Office of Counterterrorism and Counterproliferation
Nuclear Incident Policy and Cooperation

Radiological and Nuclear Security Threats

This work was done by Mission Support and Test Services, LLC, under Contract No. DE-NA0003624, with the U.S. Department of Energy. DOE/NV/03624--0148

Objective

This module is designed to enhance awareness regarding radiological and nuclear security threats and the types of radioactive materials that can be used for criminal purposes or terrorist acts.

Goals

- Recognize Potential Radiological and Nuclear Security Threats
- Identify Categories of Radioactive Materials
- Understand the term Material Out of Regulatory Control (MORC)
- Learn about Medical, Commercial, and Naturally Occurring Radioactive Materials (NORM) sources
- Understand the basics of:
  - Radiological Dispersal Devices (RDD)
  - Radiological Exposure Devices (RED)
  - Inhalation, Ingestion, and Immersion (I^3)

Threat of Nuclear/Radiological Terrorism

“Terrorists and criminals will try to exploit any vulnerability in the global nuclear security system. Any country, in any part of the world, could find itself used as a transit point. And any country could become the target of an attack."

IAEA Director General Yukiya Amano
Press Release, November 2016

Malicious or Criminal Threats

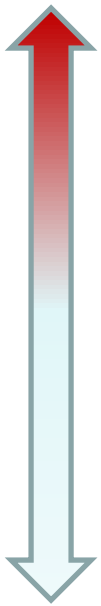
- **Lost or Stolen Legitimate Radioactive Materials**
  - Perception of malicious use or criminal act
- **Radiological Exposure Device (RED)**
  - Deliberate act to irradiate people at fixed point
- **Radiological Dispersion Device (RDD)**
  - Aimed at causing mass panic and contamination
- **Inhalation, Ingestion, and Immersion (I^3)**
  - Material forced into victims body for internal dose
- **Sabotage Attack Upon a Nuclear Facility**
  - Aimed at causing an uncontrolled radiation release
- **Improvised Nuclear Device (IND) or Nuclear Material**
  - Aimed at producing a device with a nuclear yield device

Threat Assessment

What is the Threat?

Radiological materials or devices with the potential of being used to conduct a malicious intent or criminal act

- ***Lost or stolen radioactive materials***
- Inhalation, Ingestion and Immersion (I^3)
- Radiological Exposure Device (RED)
- Radiological Dispersion Device (RDD)
- Improvised Nuclear Device (IND)



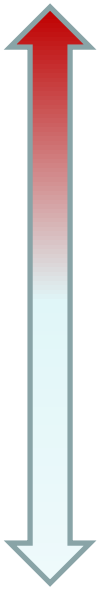
Highest Probability

Lowest Probability

Categories of Radioactive Materials

- ***Industrial and medical radioactive sources are widely used and routinely transported in commerce***
- ***Increases their probability of being diverted for criminal or terrorist acts***

Highest Probability



Industrial/Medical: Cs-137, Am-241, Co-60, Ir-192, Sr-90, Ra-226

Radiopharmaceuticals: Tc-99m, Tl-201, Ga-67, I-123, I-131, I-125, Au-198, Pd-103

Naturally Occurring Radioactive Materials (NORM): K-40, U-238, Th-232, and Commercial Products

Lowest Probability

Special Nuclear Materials (SNM): U-235, Pu-239, U-233

Vulnerabilities and Motivation

- **Vulnerabilities**
  - A large number of radioactive sources out of regulatory control have not been recovered
  - Radioactive sources at facilities of origin have inadequate protection and potential for theft
  - Sufficient materials for a RDD could be obtained relatively easily by criminals through theft and fraud
- **Motivation**
  - Reports showing intention to acquire and/or use radioactive materials for criminal purposes

Other Radioactive Materials Routinely Used in Commerce

Are these materials dangerous?

The following materials are not dangerous but are used in commerce and routinely detected when conducting radiological searches or surveys

Medical Radioisotopes

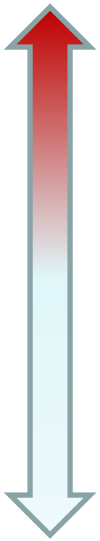
Naturally Occuring Radioactive Materials (NORM)

Commercial Products

Medical Radioisotopes

- ***The primary source (99%) of radiation alarms are individuals with medical radiopharmaceutical treatments***
- ***However, this is Not a sufficient radioactive material to pose a threat***

Highest Probability



Lowest Probability

Diagnostic – radiation source injected for imaging

Tc-99m (most common), Tl-201, Ga-67, I-123, I-125, I-131, In-111

Relatively short half-lives – hours to days

Relatively low activities < 740 MBq (20 mCi)

Therapeutic – radiation source inserted for treatment

I-125, Cs-131, Pd-103, Au-198 (permanent inserted seeds)

NORM

Naturally Occurring Radioactive Material (NORM)

NORM:

- Acronym for ***N****aturally* ***O****ccurring* ***R****adioactive* ***M****aterial*
- Includes all radioactive elements found in the environment

This includes:

- Long-lived radioactive elements, such as uranium, thorium, potassium, and their decay products, such as radium and radon
- NORM typically occurs in very small quantities in virtually all materials, but can be slightly elevated in certain materials and detectable with radiation detectors
- Routine items in commerce that are not under statutory regulation can contain small concentrations of NORM

Radioactive NORM Materials

- *Some commercial products contain NORM (K-40, U-238, Th-232) in small quantities, but when in bulk can appear as a radiation source*
- *However, there is not sufficient radioactive material to pose a threat*

Examples of products containing NORM:

- Fertilizer
- Ceramic tiles
- Granite
- Raw ores
- Porcelain
- Bricks
- Abrasives
- Absorbents

Activity < 370 kBq (10 μCi)

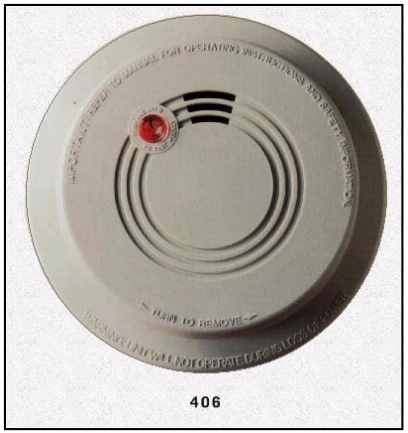
Radioactive Commercial Products

- ***Some commercial products use small quantities of radioactive materials and are safe to use***
- ***However, there is not sufficient radioactive material to pose a threat***

Examples of Commercial Products:

- Ra-226 in old dials, gauges, watches, clocks
- Am-241 in smoke detectors
- Cs-137 in spark gap electronics
- Th-232 in lantern mantels, camera lens, welding rods
- U-238 in glass, ceramics

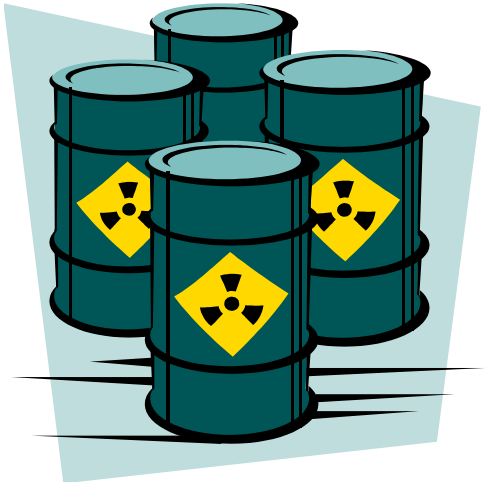
Activity < 370 kBq (10 μCi)



Nuclear or other Radioactive Material Out of Regulatory Control (MORC)

Material Out of Regulatory Control (MORC)

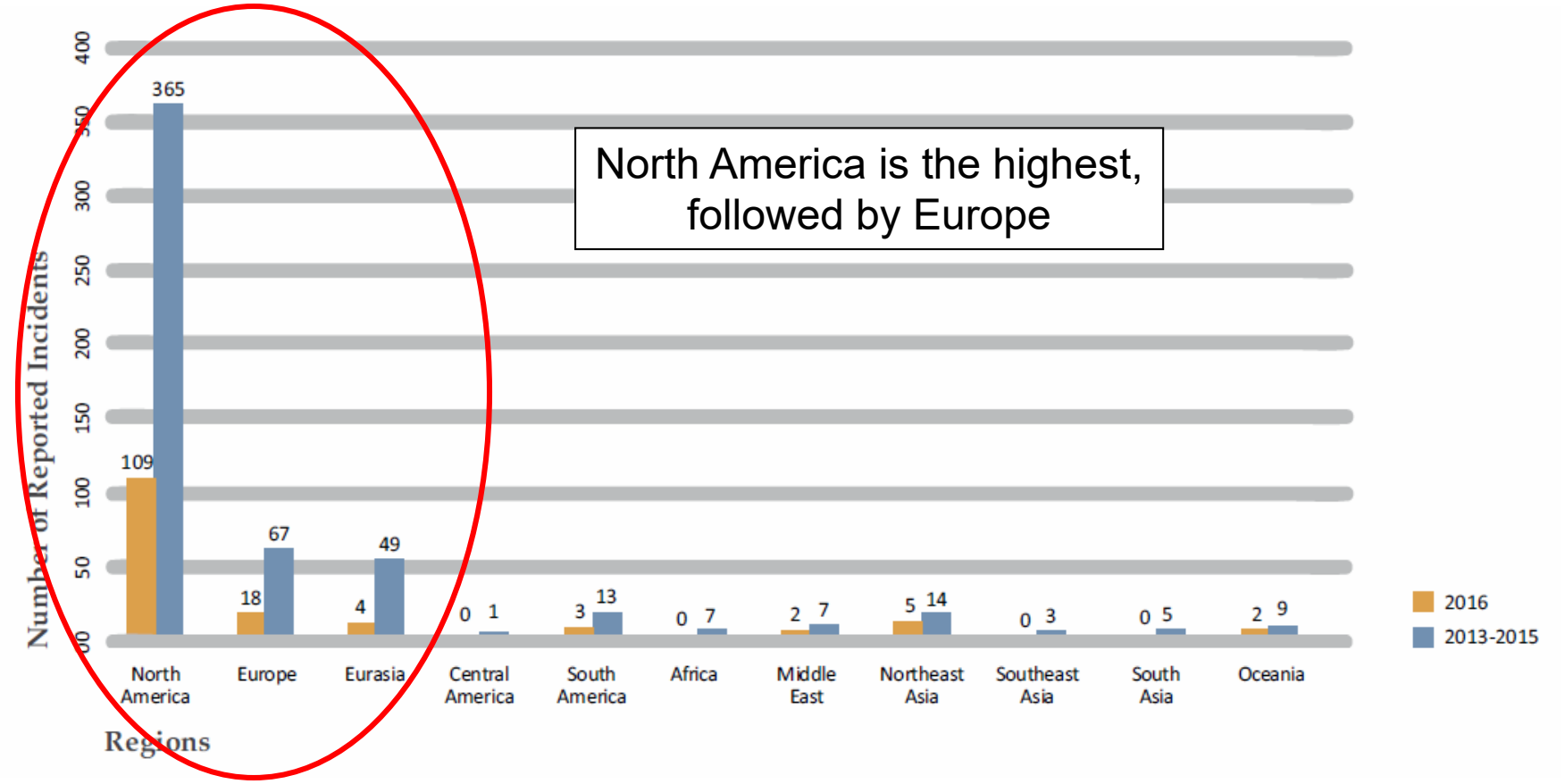
- *One of the most likely sources of radioactive material for malicious use is Material Out of Regulatory Control*
- *Each year, all around the world, hundreds of industrial radiation sources are discarded, orphaned, lost, or stolen*



Radiography Sources
and
Moisture Density Gauges

Examples of Recovered MORC

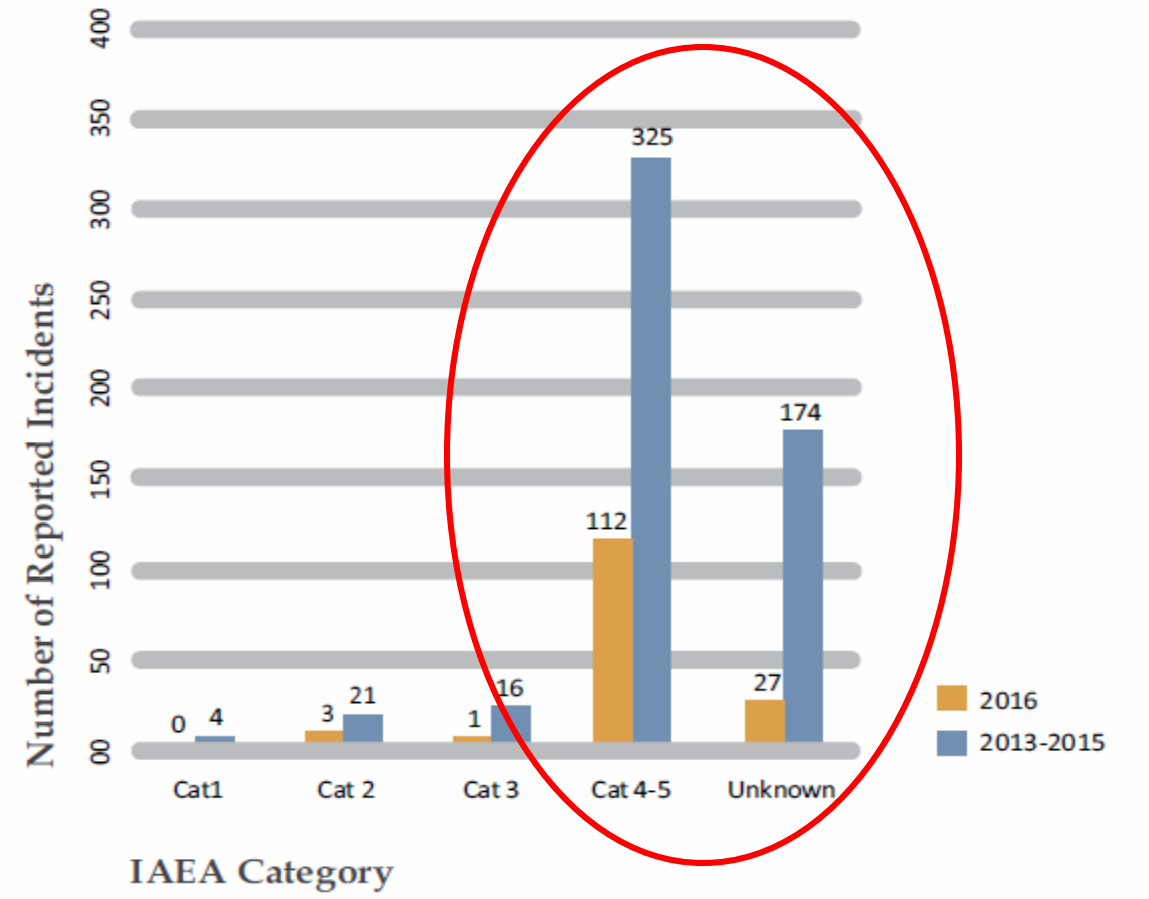
Reported Incidents by Region*



2013 - 2016: 683 reported incidents in 48 countries

*CNS Global Incidents and Trafficking Database, 2016 Annual Report, April 2017

Incident by IAEA Category*



Most incidents involved IAEA Category 4 and 5 sources

*CNS Global Incidents and Trafficking Database, 2016 Annual Report, April 2017

IAEA Categories for Radiation Sources*

- ***The IAEA Categorization System is based on the concept of "dangerous sources"***
- ***Based on the source activity, if not under control, could cause severe health effects***
- ***Category 1 is the most dangerous and Category 5 is the least dangerous***

Category 1: Radioisotope Thermal Generators, Irradiators, Tele-therapy Sources

Category 2: Industrial Radiography, High Dose Brachytherapy Sources

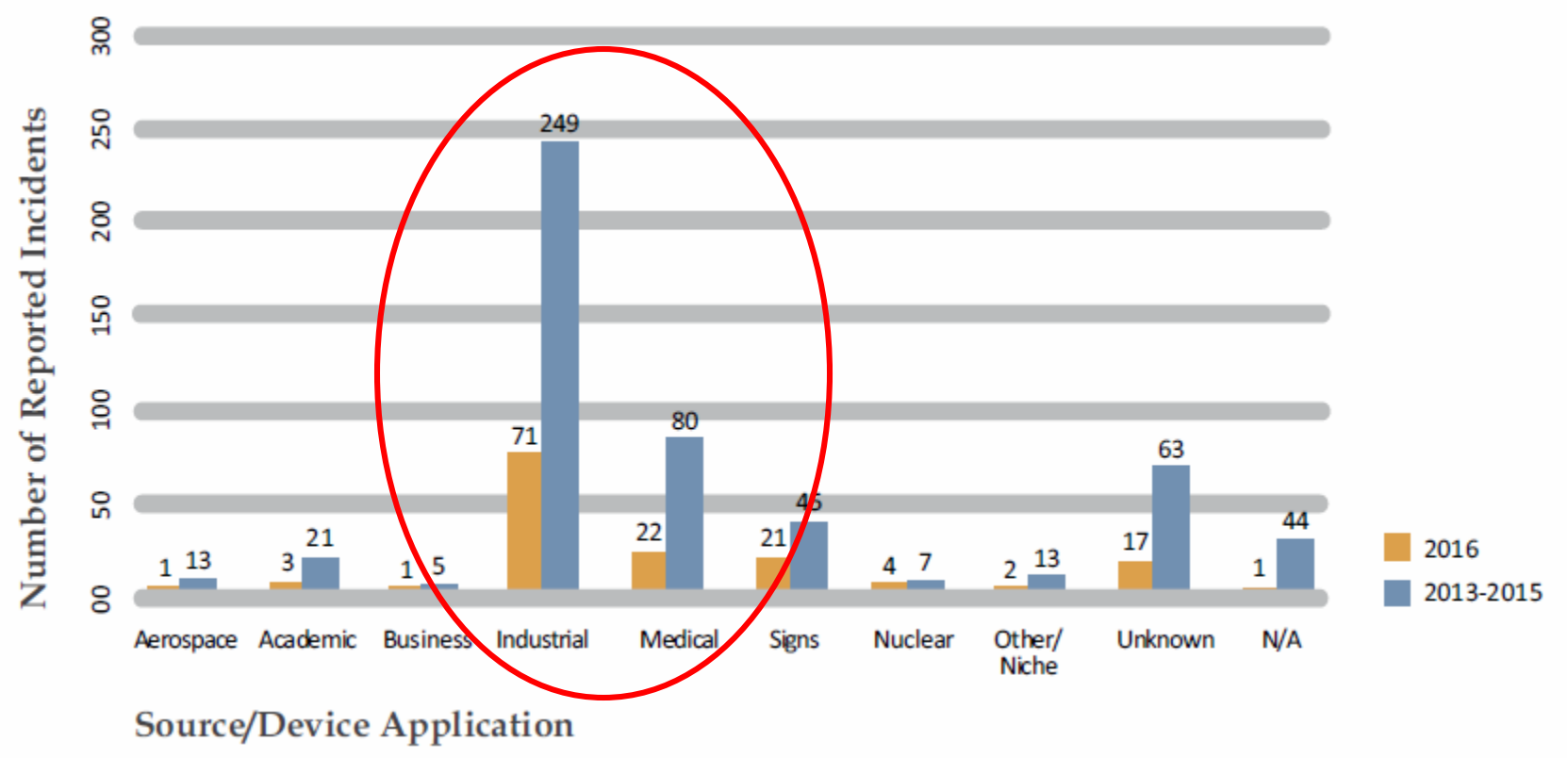
Category 3: High Activity Fixed Industrial Gauges, Well Logging Sources

Category 4: Low Dose Brachytherapy and Low Activity Industrial Gauges

Category 5: X-ray Fluorescence, Laboratory Test and Calibration Sources

*Categorization of Radioactive Sources, IAEA Safety Standards, No. RS-G-1.9 (2005)

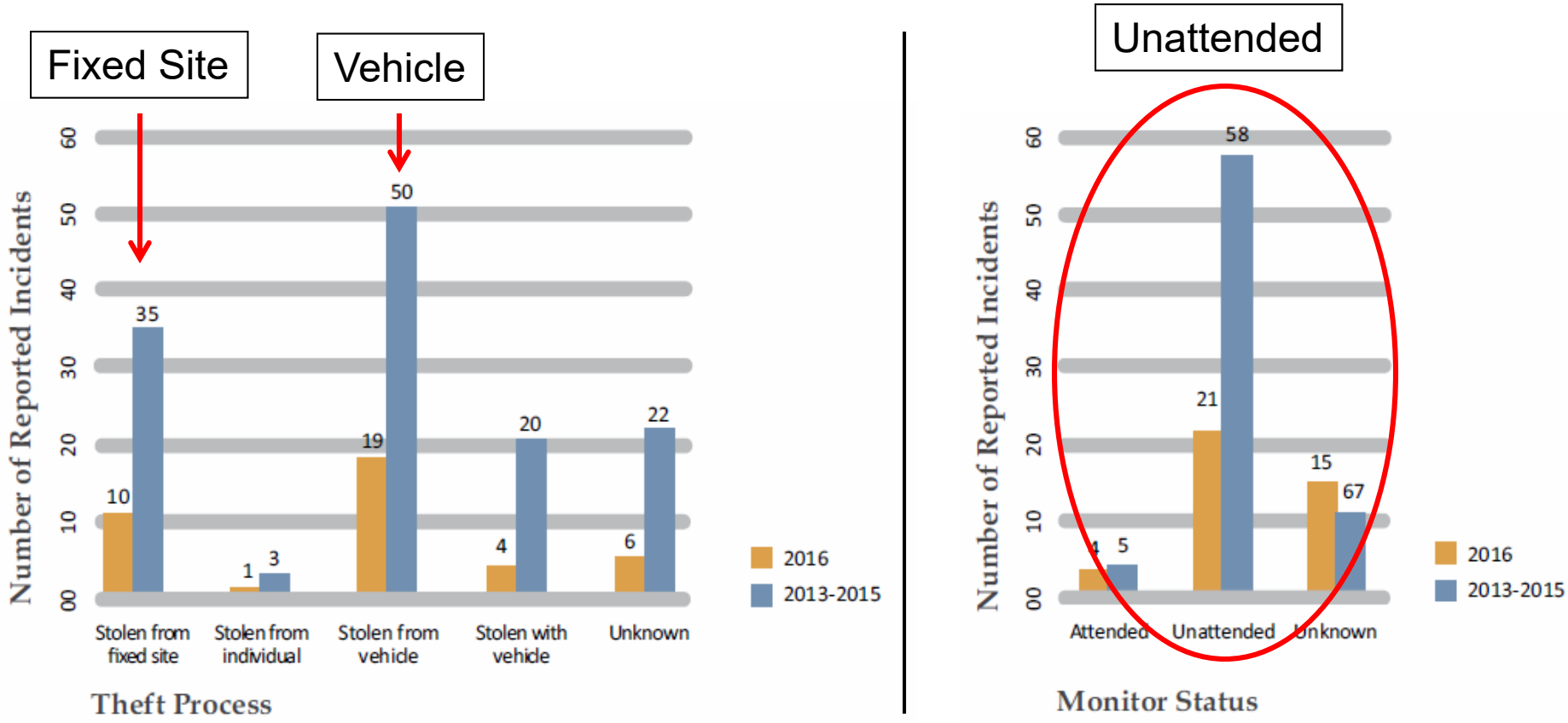
Source or Device Application*



Most incidents involved industrial or medical sources

*CNS Global Incidents and Trafficking Database, 2016 Annual Report, April 2017

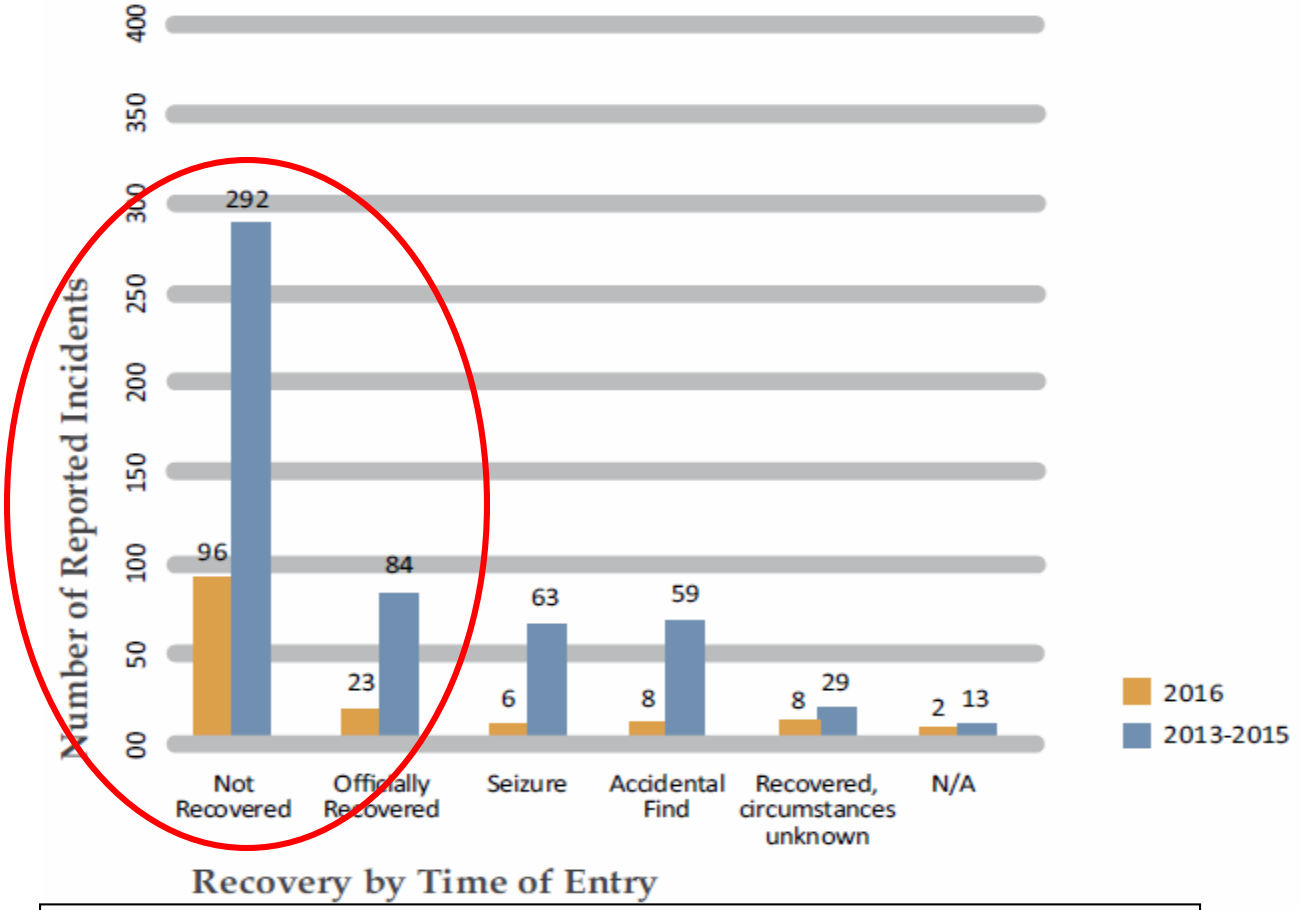
Type of Thefts/Monitor Status*



Theft Process – Most stolen from vehicles or fixed sites
Monitor Status – Sources most likely were unattended when stolen

*CNS Global Incidents and Trafficking Database, 2016 Annual Report, April 2017

If/How Material was Recovered*



Often sources are not recovered, followed by Officially Recovered, Seizures, and Accidental Finds

*CNS Global Incidents and Trafficking Database, 2016 Annual Report, April 2017

Incidents by Material Type*

Material of Principal RDD Concern	Incidents 2013-2016
Cesium-137	191 to 194
Americium-241	154 to 159
Iridium-192	41 to 42
Radium-226	32 to 36
Cobalt-60	26
Strontium-90	21

Nuclear Material Incidents, 2013-2016

Primarily involve Uranium – Depleted and Natural
Very few involve LEU/HEU or Pu-239

IAEA Illicit Trafficking Database reports 16 HEU/3 Pu incidents from 1993-2015

*CNS Global Incidents and Trafficking Database, 2016 Annual Report, April 2017

Dangerous Industrial/Medical Sources

High activity Cs-137, Ir-192, and Co-60 radiation sources are routinely used in industry

Radiography Camera

Activity from 750–3700 GBq (20–100 Ci)

Dangerous - Out of shield > 0.5 Sv/h (50 R/h) at 1 m

Gamma Irradiators

Activity from 3700–37000 GBq (100–1000 Ci)

Dangerous - Out of shield > 1 Sv/h (100 R/h) at 1 m

Tele-therapy Unit

Activity exceeding 220,000 GBq (6000 Ci)

Dangerous - Out of shield > 1 Sv/h (100 R/h) at 1 m

High Activity Sources are Difficult to Divert

Higher activity sources are more difficult to divert as they require heavy shielding and strict regulatory controls for access

Small radiography sources:

- **Typical activity MBq to GBq**
- **10-20 kg (22-44 lbs) shielding**

Medium radiography sources:

- **Typical activity ~1TBq**
- **100-200 kg (220-440 lbs) shielding**

Large irradiator source:

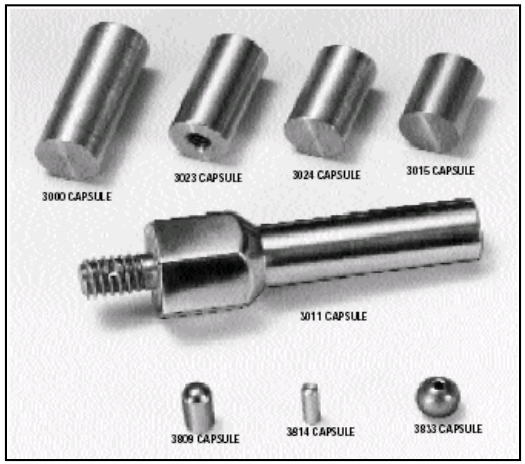
- **Typical activity 100's TBq**
- **> 1000 kg (2200 lbs) shielding**

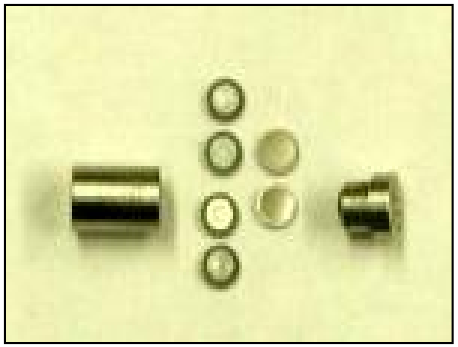
Source Materials and Holders

- *Sources of concern are typically small in physical size*
- *To buildup activity for industrial use, multiple capsules are employed*
- *Sources are typically double encapsulated, stainless steel, and very rugged*

Examples of Sources:

- Pig tail: 1-2 cm long by 0.2-0.4 cm diameter
- Capsule: 1-2 cm long by 0.5-1 cm diameter
- Disk: 0.1-0.2 cm wide by 0.1 cm thick
- Material Form: Metal, ceramic, or powder





Well-Logging Sources - AmBe

- Americium-241 (^{241}Am) is mixed with Beryllium (Be) to produce a neutron source used for down-hole well-logging measurements

- Material form is a dispersible pressed powder

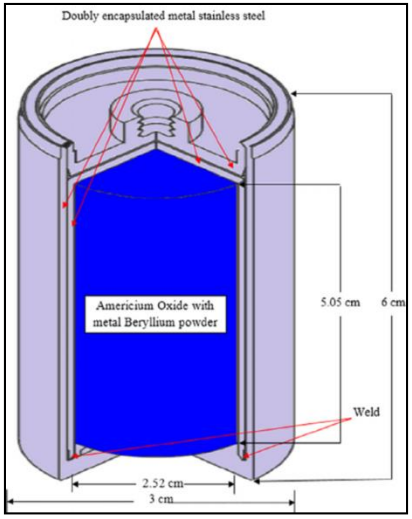
- Units have been lost by oil exploration companies

- Contains ^{241}Am, up to 740 GBq (20 Ci)

- Size: 1 cm diameter by 3 cm long

- In container, safe < 0.1 mSv/h (10 mR/h) at 1 meter

Dangerous - outside container
> 1 Sv/h (100 R/h) at 1 meter



Radioisotope Thermal Generators

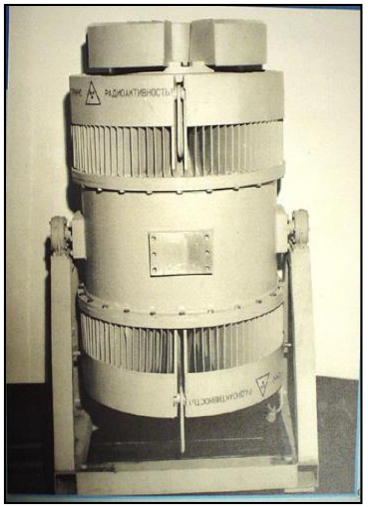
- Radioisotope Thermal Generators (RTGs) are used in remote areas and lighthouses where long term electrical power is required

- Note: Units have been abandoned with Strontium-90 (^{90}Sr) as the primary radioactive material

- Contains ^{90}Sr, up to 11,100 TBq (300 kCi)

- In container, safe < 0.1 mSv/h (10 mR/h) at 1 meter

Dangerous - outside container > 1 Sv/h (100 R/h) at 1 meter



- Review
- Questions
- Break?

Nuclear or other Radioactive Material Out of Regulatory Control

Case Studies

Case Study 1 – Africa 2012

A cargo container with metal products triggers an alarm while passing through a radiation portal monitor at a shipping port. Secondary inspection reported Co-60.

The manifest lists the contents as metal products - hammers, bolts, valves, etc. The container is opened and surveyed for dose rates and contamination.

The Co-60 was embedded in the metal housing of water meters. Nearly 200 boxes of water meters were contaminated at low activity levels.

How does Co-60 end up in commercial products?

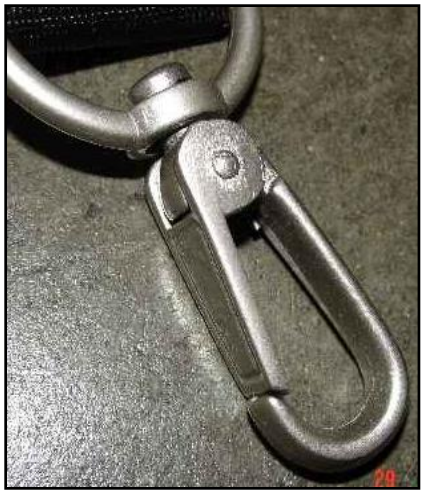
A high activity orphan Co-60 source is discarded in scrap metal and sent to a recycler. These radiography, medical and sterilization units can contain over 3700 GBq (100 Ci).

At the metal foundry, the Co-60 is smelted in a blast furnace with the scrap metal and ultimately distributed throughout the batch of molten metal.

The Co-60 contaminated metal is then formed into billets which are sold to manufacturers to make commercial products.

Examples of Co-60 in Recycled Metal

Access covers



Luggage fasteners

Tissue boxes

Case Study 2 – Mexico 2013

A vehicle transporting a Co-60 tele-therapy medical source was stolen from a gas station in Mexico. The source activity was 111 TBq (3000 Ci) and very dangerous.

The activity was so high that approaching the source posed a severe health risk to the responders. Robots were used to secure the source.

The source was secured in a shielded container and taken to the waste storage facility.

Case Study 3 – Southeast Asia 2015

A cargo container with scrap metal triggers an alarm while passing through a radiation portal monitor at a shipping port. Secondary inspection reports gammas and neutrons.

The manifest lists 18,000 kg (20 tons) of stainless steel scrap metal parts. The container was hand loaded.

The source was RaBe, 185 MBq (5 mCi), which had been removed from an industrial gauge. The holder was stainless steel.

Radiation Sources used for Malicious Intent, Criminal Act, or Terrorist Incident

Radiation Dispersal Device (RDD)

Radiation Exposure Device (RED)

Inhalation, Ingestion, Immersion (I^3)

Radiation Dispersal Device

A Radiation Dispersal Device (RDD) could contaminate a large area, deny its use, and cause mass disruption

Explosive with radioactive material

Dispersion in an urban environment

Denied contaminated area

Characteristics of an RDD

- ***A Radiation Dispersal Device (RDD) is often referred to as a "Dirty Bomb"***
- ***The illicit intent of an RDD is to disperse radioactive material and cause mass disruption***

An RDD:

- Contains a large quantity of radioactive material
- Must use radioactive material in a form that can be spread
- Uses conventional explosives or other means to spread
- Contaminates a large area with radioactive material, which denies use of that area
- Likely results in few injuries due to radiation exposure
- Can cause major psychological effects on the public
- Is NOT a nuclear explosion, but media and the public may think of it and treat it as one

Goiania, Brazil: RDD Comparison

- ***In 1987, an abandoned hospital tele-therapy unit was stolen by metal scavengers***
- ***Source was removed, disassembled, and the radioactive material inadvertently dispersed***

Tele-therapy unit containing 52 TBq (1400 Ci) cesium-137 (^{137}Cs) in powder form.

Impact of the spread of Cesium-137 powder:

- Generated 6000 tons of radioactive waste for disposal from 93 grams of Cesium-137
- 755 people worked for three months in the main cleanup effort
- Cleanup threshold was 370 GBq/km^2 (10 Ci/km^2) for ground contamination
- Population in and near Goiania suffered major psychological effects
- 250 people were contaminated, and 5000 more people came to medical facilities claiming acute radiation symptoms
- Four people died due to radiation exposure from both contact and ingestion

Radiation Exposure Device

A Radiation Exposure Device (RED) could be used to expose the public or individuals to high radiation doses

Major Public Event

Festival

Unshielded high activity radiation source

Characteristics of an RED

- ***A Radiation Exposure Device (RED) is designed to expose people to dangerous levels of radiation***
- ***Individuals exposed to high levels of radiation will exhibit symptoms of radiation sickness***

An RED:

- Has a large quantity radioactive material
- Is hidden in a place where it will expose people to radiation
- Is left unshielded (and not intended to spread contamination)
- Delivers a higher dose the closer people get to the device
- Results in serious injuries for people who are near it for a long time
- Can create major psychological effects on the public
- Is NOT an RDD or nuclear explosion, but media and the public may interpret it as one

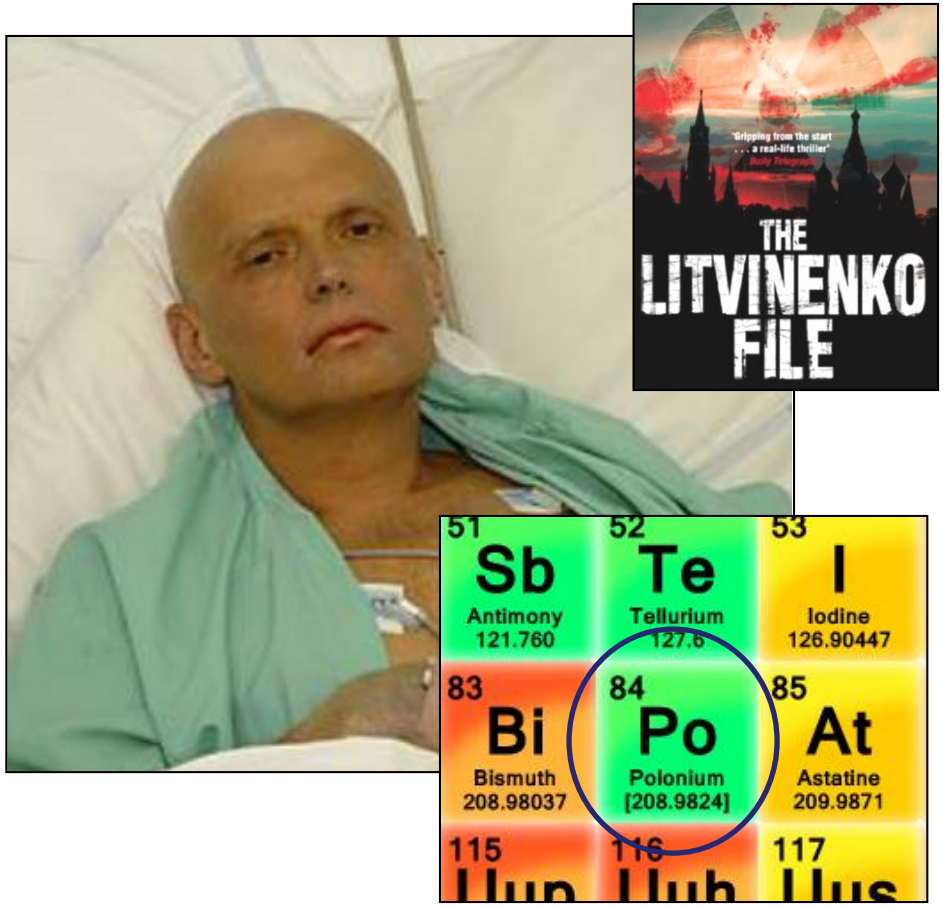
Top 10 Targets for Use in RDD's and RED's

1. Transportation of cobalt-60 sources
2. Tele-therapy source user facilities (cancer treatment centers)
3. Disused and orphaned RTGs
4. Orphaned seed irradiators
5. Industrial and blood irradiators, radiography sources in use
6. Sales and resales of cobalt-60 sources and radiography sources
7. Well-logging source users
8. Disused well-logging sources
9. Sales and resales of radiography sources and blood irradiators
10. Transportation of radiography, well-logging, and blood irradiators

Litvinenko Case Study - London 2006

Inhalation, Ingestion, and Immersion (I^3)

Litvinenko was poisoned when he ingested (drank) tea contaminated with radioactive polonium-210 in October 2006 (died in November 2006)



^{210}Po is difficult to detect by standard gamma spectroscopy (only 1 in 10,000 decays results in a gamma ray)

- *It is primarily an alpha emitter, an internal hazard*

Characteristics of an I^3 Source

The Inhalation, Ingestion, and Immersion (I^3) of radioactive material is designed to poison with internal radiation exposure

An I^3 Source:

- Uses a small quantity of radioactive material to cause serious harm
- Produces medical symptoms common to other illnesses
- May use radioactive material which requires special instruments to detect
- May require laboratory analysis to confirm the radioisotope
- Can cause major injuries significant and be life threatening
- Has limited medical treatments and often has no cure

Summary

It is important to recognize and understand potential threats using radioactive materials:

- An important area of concern for potential malicious use or criminal acts is Material Out of Regulatory Control (MORC)
- There are other legitimate radiation sources routinely used in commerce including medical isotopes, NORM, and commercial products
- Working knowledge of RDDs, REDs, and I^3 is critical information for the safety of emergency responders and protecting the public

Office of Counterterrorism and Counterproliferation
Nuclear Incident Policy and Cooperation

Radiological and Nuclear Security Threats

Questions/Discussion