Protection through Detection

# Detecting Radiation

Animations in this training work best in Windows XP

February 2006

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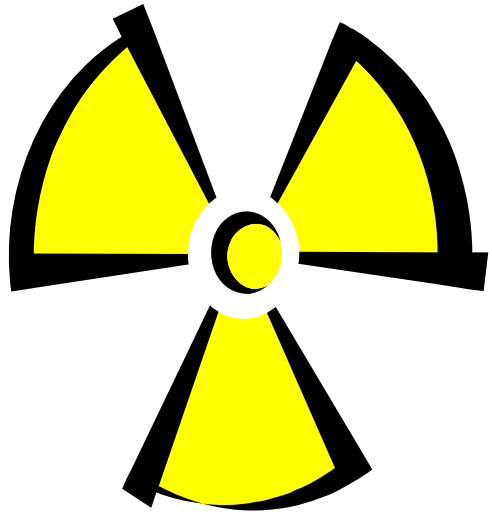
# Why Detect Radiation Today?

- Medicine
  - Imaging
  - Cancer treatment and therapy
- Industrial
  - Imaging
  - Gauges
- Power
- Agriculture
- Radiological terrorism

# Topics

- Detection Technologies
  - Scintillators
  - Solid State Sensors
  - Geiger-Mueller Tubes
- Types of Detectors
- How to Use Detectors



# Detection Technologies

- Radiation is detected using sensors
  - Different sensors detect different types and ranges of radiation, and are used for different applications
- Applications
  - First responders/safety
  - Health physics/plant safety
  - Industry– gauges and imaging
  - Medical imaging

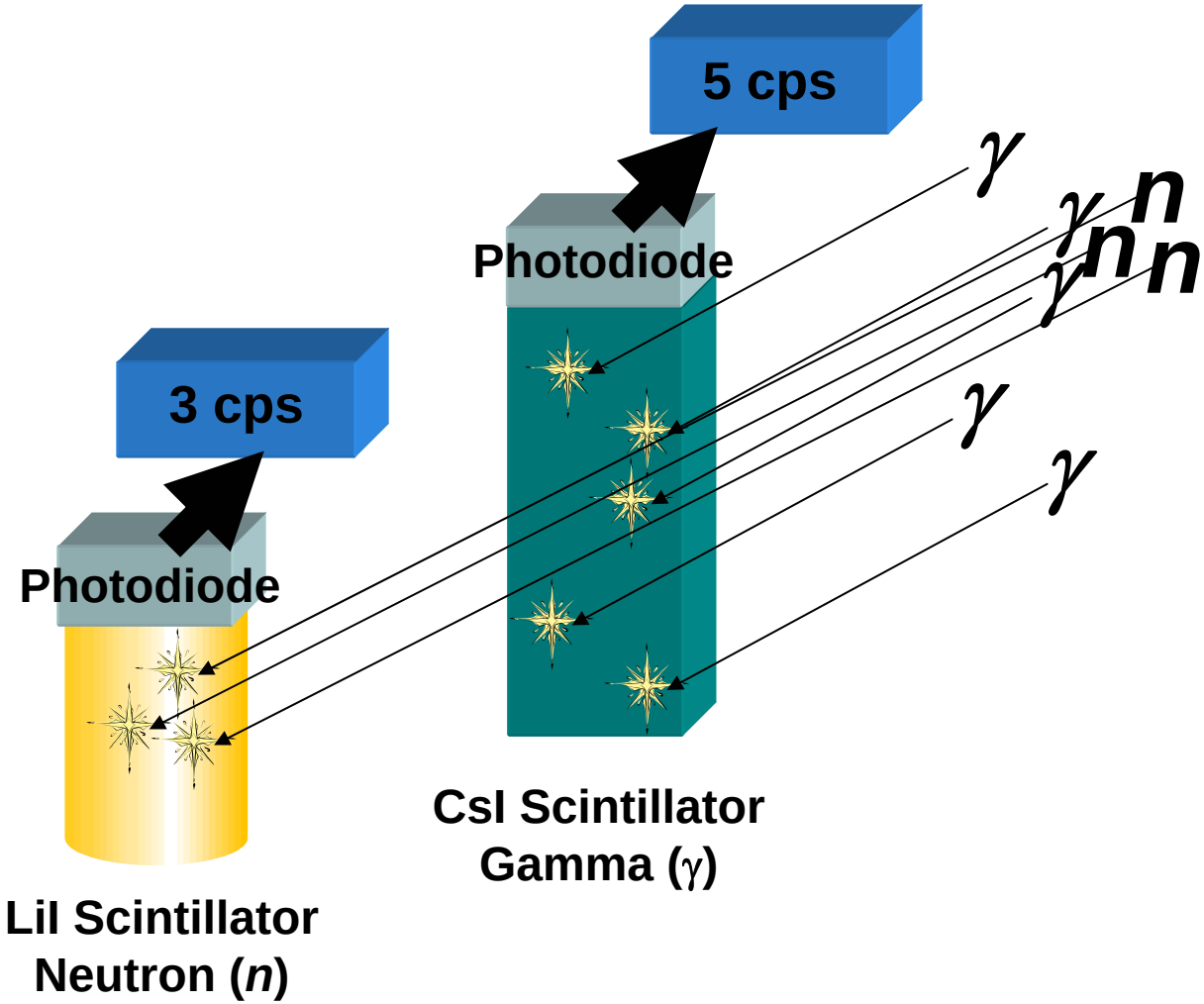
# Sensors

- Scintillation crystals
  - Used for fast gamma and neutron detection and spectroscopy
- Geiger-Mueller tubes
  - Used for gamma detection and high range applications
- Solid-state/semiconductor detectors
  - Used for fast gamma detection and high range applications

# Scintillation Crystals

- Convert energy from radiation into visible light (fluoresce), which is then collected by a photodiode or photomultiplier tube (PMT) and converted into electric current
- The amount of light collected is proportional to the amount of radiation deposited
- Crystals are very dense, and generally provide a fast, strong signal
- Can be inorganic, organic, or plastic

# Scintillation Radiation Detectors



# Inorganic Scintillators

- Alkali halide crystals are “doped” with an activator impurity to enhance performance
  - NaI(Tl): Thallium activated sodium iodide
  - CsI(Tl): Thallium activated cesium iodide
  - LiI(Eu): Europium activated lithium iodide
- Gamma: NaI, CsI, (BGO)
  - High light yield
  - Good for spectroscopy
- Neutron: LiI
  - Good for a wide range of neutron energies, particularly good for low energies

# Organic Scintillators

- Can be pure solids, liquids, or plastics
- Good for beta and alpha detection, and sometimes fast neutron detection
- Plastics are good where large crystals are needed, but they degrade more easily

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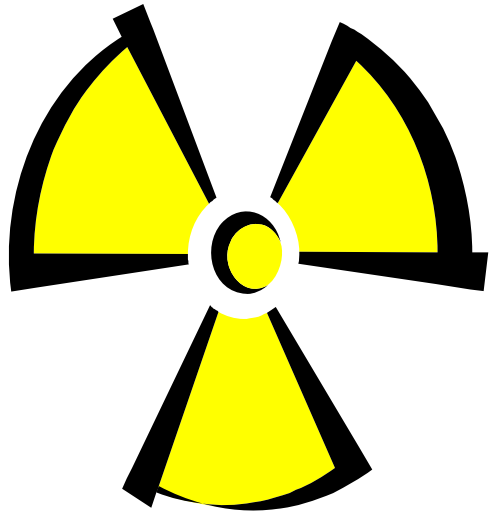

# Solid State Detectors

- Radiation is converted directly into electric current by the semiconductor
- Relatively fast response, with good energy resolution
  - Good for spectroscopy
- More prone to radiation damage than scintillators and GM tubes
- Compact and rugged → Good for personnel monitoring

# Solid State Detectors

- Silicon (Si)
  - Charged particle spectroscopy
  - Personnel monitoring
- Germanium (Ge)
  - Gamma spectroscopy
  - Must be cooled
  - Expensive
- Cadmium Zinc Telluride (CZT)
  - Good efficiency at low gamma energies
  - Expensive
  - Manufacturing difficulties

# Topics

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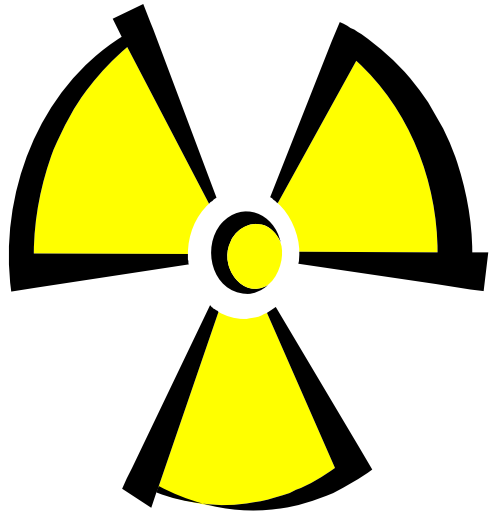
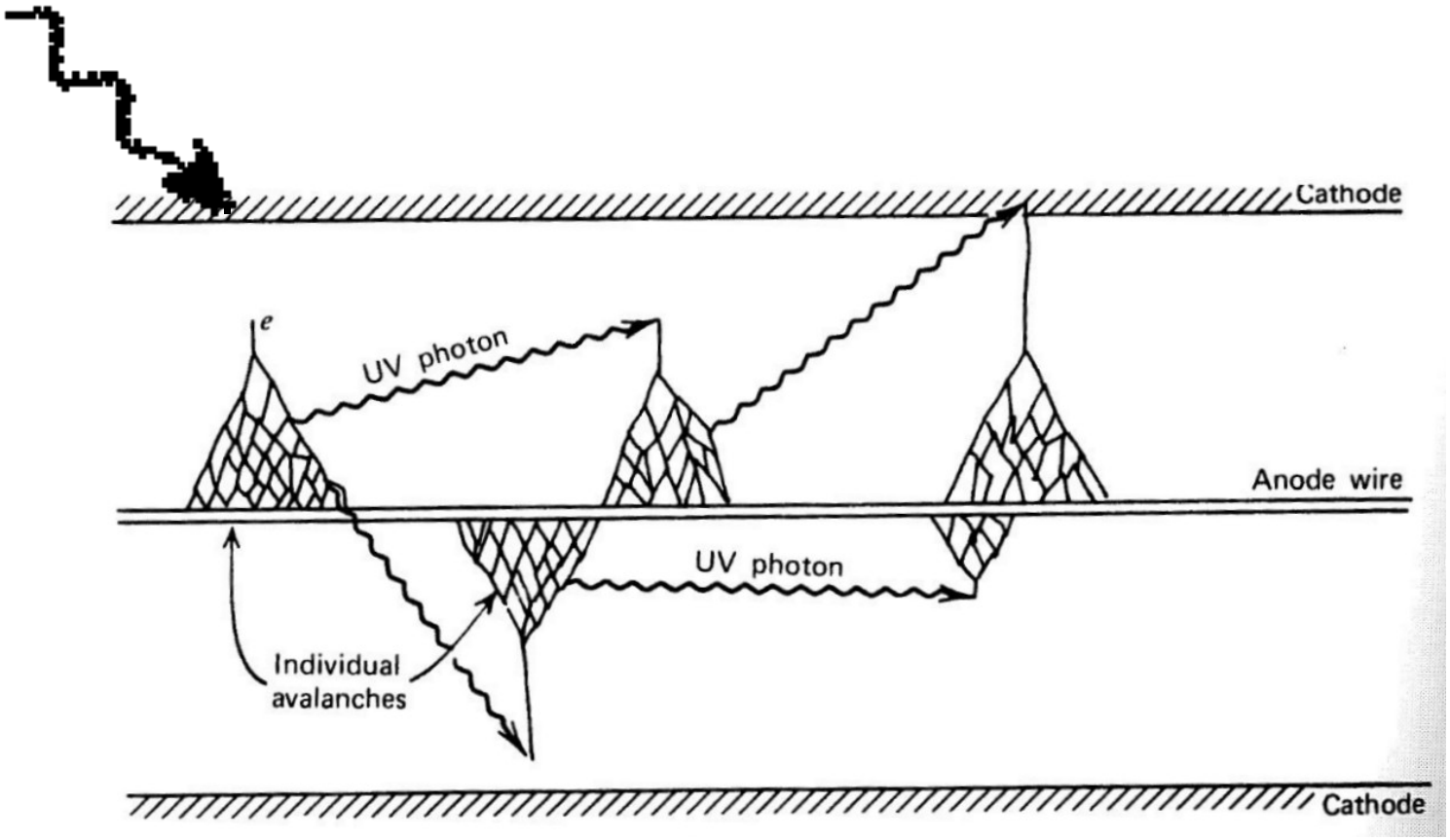


# Geiger-Mueller Tubes

- Gas-filled chamber with an electric field applied
- Radiation hits the gas or chamber wall (cathode) and knocks an electron into the chamber, which then causes a current in the anode



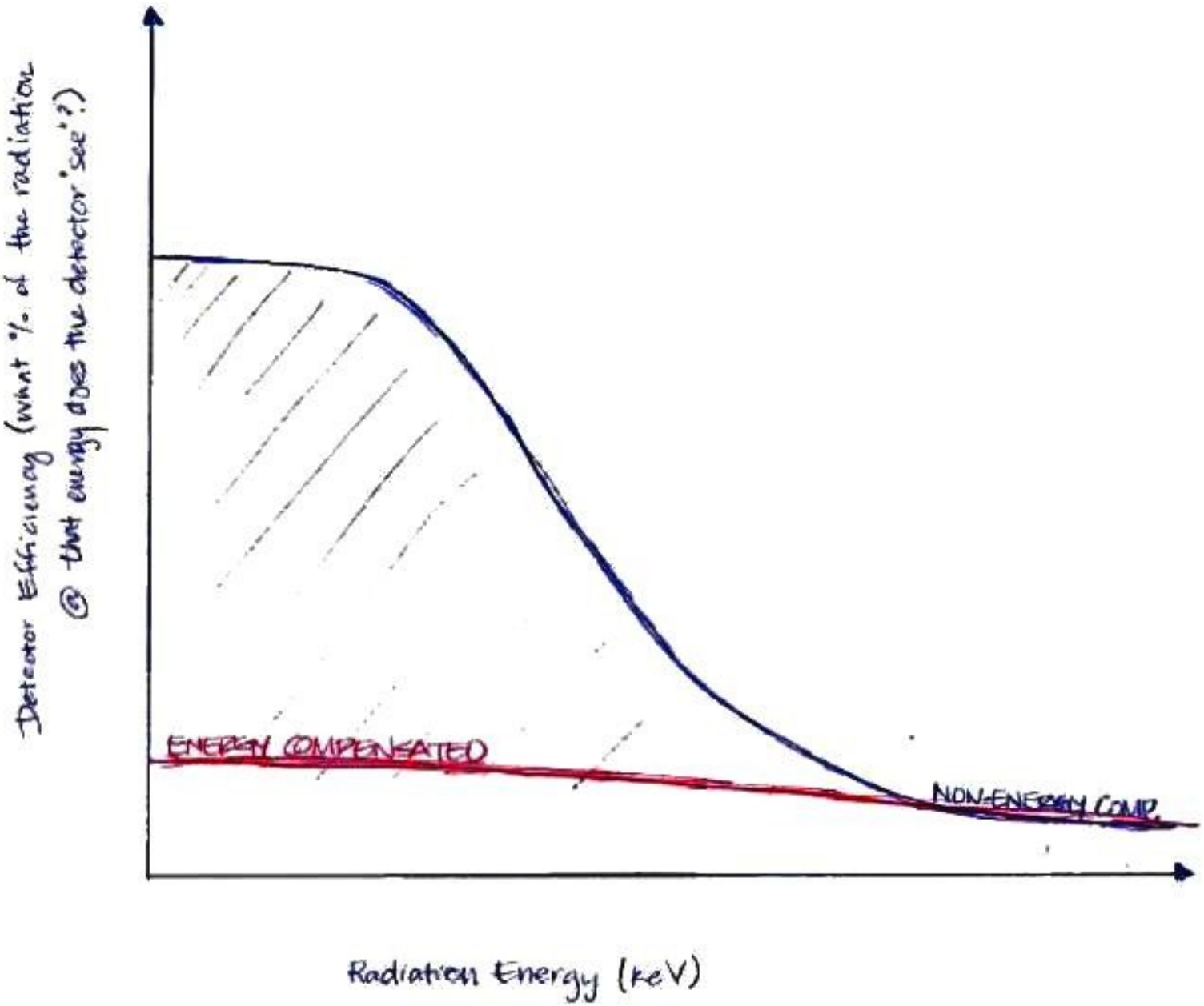
# Geiger-Mueller Tubes

- Functions as a counter only– no spectroscopy
- Large dead time– corrections have to be applied at high count rates
- Great for charged particle counting-- ~100% efficiency
- Counting efficiency for gamma can vary based on chamber materials and gamma energy

# Energy Compensation

- Each sensor/detector has an efficiency curve based on the energy of the radiation
  - Most sensors are more sensitive to lower energies→ skews readings
- Energy compensation evens out the efficiency curve by applying filters to the sensor to block out some of the low energy radiation
- G-M tubes are often energy compensated
  - Dosimeters
- Scintillators and solid state sensors are sometimes compensated

# Energy Compensation



# Detection Sensors

| | Scintillators | Geiger-Mueller (GM) Tubes | Solid-State |
|---|---|---|---|
| **Form** | Crystal with a light collection device attached (photodiode, PMT) | Gas-filled tube with an electric field applied | Radiation-sensitive integrated circuit |
| **Response Time** | Very fast | Medium | Fast |
| **Efficiency** | Very high | Varies/Medium | High |
| **Typical Uses** | Mostly detectors, spectroscopy | Mostly dosimeters, survey meters | Both detectors and dosimeters |
| **Additional Info** | Can be energy compensated, NaI and CsI crystals for Gamma, LiI for Neutron | Often energy compensated for better total actual dose reading | Prone to radiation damage at high doses |

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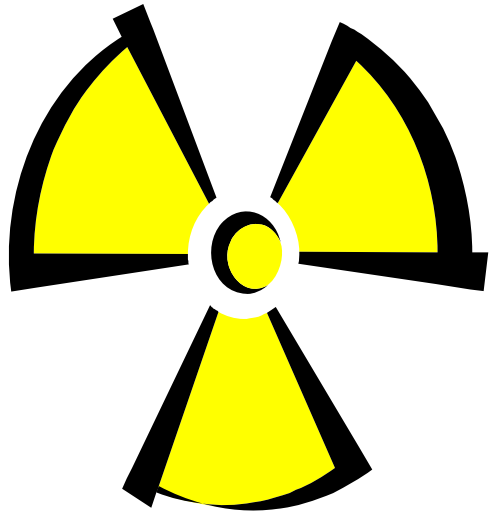

# Personal Radiation Detectors (PRDs)

- Pagers with real time measurement and alarms
- Fast-responding –use for searches and survevs for contamination
- Great for first-responders
- "Pervasive" monitoring
  - More sensors = more security
- *Not* energy compensated – optimized for greatest sensitivity to alarm for the highest threats
- Sensors
  - Scintillators

# Detector versus Dosimeter

- The speedometer tells us how many miles per hour we are traveling
- A dose rate meter (detector) tells us how many µSv or µrem are received per hour


- The odometer shows how many miles the car has traveled
- The dosimeter show many µSv or µrem one has received altogether

# ectronic Personal Dosimeters (EPDs)

- Pager that measures the **cumulative** radiation exposure for an individual
- Some give direct reading of dose rate
- Calculates total dosage in dose equivalent rate (Rem or Sv)
- Memory and alarm features
- Slower responding than detectors
- Energy-compensated with low interference
- Sensors
  - GM tubes
  - Solid-state

# Survey Meters & Spectrometers

## Survey Meters:

- Have alpha, beta, gamma and neutron detection capability
- Can survey for contamination
- Sensors
  - Geiger-Mueller tubes
  - Scintillators

## Spectrometers:

- Use the differences in radiation energies to determine which isotope is present
- Can identify contamination
- Sensors
  - Scintillators
  - Solid state

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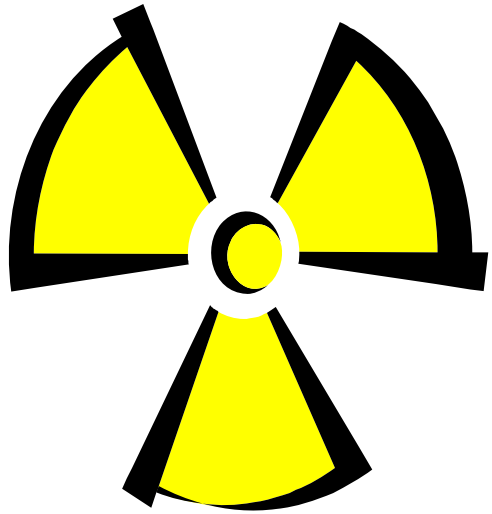

# Uses of Radiation Detection

- Law Enforcement
  - State & Local Police
  - FBI, Secret Service, Homeland Security
- Fire/HazMat
- Military (USCG, Navy, Army, Air Force)
- Points of entry
  - Customs, Border Patrol, TSA, port offices, shipping firms, bonded warehouses
- Industrial imaging, measurements
- Security officers in nuclear power facilities, government laboratories, banks
- Medical waste handling
- Mining operations
- Landfills
- Recycling Plants

# Commonly Orphaned Isotopes

## Commonly Available Isotopes That Are Suitable For RDDs

| Radioisotope | Half-Life | Alpha Emission | Beta Emission | Gamma Emission | Neutron Emission | Detect with GammaRAE II? |
|---|---|---|---|---|---|---|
| Cobalt-60 | 5.3 yrs | No | Low Energy | High Energy | No | Yes |
| Cesium-137 | 30 yrs | No | Low Energy | Delayed High Energy | No | Yes |
| Iridium-192 | 74 days | No | High Energy | High Energy | No | Yes |
| Stronium-90 | 29 yrs | No | High Energy | No | No | Yes |
| Americium-241 | 433 years | High Energy | No | Low Energy | No | Yes |
| Californium-252 | 2.6 years | High Energy | No | Low Energy | Yes (Spont. Fission) | Yes |
| Plutonium-238 | 88 yrs | High Energy | No | Low Energy | Yes (Spont. Fission) | Yes |

Source: "Commercial Radioactive Sources: Surveying the Security Risks," Monterey Institute of International Studies, 1/2003

# GammaRAE II Features

- Gamma (γ) radiation detector
- CsI (γ) crystal: Fast <2s response
- Alerts/Alarms: LOUD buzzer, big flashing LEDs, vibration– can be turned off separately
- Immersible (IP67) in water for easy decontamination
- Datalogging (60,000 points) downloaded via Bluetooth®
- Dust and shock resistant
- Battery run time: 800 hours (2 AA)


Protection through Detection

# GammaRAE II Features

- Reversible, backlit display
- Dose rate, approximate dose, peak rate, min rate, and status readouts
- Datalogging– transferred via Bluetooth® radio
- **Search Mode**: Alarm threshold set at a percentage above background
- **Safety Mode**: Absolute alarm thresholds set by the user
- Long calibration life

# GammaRAE II Applications

Protection through Detection

- First responders– alert to threats, protect responders
- Security at nuclear power plants and research facilities, airports, government buildings, banks, infrastructure
- Security at medical facilities (oncology, imaging, x-ray, radiology)
- Manufacturing facilities using radioactive materials
  - Nuclear fuel fabrication
  - Smoke detectors
  - Medical imaging equipment
- Customs & border patrols
- Law enforcement
- Military
- Government agencies
- HazMat teams, especially those near nuclear facilities
- Fire departments
- Police officers

# How to Use the GammaRAE II

- One pager per responder/person
- Can be used as a survey meter to find hidden radioactive material
- **Protects user** by telling them when they are near dangerous radiation fields
- Can be mounted in vehicles
- Use for basic protection
  - Areas where an incident is less likely

# NeutronRAE II Features

Protection through Detection

- Gamma (γ) and Neutron (n) detector
- CsI (γ) and LiI (n) crystals: Fast <2s response
- Alerts/Alarms: LOUD buzzer, big flashing LEDs, vibration– can be turned off separately
- Immersible (IP-67) in water for easy decontamination
- Dust and shock resistant
- Intrinsically safe
- Datalogging (60,000 points) downloaded via Bluetooth®
- Battery run time: 800 hours (2 AA)
- *Announced on February 13, 2006, available in April 2006*

# NeutronRAE II Features

- Reversible, backlit display
- Dose rate (γ & n (cps only)), approximate dose (γ only), peak rate, min rate, and status readouts
- Datalogging– transferred via Bluetooth® radio
- **Search Mode**: Gamma and neutron alarm thresholds set at a percentage above background
- **Safety Mode**: Absolute gamma alarm thresholds set by the user (neutron alarm is still relative to background)
- Long calibration life

# NeutronRAE II Applications

Protection through Detection

- First responders– alert to threats, protect responders
- Security at nuclear power plants and research facilities, airports, government buildings, banks, infrastructure
- Security at medical facilities (oncology, imaging, x-ray, radiology)
- Manufacturing facilities using radioactive materials
  - Nuclear fuel fabrication
  - Smoke detectors
  - Medical imaging equipment
- Customs & border patrols
- Law enforcement
- Military
- Government agencies
- HazMat teams, especially those near nuclear facilities
- Fire departments
- Police officers

# How to Use the NeutronRAE II

- One pager per responder/person– can be combined with GammaRAE II pagers
- Can be used as a survey meter to find hidden radioactive material
- **Protects user** by telling them when they are near dangerous radiation fields
- Can be mounted in vehicles
- Provides **advanced** protection to personnel– alerts when neutrons are present (a good indication of very bad things to come)

# Questions?

Protection through Detection

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