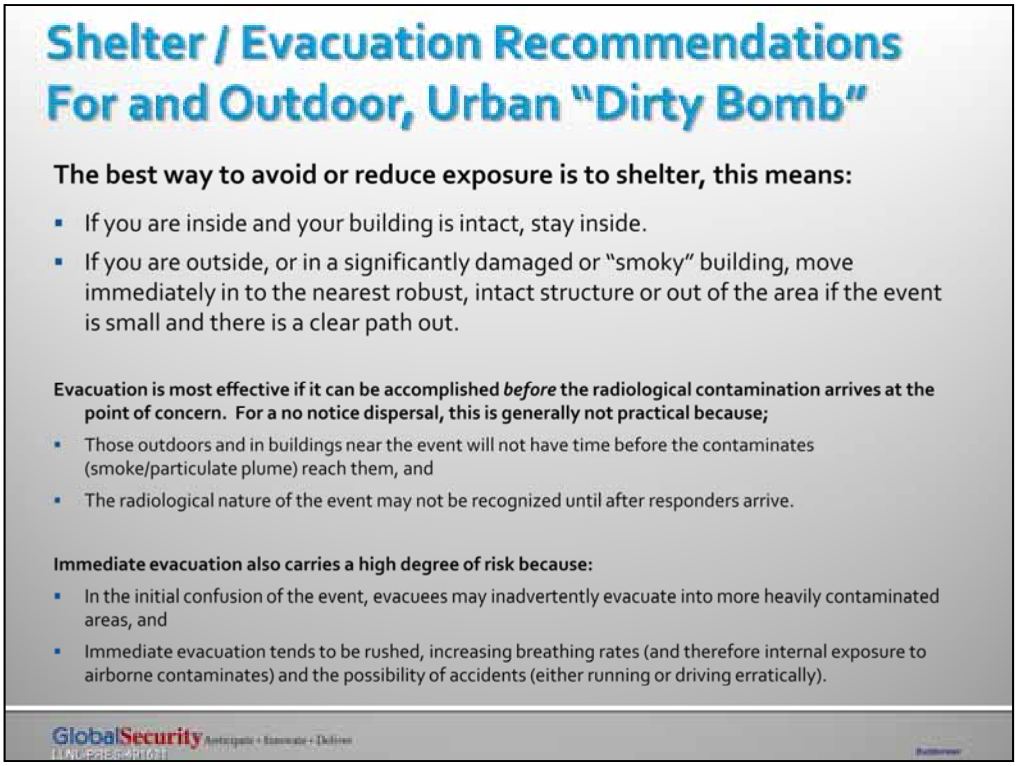
GlobalSecurity Anticipate • Innovate • Deliver

From Harper and Musolino



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

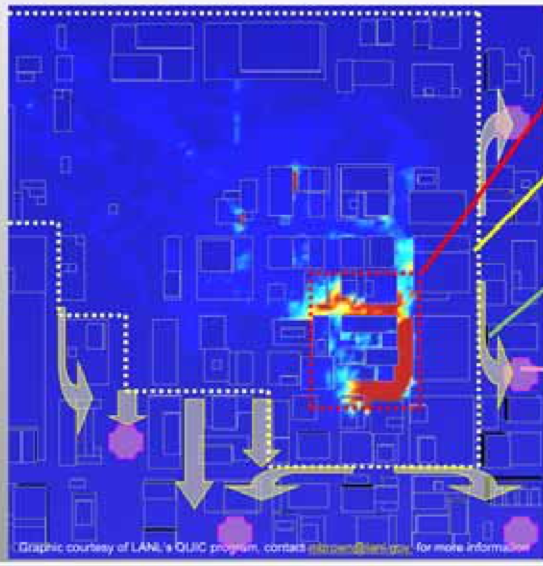
One out of the smoke/dust area, Stop using ad-hoc protection.



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

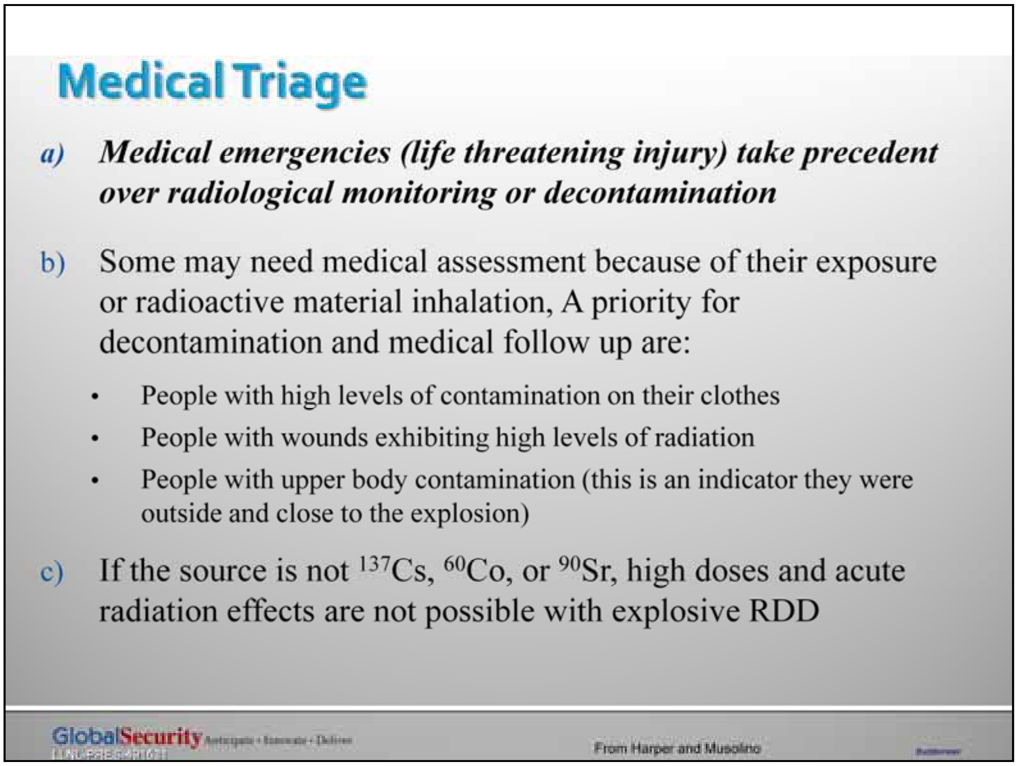


Dangerous Radiation Zone (>10R/h)

Hot Zone Boundary based on natural breaks & < 10mR/h

Evacuees directed to triage & monitoring sites

Triage & Monitoring sites; identify & manage highly contaminated



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 <u>ineffective</u> against a primary dose concern; groundshine radiation.* Using level A or B may actually <u>increase a responders dose</u> as it limits functionality and communication which will increases 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

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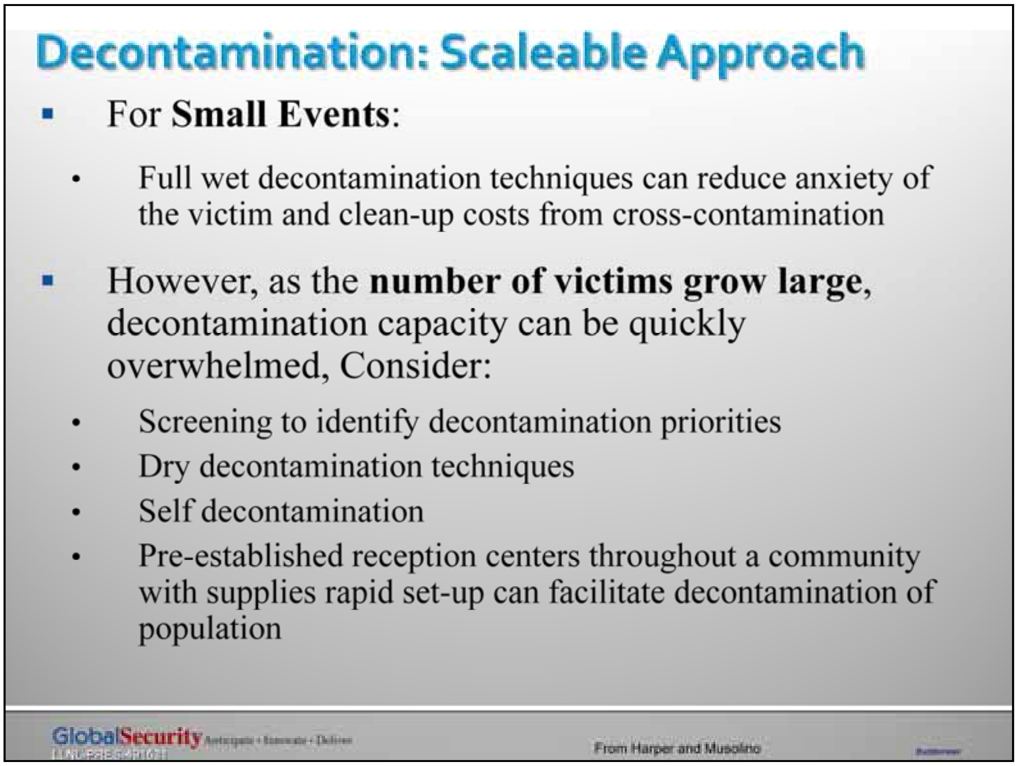
From Harper and Musolino

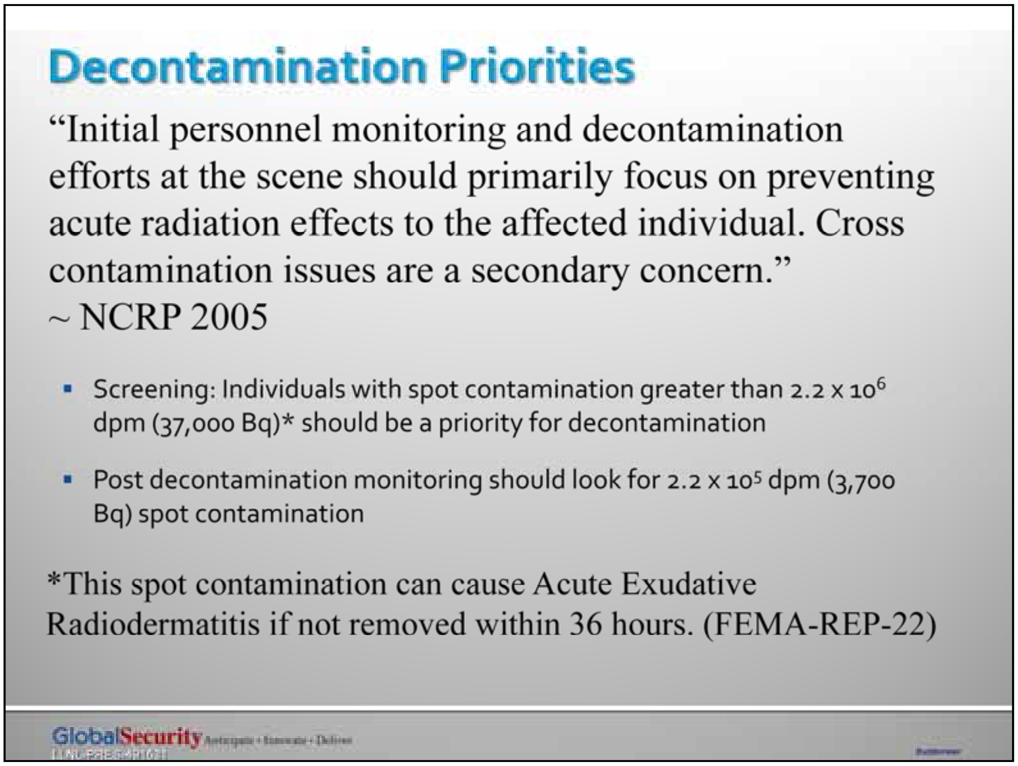


Decontamination strategies must consider:

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.



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 µCi/cm2 (may also be expressed as 7 rem per µCi h/cm2). 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 µCi h** (i.e., 1,200 rem)7 rem per µCi h/cm2 x 0.2 cm2). Dividing 34 µCi 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 µCi Threshold) 2.2 x 10^5 dpm (3,700 Bq) Probe Speed (inches/s)	Height Of Probe (inches)	Path Width (inches)	Time Needed to Monitor an Adult[b] (minutes)	Loose-Plus-Fixed Contamination (1.0 µCi Threshold) 2.2 x 10^6 dpm (37,000 Bq) Probe Speed (inches/s)	Height of Probe (inches)	Path Width (Inches)	Time Needed to Monitor an Adult[b] (minutes)
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[7]	●	○	○	—	—	—	—	—	—	—
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[8] & Facility[9] Contamination Monitoring	○	—	○	○	●	—	○	—	—	[illegible]

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 a 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 materiel 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.

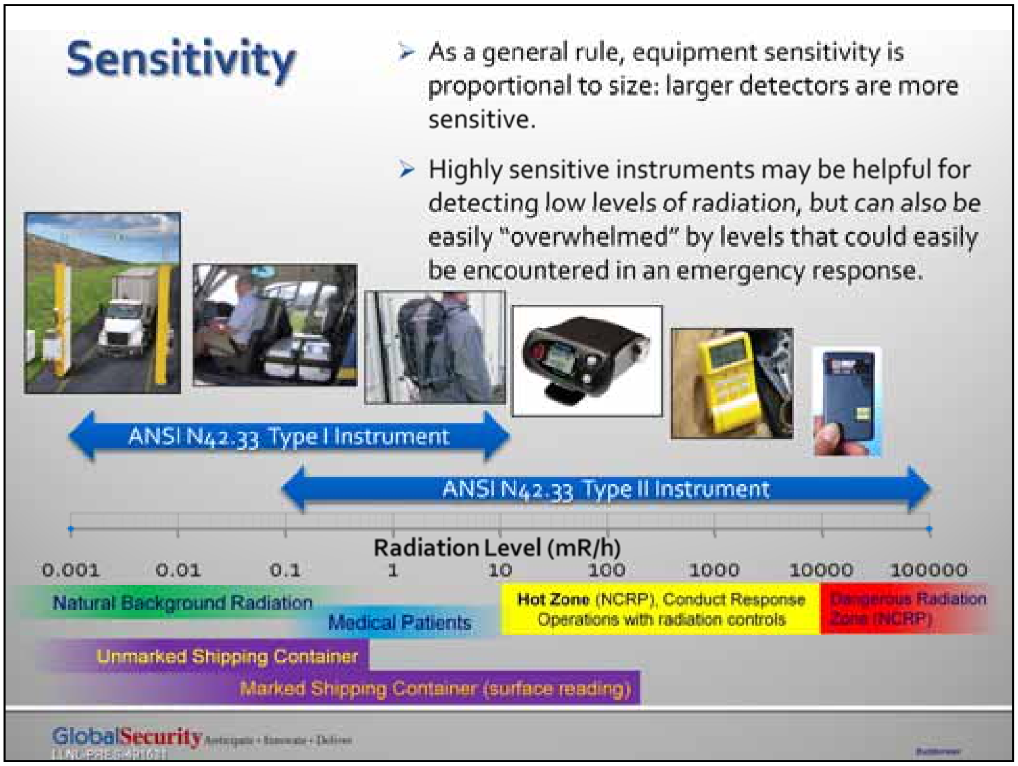
- ⇨ Sensitive detectors can measure very low levels of radiation.

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.
ANSI N42.33 Type I Instrument
ANSI N42.33 Type II Instrument
Radiation Level (mR/h)
0.001
0.01
0.1
1
10
100
1000
10000
100000
Natural Background Radiation
Medical Patients
Hot Zone (NCRP), Conduct Response Operations with radiation controls
Dangerous Radiation Zone (NCRP)
Unmarked Shipping Container
Marked Shipping Container (surface reading)
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Selectivity

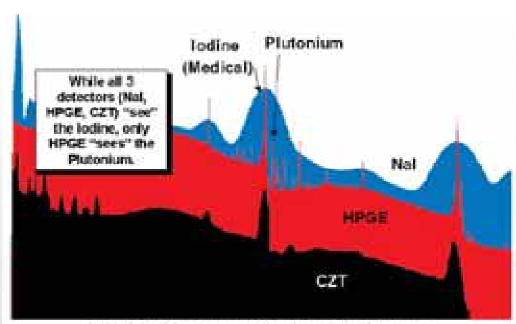
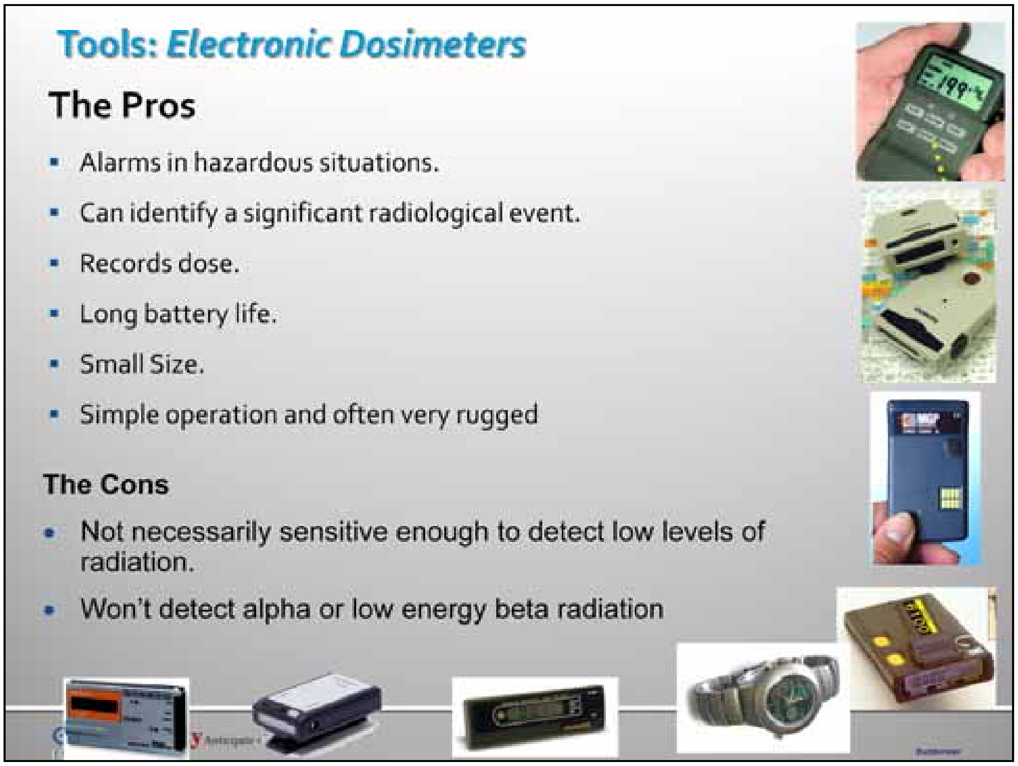


Figure 2. HPGe in comparison to NaI and CZT detectors.

- 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

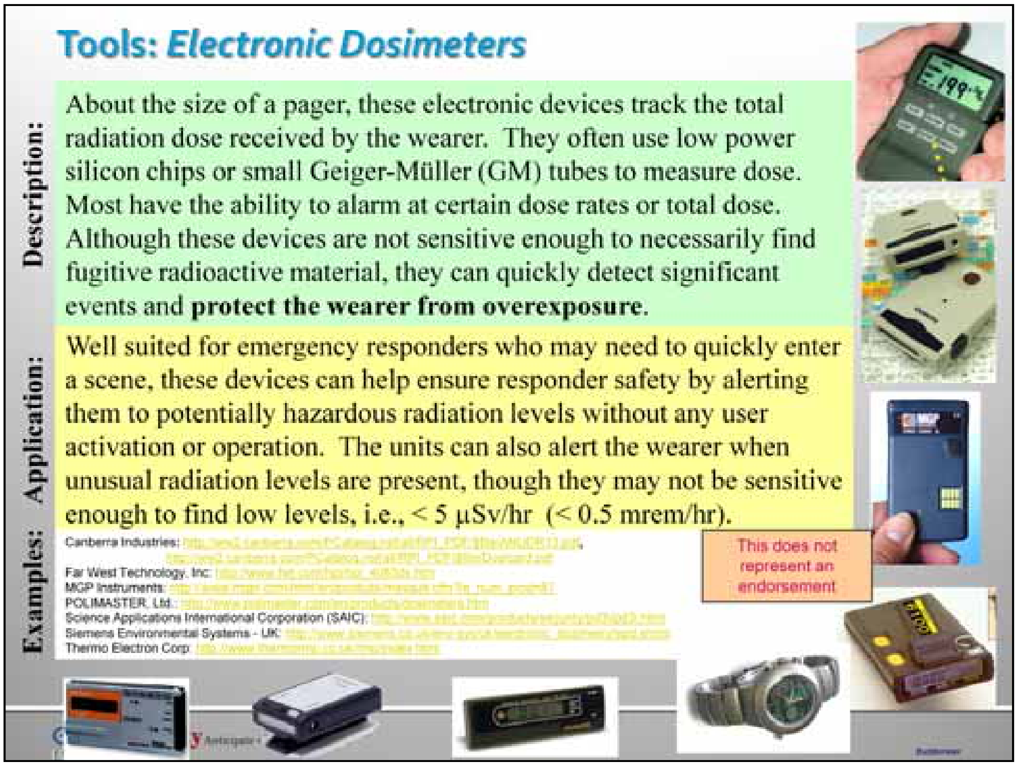


Although the perfect tool does not currently exist, there are a few different types of instruments that have some of the right properties. One example would be the one of the numerous electronic dosimeters that are currently on the market.

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]



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

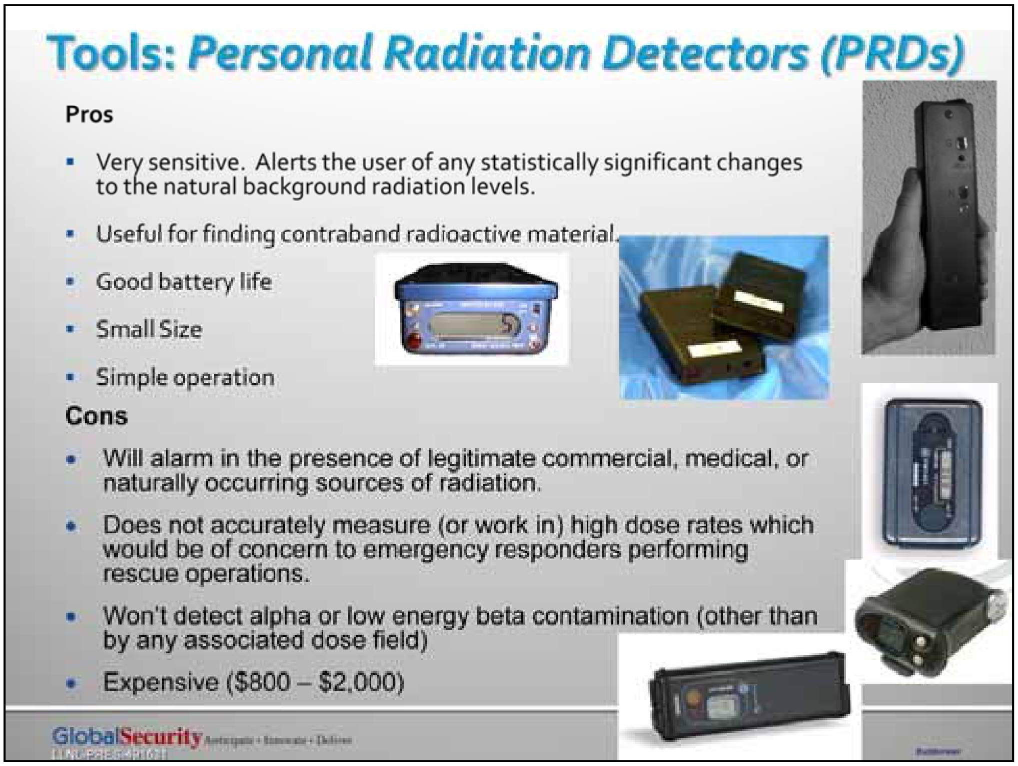
In summary, the issues associated with electronic Dosimeters are
Well suited for emergency responders who may need to quickly enter a scene, these devices can help ensure responder safety by alerting them when radiation is present, but they may not be sensitive enough to identify the radiological nature 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 µSv/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!

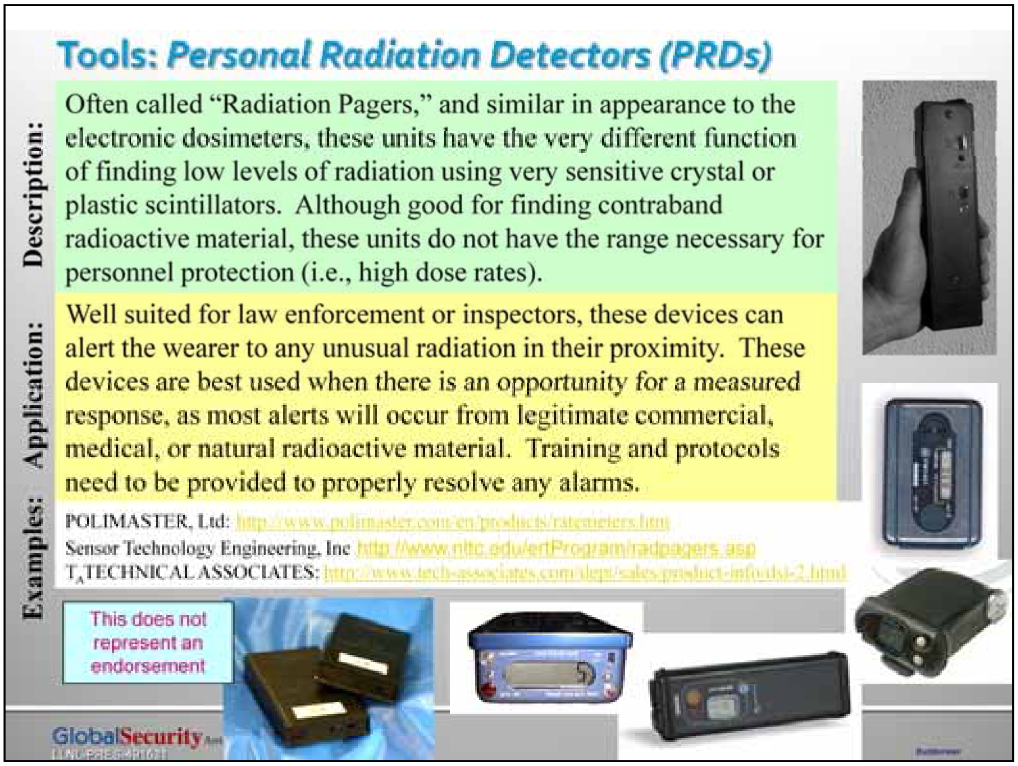


Although it looks similar to a electronic dosimeter, there is a very different kind of detector out there which I call "Personnel Radiation Proximity Alert Systems."

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)



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.

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.

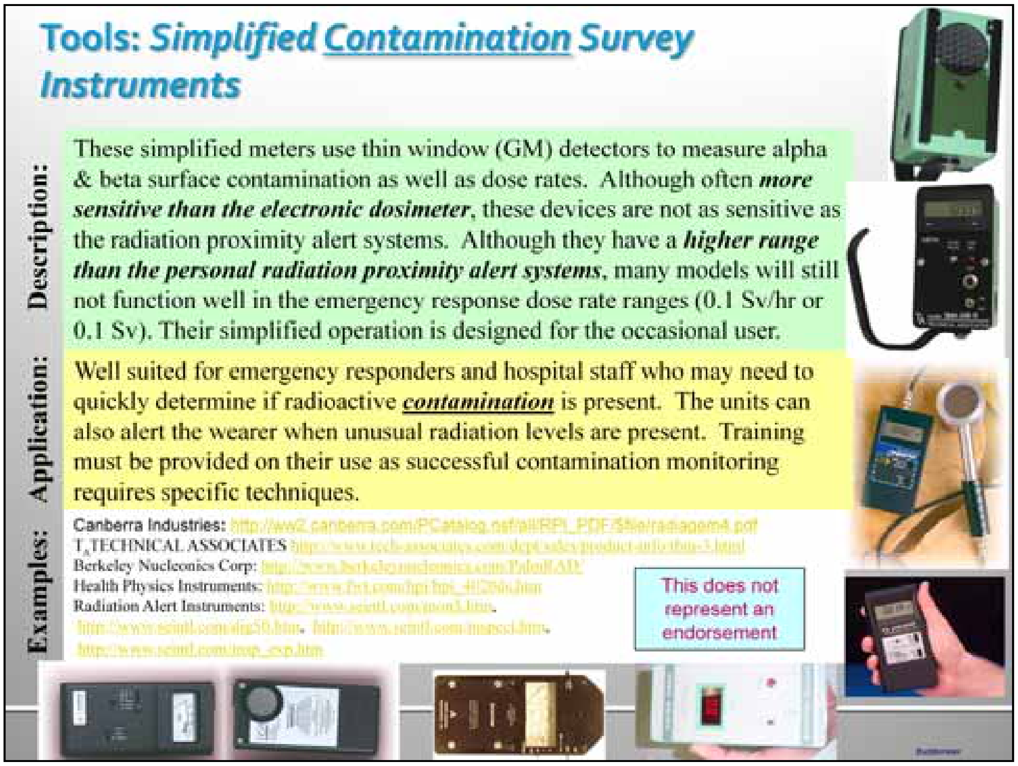
[Click to show Cons]

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 | >10R/hr).

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



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.

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]

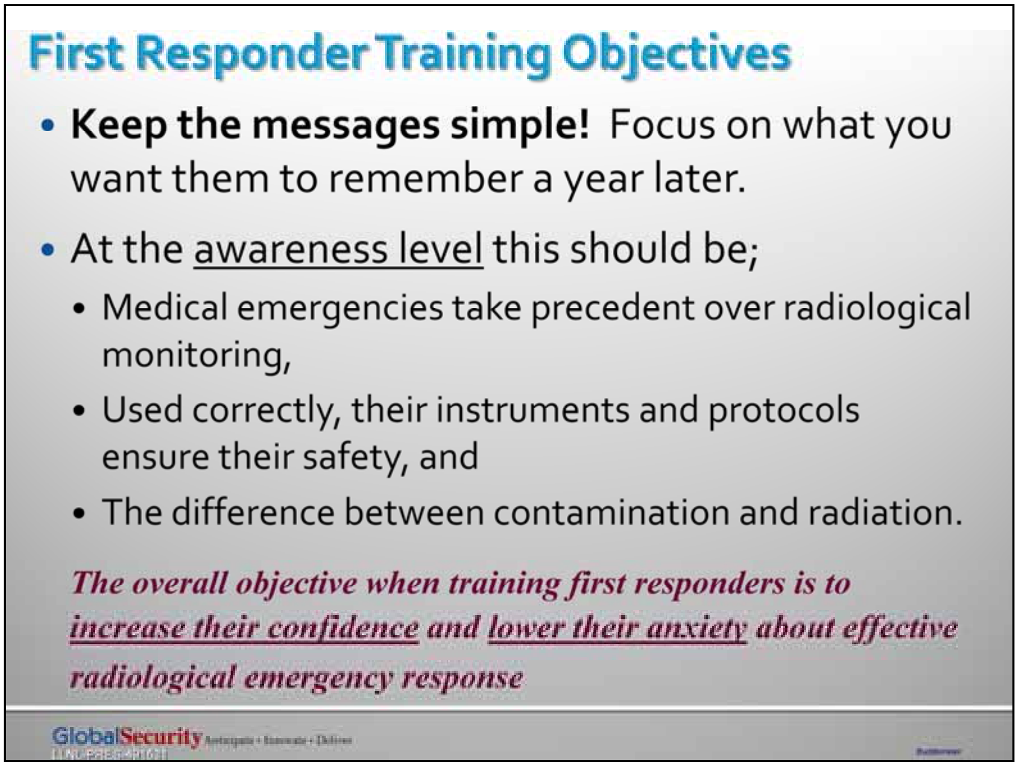
Cons

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.

- Will alarm in the presence of legitimate commercial, medical, or naturally occurring sources of radiation (though the analysis can often resolve this)
- Expensive ($8,000 - $12,000)
- Won't detect alpha or low energy beta contamination.
- Requires extensive training or support to use properly

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.



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.


Questions
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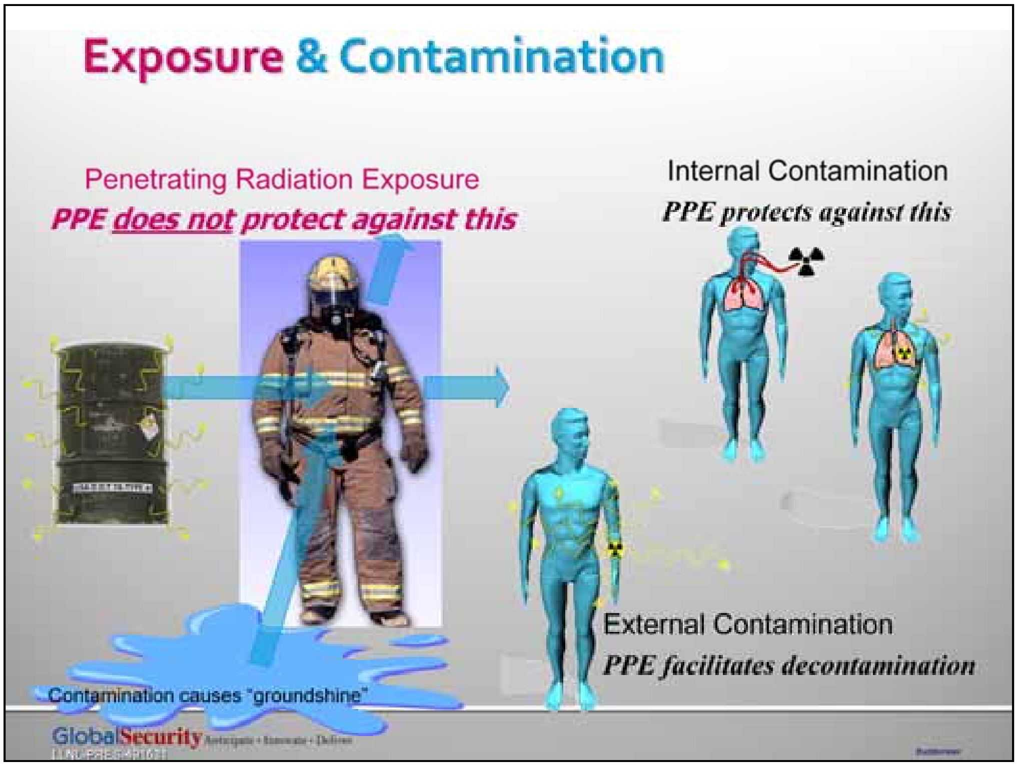
Exposure & Contamination
Penetrating Radiation Exposure
PPE does not protect against this
Internal Contamination
PPE protects against this
External Contamination
PPE facilitates decontamination
Contamination causes "groundshine"
GlobalSecurity

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 [illegible] or by contacting DOE's Emergency Operation Training Academy at www.eota.doe.gov or call (505) 845-5170 ext.172

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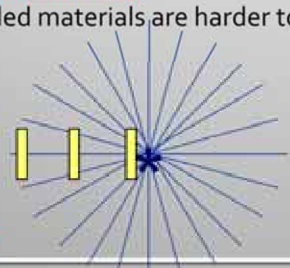
Need to Add some window dressing, pics of instrumentation and operators…

Detecting Weak Sources of Radiation

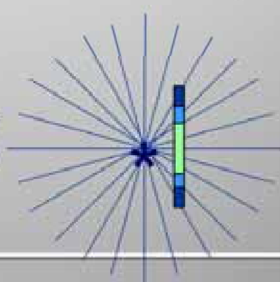
Time, Distance, and Shielding also apply to the probability of detection, though the principal is reversed

- **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



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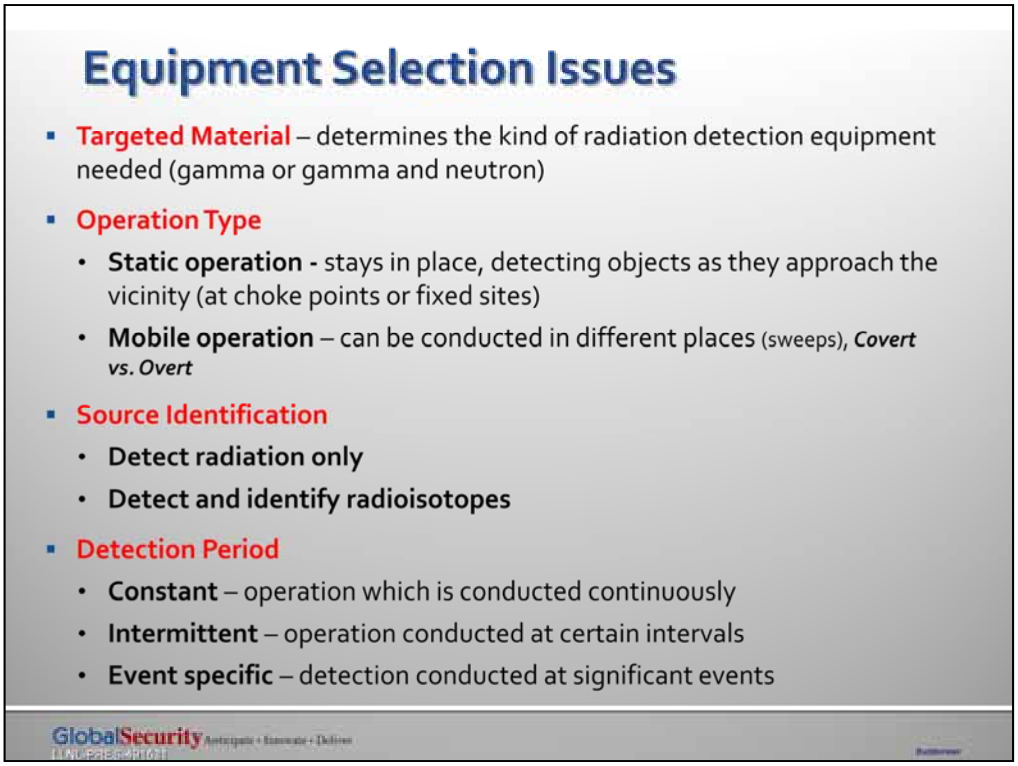
Human Portable Detection Equipment

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)**



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)

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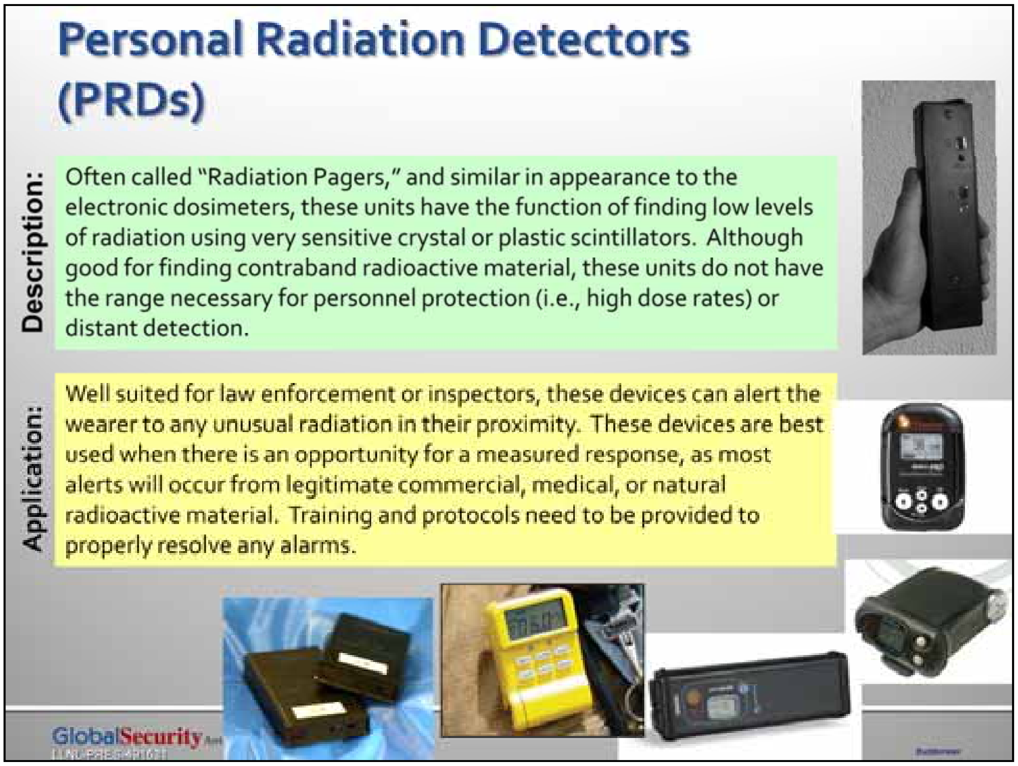
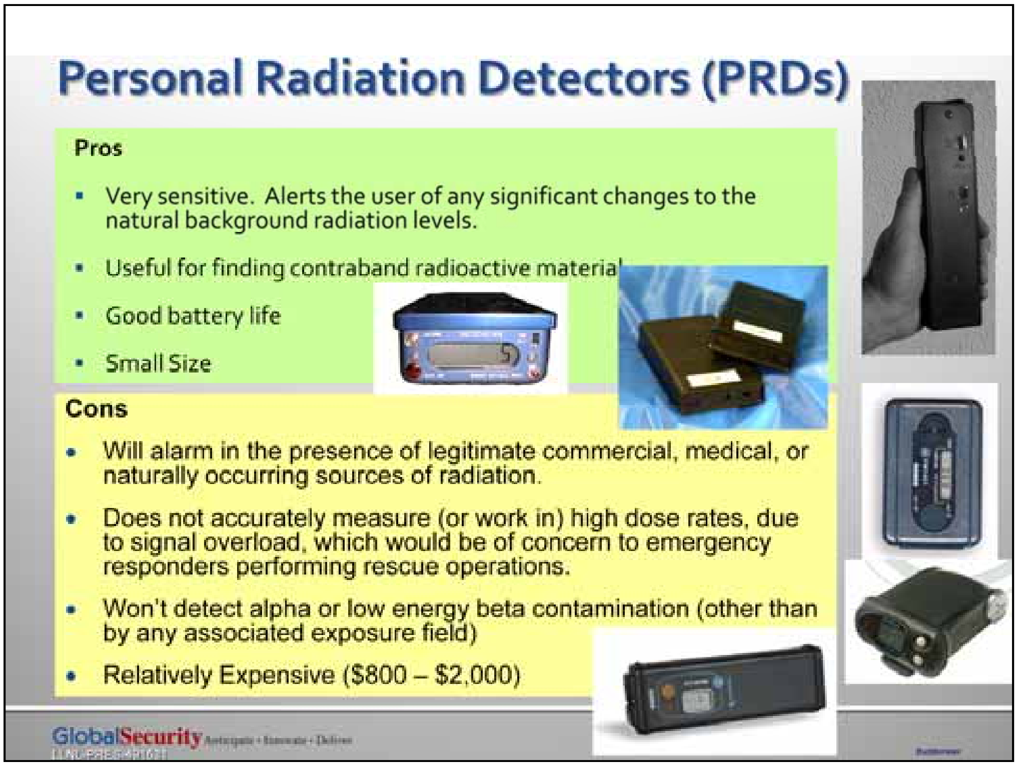


In summary
Well suited for law enforcement or inspectors, these devices can alert the wearer to any unusual radiation in their proximity. These devices are best used when there is an opportunity for a measured response,
Training must be provided to ensure that the user realizes that the alarms do not 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.



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)


Personal Radiation Detectors (PRD)
- examples
BNC nukeAlert 951
Thermo Scientific RadEye
BNC 1703MB/GNB
STE Handheld
Laurus Mini rad-D
mini
rad-D
Personal
Radiation
Detector
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Personal Radiation Detectors -
examples (cont'd)
UltraRadiac MRAD-TRN, Ludlum PRM
Polimaster 1401GNA/GNB
This does not represent an endorsement
BNC 1703 MO-1
Polimaster 1703 GN/GNA/GNB
Polimaster 1401MA
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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





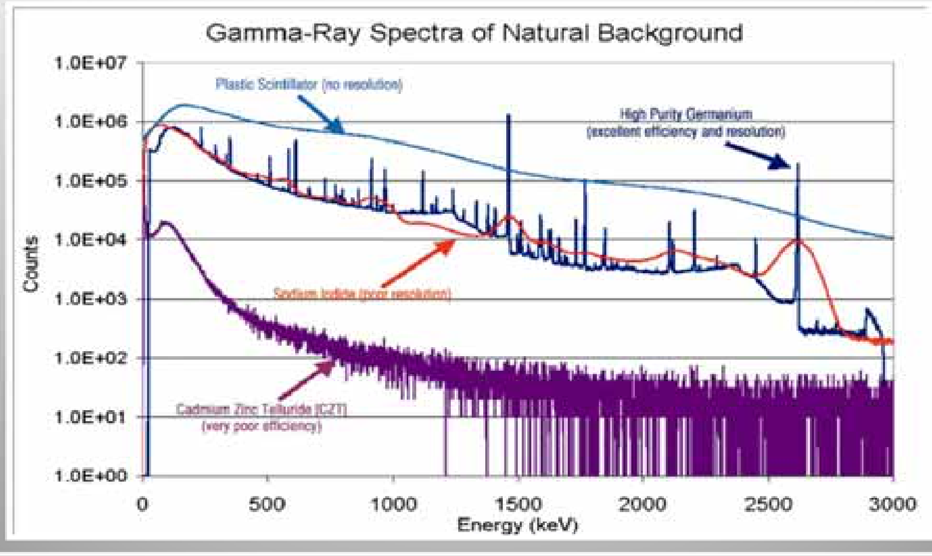
	Thermo RadEye	Polimaster 1703 GNB	STE Radiation Pager	Thermo Sci. Interceptor	Ludlum Personal R.M.
Gamma Det'n	Yes	Yes	Yes	Yes	Yes
Neutron Det'n	Opt	Yes	No	Yes (He-3)	No
Weight (oz)	5.6	8.5	6.0	13.8	5.1
LxWxH (in)	1.25x2.4x3.78	3.38x1.25x2.88	4.1x0.9x2.4	4.4x2.4x1	3.0x0.69x5.4
Temp. (deg. F)	-22 to 141	-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)	½x 1 ½ CsI(Tl)	CZT	E comp GM
Sensitivity	1.5 cps / µR/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



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Quick detector resolution comparison

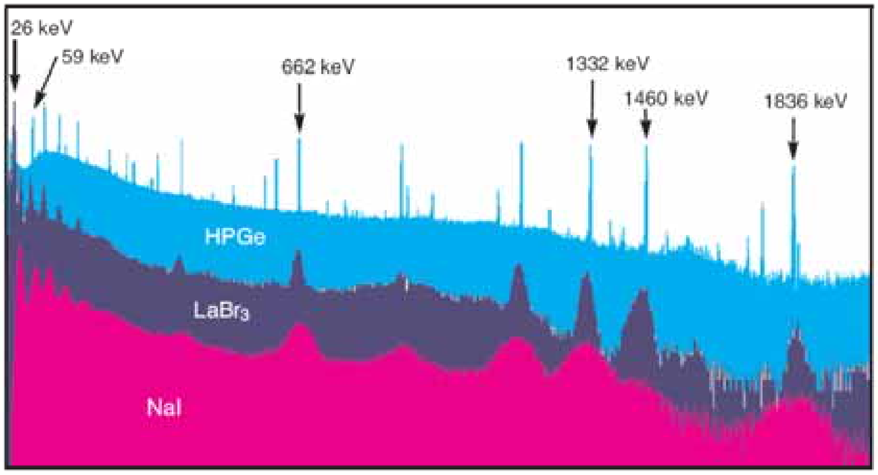


Figure 1. Comparison for LaBR3(Ce), NaI(Tl), and HPGe spectra.

Quick detector resolution comparison

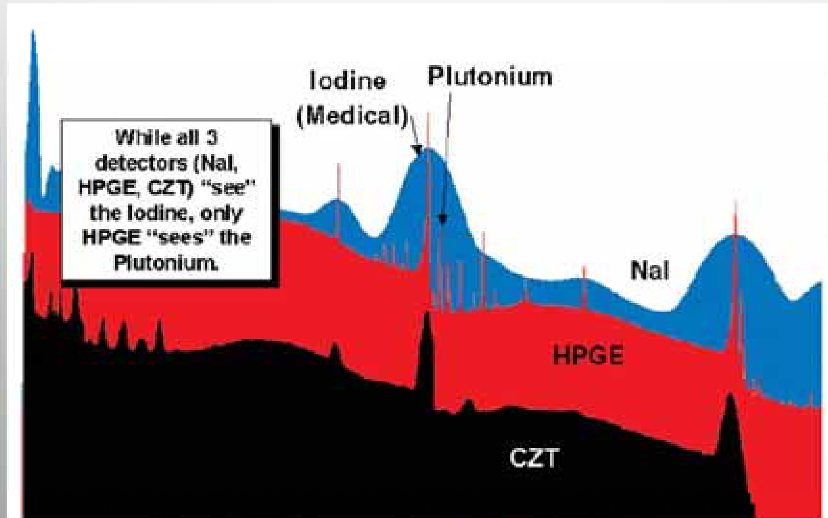
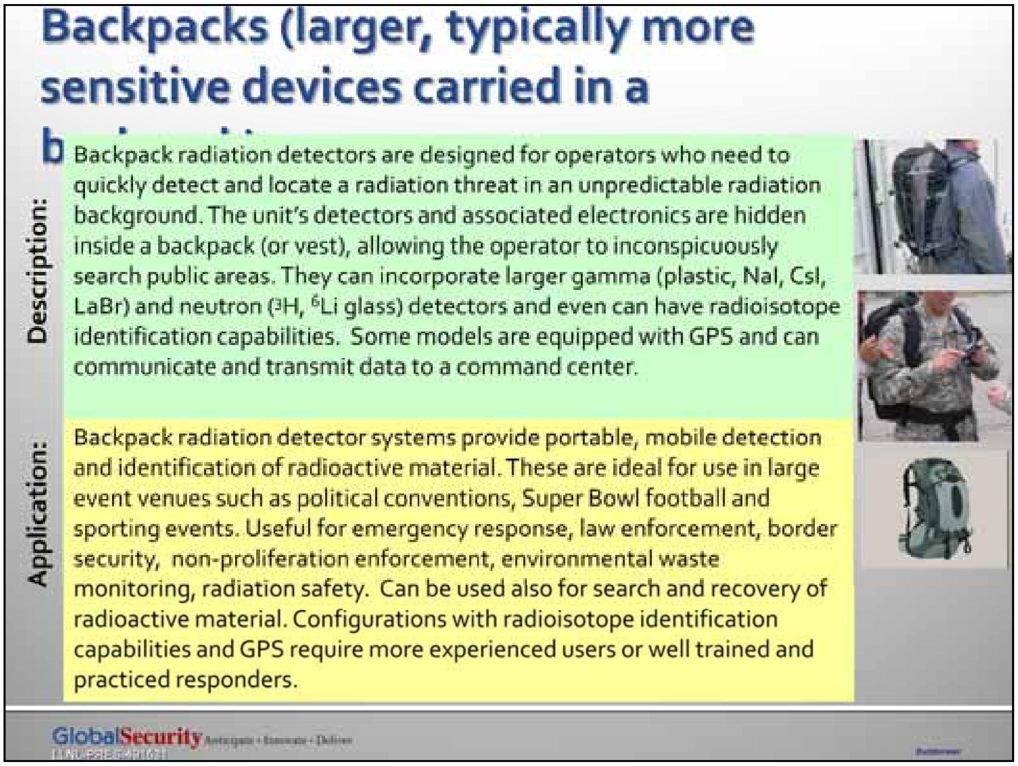
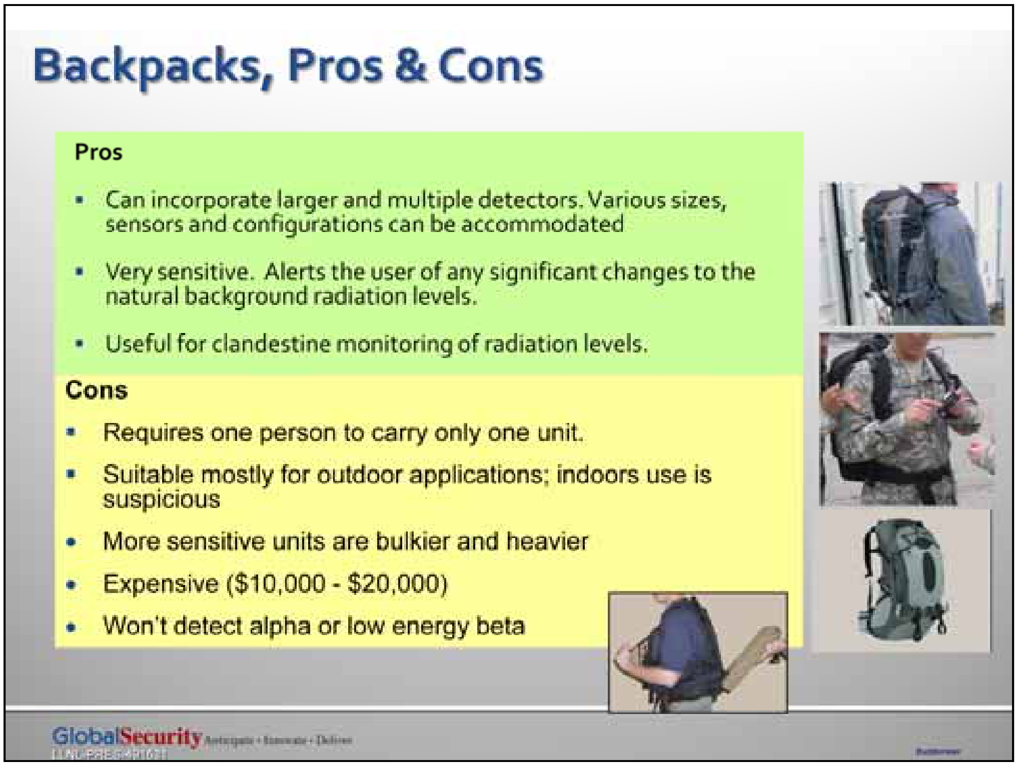


Figure 2. HPGe in comparison to NaI and CZT detectors.



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
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Backpacks - examples

Thermo Scientific Packeye Backpack

BNC RD-100

Nucsafe backpack/vest

Nucsafe backpack

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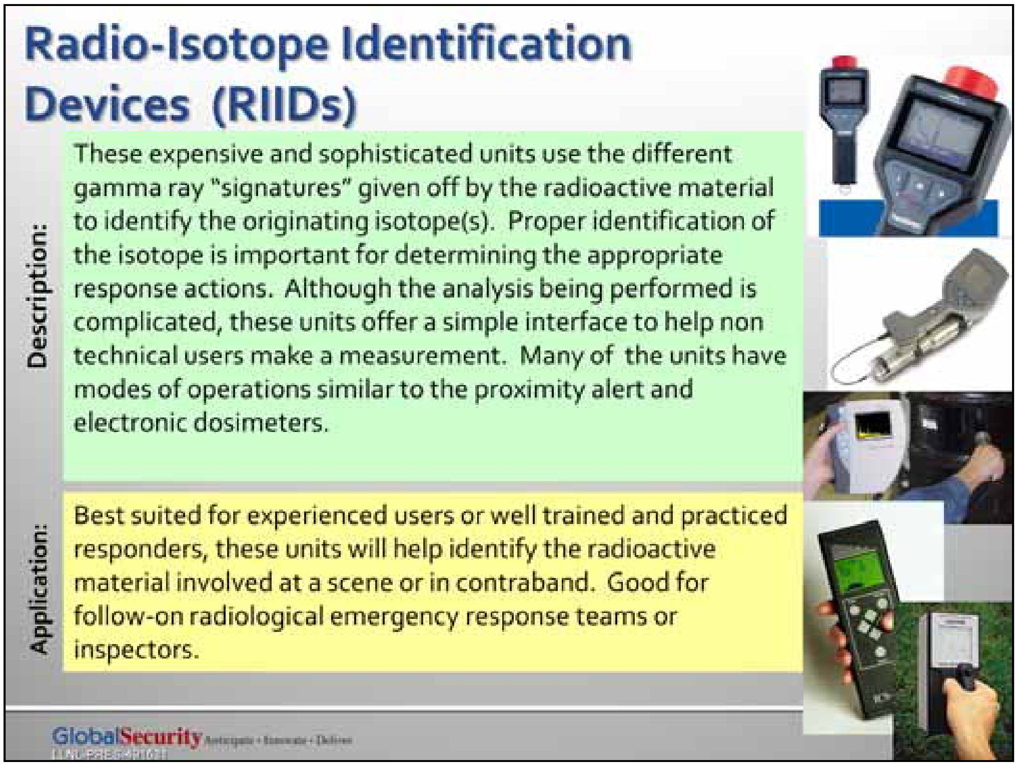

In Summary,
Their cost prohibits them from being in every first responder's back pocket, but they can be a valuable tool in the hands of a well trained regional responder.
Although most units have been ruggedized, the technology is inherently shock sensitive and the automated analysis is not 100% effective.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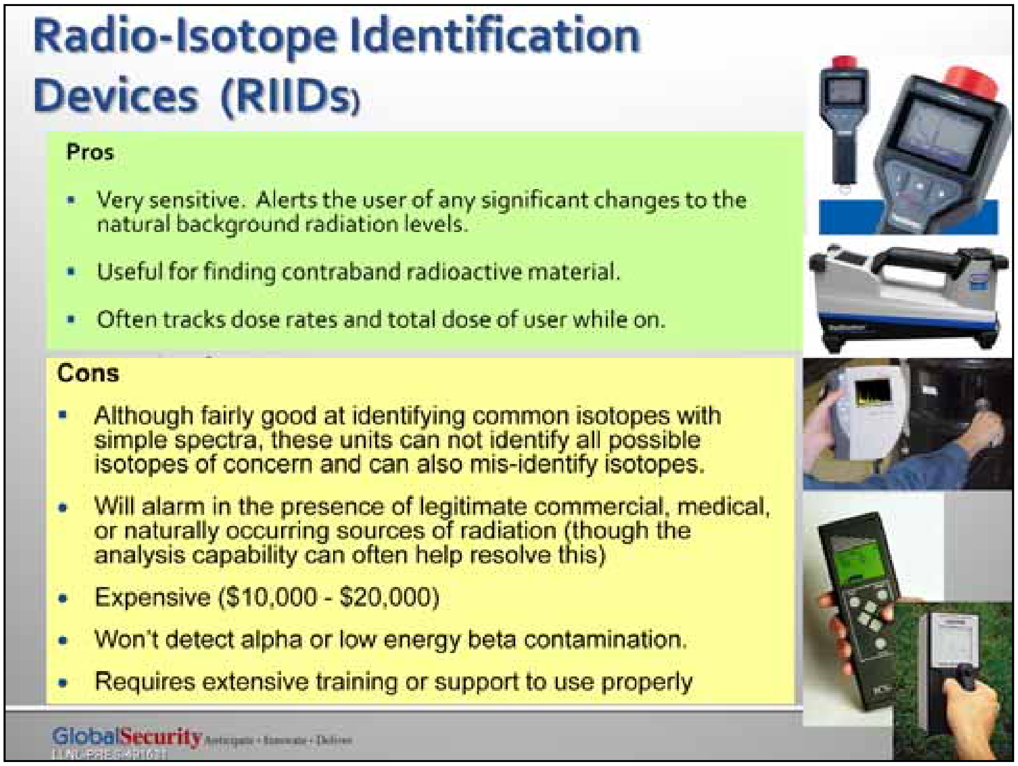

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- Useful for finding contraband radioactive material.
- Often tracks dose rates and total dose of user while on.
- Can identify many common isotopes

[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.

- Will alarm in the presence of legitimate commercial, medical, or naturally occurring sources of radiation (though the analysis can often resolve this)
- Expensive ($10,000 - $12,000)
- Won't detect alpha or low energy beta contamination.
- Requires extensive training or support to use properly

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

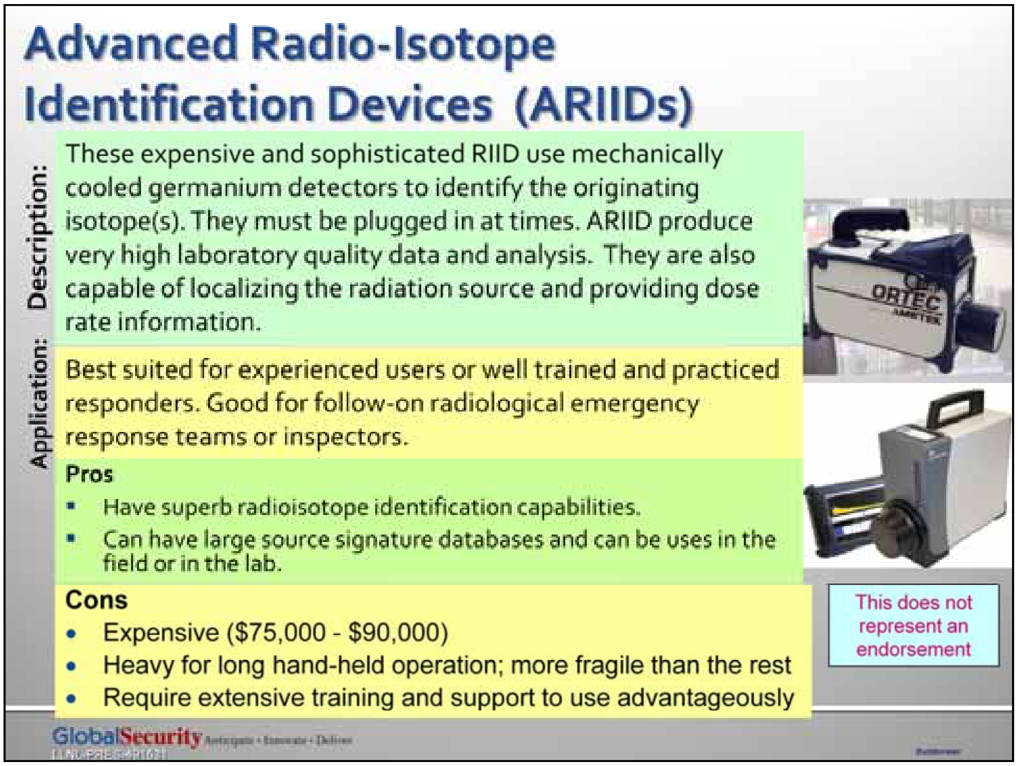
Ludlum Model 703 Isotope Identifier

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



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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

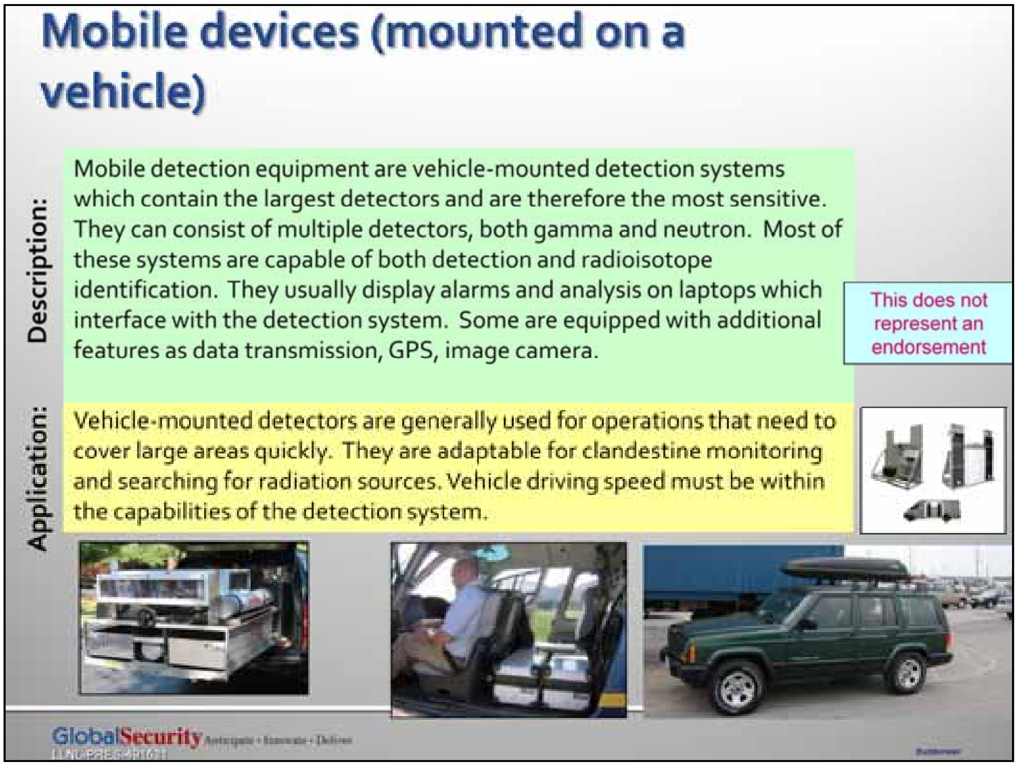
ORTEC Micro-Detective-HX

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



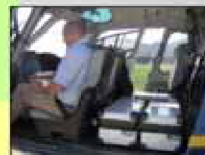
These are usually built to meet the requirements of the customer and can have various configurations. They can have large and multiple detectors with high overall sensitivity, gamma and neutron detectors, often radioisotope identification capabilities , GPS positioning and data transmission capabilities.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

Mobile devices

Pros

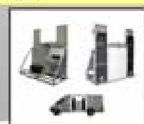
- Very sensitive; can incorporate large and multiple detectors
- Useful for covering large areas.
- Can be tailored towards specific requirements.
- Often have additional capabilities – radioisotope identification, GPS, data transmission, computer analysis, take images
- Can be used for clandestine monitoring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

This does not represent an endorsement



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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Mobile devices - examples

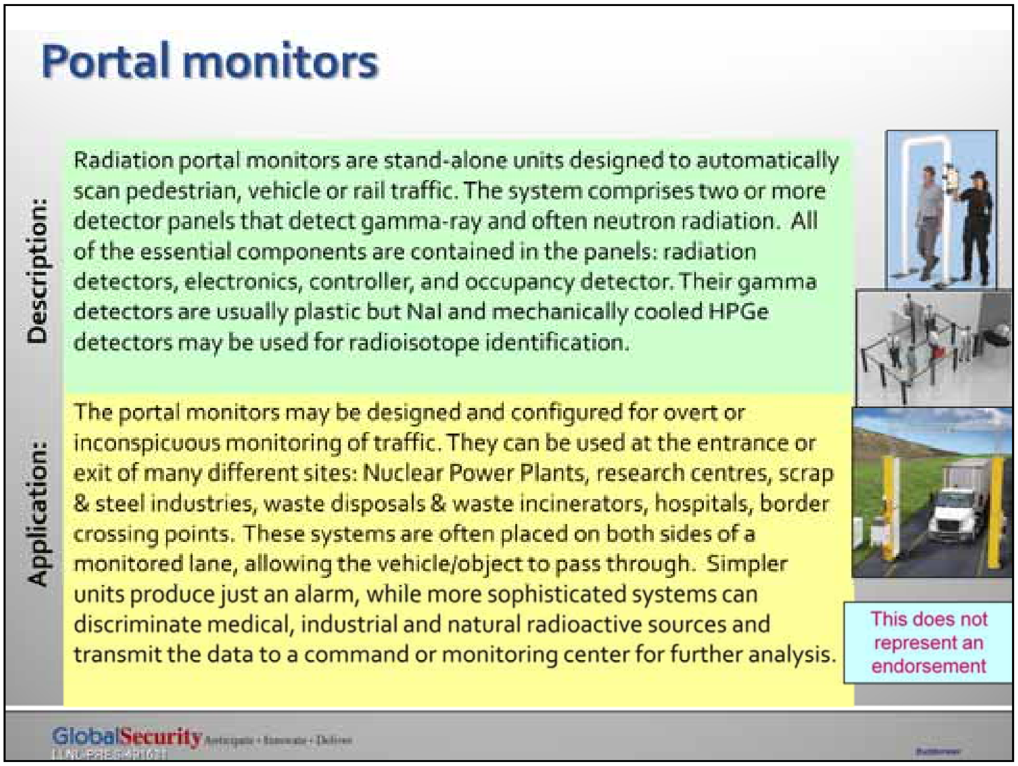
Thermo Scientific Mobile ARIS

TSA MDS134A

Mirion SPIR-Ident-mobile

BNC Textron IST RadTruck

SAIC Exploranium GR-460



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.

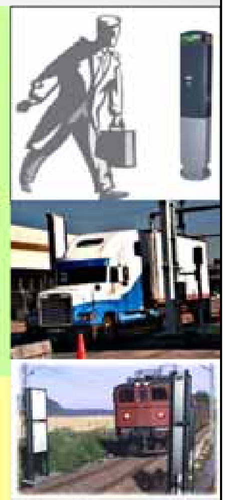
Portal monitors

Pros

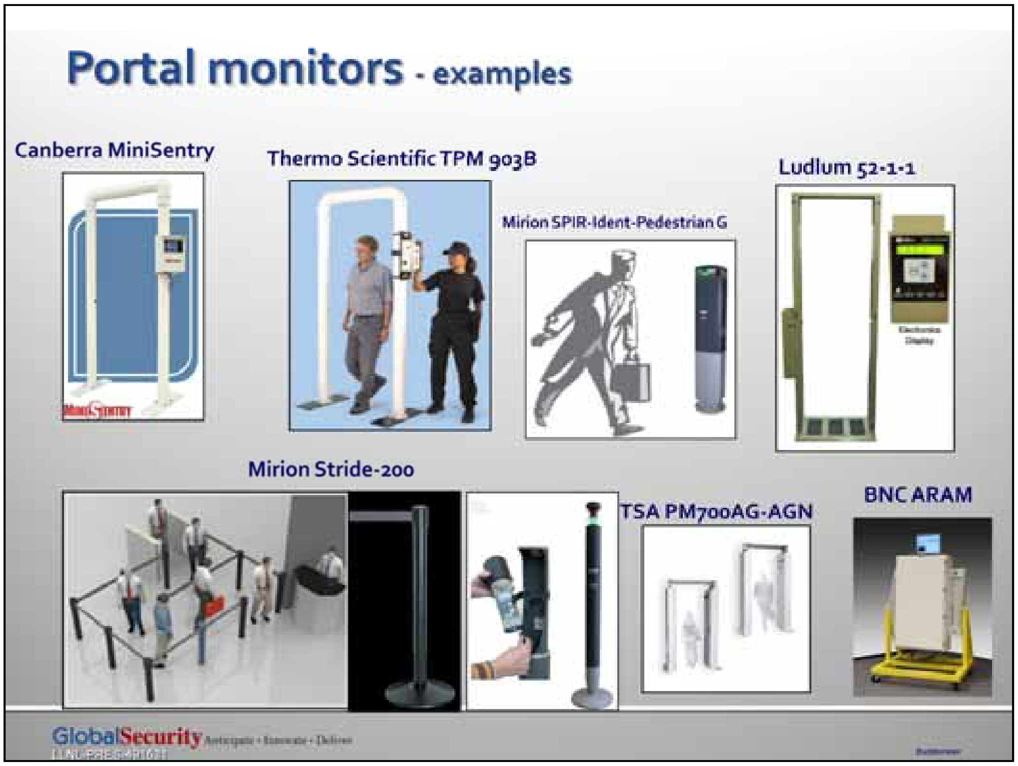
- Can incorporate large and multiple detectors both for gamma and neutron emitting sources
- Very sensitive
- Most are maintenance free and do not require frequent calibration
- Can be set up for unattended and/or covert operation.
- More sophisticated systems have radioisotope identification capabilities.
- 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)



This does not represent an endorsement


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
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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

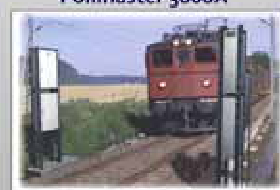
Detectors inside a panel

Polimaster 5000A

Canberra GPS Portal SS

SAIC/Exploranium AT 980

Polimaster 5000A



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
  - Initiate organizational protocols to ensure the health and safety of

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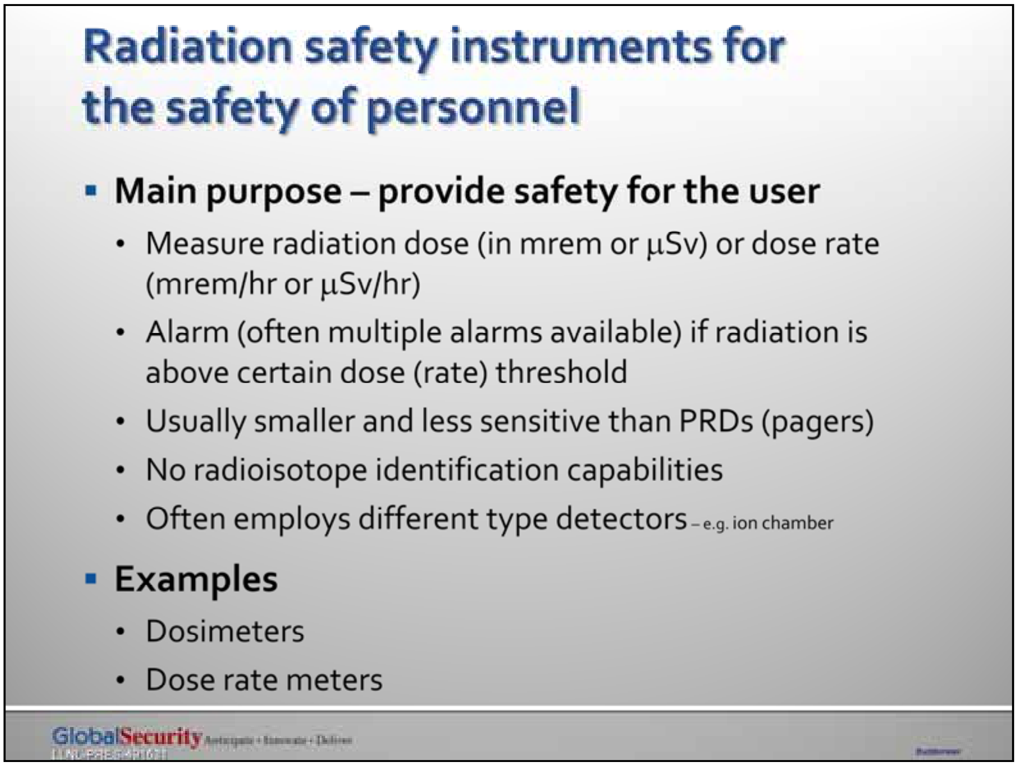
Talk through how this maps to ConOps, mention CTOS for equipment training, DNDO for mission planning, etc. (more to follow from Sean on this topic)



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

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).

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.

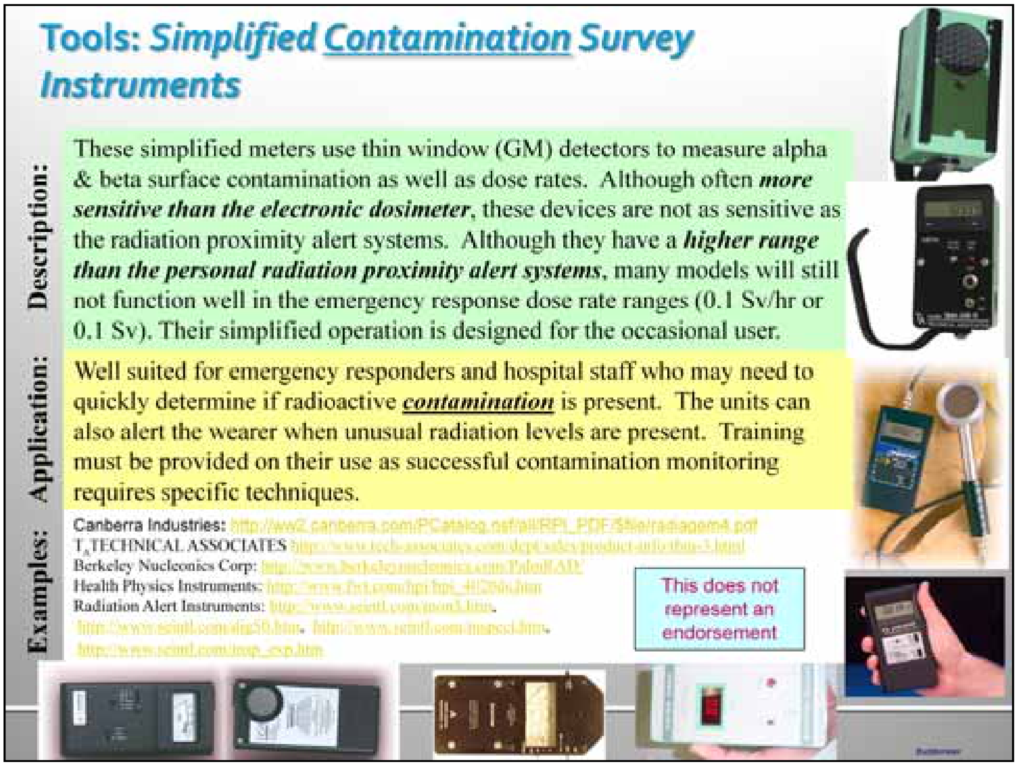
[Click to show Cons]

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 | >10R/hr).

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



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.