

# Radioactivity

Lecture 26

Radioactivity and Homeland Security

# The New Fear: Terrorists!



TERROR  
ALERT

Since 911 fear of terror attacks dominates the discussion. The fear of nuclear terror through small or medium sized “nuclear bombs” from former Soviet arsenals and fear of “dirty bombs” makes headline news in the media channels.

# Terror as a Weapon

Terrorism is the ... deliberate targeting of Civilians in order to undermine their support for the politics of their political leaders” (Caleb Carr 2002)

Deliberate use by military forces

- o Roman Army: 1<sup>st</sup> to 3<sup>rd</sup> century
  - o Mongol Armies: 13<sup>th</sup> to 15<sup>th</sup> century
  - o German Navy: unrestricted submarine warfare in WW1
  - o Japanese Army: Manchuria, China, Philippines, ...
  - o Spanish Army: Civil War in Spain
  - o German Armies: occupation policies in WWII
  - o British Air Force: Bomb War against cities in WW2
  - o US Air Force: Bomb War against civilian targets Germany & Japan in WW2,  
Hiroshima & Nagasaki  
Vietnam
  - o Israeli Army: Palestine population
  - o Yugoslav Army: Muslims, Croats, Albanians
  - o Indonesian Army: East Timor
  - o Myanmar Army: Rohingya
- And many examples more ....

# Guerilla

Guerilla: civilian fighters against occupying forces:

- o Spanish Guerilla (little war) against Napoleonic troops
- o Russian partisans against German Armies
- o Polish and Yugoslavian partisans against German Armies
- o French Resistance against German Occupation
- o Kuomintang & Red Army against Japanese Occupation
  
- o American Revolution against British Rule
- o Boers against British take-over of Transvaal
- o Mau-Mau Uprising against British Colonial Rule in Kenya
- o Vietminh against French Colonial Forces in Vietnam
- o Front de Libération Nationale – FLN fighters against French Colonial Forces in Algeria
- o Vietcong against US occupation in South Vietnam
- o Sunni Iraqi against US occupation in Iraq
- o Taliban against US troops in Afghanistan
- o East Timor against Indonesian occupation

Strictly against military occupation forces and collaborators

Against occupation and colonial forces including civilians (settlers, farmers)

Second category often depicted as terrorist acts against legal government institutions!

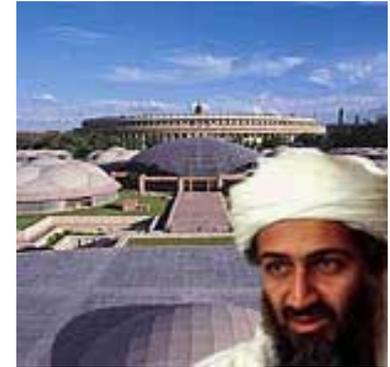
# Terrorist Movements

Terrorist actions target mainly civilian population and structures avoiding military & government installations

- o Assassins in 9<sup>th</sup>-13<sup>th</sup> century middle east
- o Anarchist terror in 19<sup>th</sup> century Europe
- o Ku Klux Klan in the US
- o IRA in Ireland and Great Britain in 20<sup>th</sup> century
- o Irgun Zvai Leumi & Lehi movement in Israel in 1940s
- o Al Fatah in Israel, Jordan, Palestine in 1970/80s
- o Red Army Fraction in Germany 1970s
- o Red Brigades in Italy 1970s
- o Euskadi Ta Askatsuna (ETA) in Spain
- o Shining Path in Peru
- o Zapatista movement in Mexico/US
- o Oklahoma City bombing
- o Unibomber (Ted Kaczynski) in 1990s
- o Right to life movements
- o Islamic Al Qaeda in 2000s
- o ISIS in 2010s



Timothy McVeigh  
Osama bin Laden



The old Man of the Mountain



Present and future generations



# Awareness in US population



Confusion in US about differences between guerilla & terrorist!  
Ignorance and confusion also about geographical location, historic reason, historic, economic, and sociological background of terrorist attacks.

# “Terrorists” Attacks

"one man's terrorist is another man's freedom fighter".

Conventional weapon based attack more likely and easier to arrange as recent history has demonstrated, but a successful nuclear attack would provide high visibility and ensure long term impact.

Logistical problems include:

Generating nuclear material ( $^{235}\text{U}$ ,  $^{239}\text{Pu}$ ); huge industrial effort requires breeder reactor and diffusion or centrifugal based separation facilities (~10-20 years), requires hosting state resources

Provision of nuclear bomb material ( $^{235}\text{U}$ ,  $^{239}\text{Pu}$ ); only possible from stockpiles of exiting nuclear powers (Israel, Pakistan, North Korea) or leftover supplies from former nuclear powers (Kazakhstan, Uzbekistan, Ukraine).

**This is not inconceivable!**



Smaller scale destruction by  
transportable nuclear device



# Preferred Target - High Visibility Object

1 kT Weapon

White House

**DYNAMIC OVERPRESSURE**

Penetrating Wounds

Capitol

The Mall

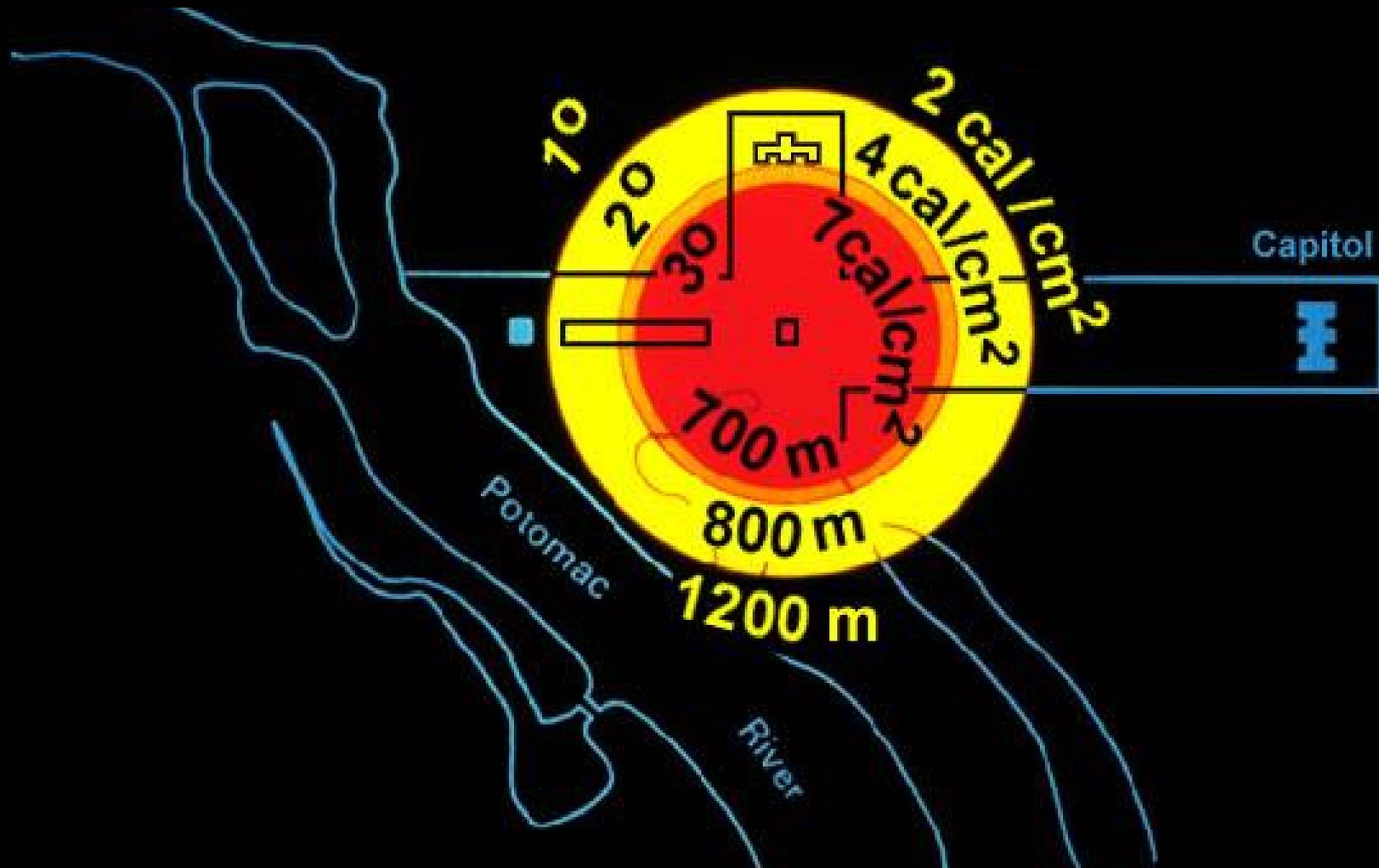
Washington Monument

e.g. White House

LD 50  
11 m/sec  
350 m



# Effective Range For Thermal Energy 1 kT Weapon



# Radiation effects would be limited to 10-20 km circle



# DIRTY BOMB

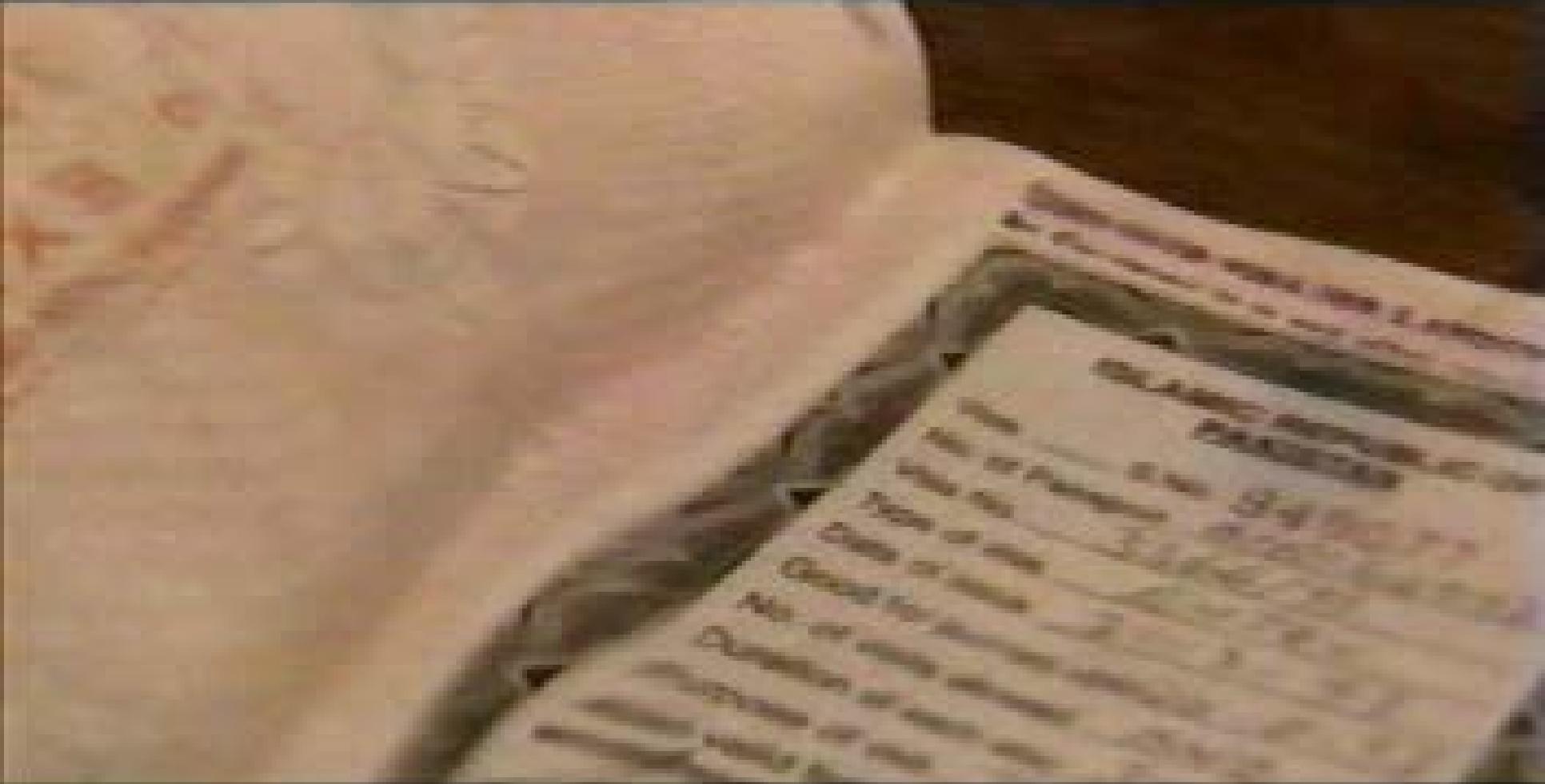




Classical version seeks to enhance the production of long-term radioactivity by adding “seed material” for neutron capture, e.g.  $^{59}\text{Co}(n,\gamma)^{60}\text{Co}$  – cobalt bomb.

The theorized **cobalt bomb** is a radioactively "dirty" bomb having a cobalt tamper. Instead of generating additional explosive force from fission of the uranium, the cobalt is transmuted into  $^{60}\text{Co}$ , which has a half-life of 5.26 y and produces energetic (and thus penetrating)  $\gamma$  rays. The half-life of  $^{60}\text{Co}$  is just long enough so that airborne particles will settle and coat the earth's surface before significant decay has occurred, thus making it impractical to hide in shelters. This would contaminate the bombed area for nearly 50 years.

What is a “Dirty Bomb” today?



# The New “Radiological” Version

The radiological dirty bomb would contain a small or medium amount of explosives (10 to 50 pounds [4.5 - 23 kg] of TNT, for example) with a small amount of low-level radioactive material (say a sample of  $^{137}\text{Cs}$  or  $^{60}\text{Co}$  from a university lab or more likely from a hospital radiology department).

To contaminate an area of  $10,000\text{m}^2$  (circle of  $\sim 60$  m radius) with  $\sim 1$  Ci/ $\text{m}^2$  ( $<1$  rad dose for by-passer) from material transported in a regular suitcase you need an initial source of  $\sim 10,000$  Ci radioactive material in your explosive device. If the material is  $^{60}\text{Co}$  this activity corresponds to  $\sim 90\text{g}$  of pure  $^{60}\text{Co}$ . The dose rate is  $\sim 20$  rad/s (depending how the carrier would hold the suitcase). For 1 h hike from terrorist headquarter to e.g. Times Square in New York the carrier would receive a lethal dose of 72000 rad. Major Pb shielding required for 1.076 and 1.33 MeV  $\gamma$  radiation from  $^{60}\text{Co}$  radioactive decay.

(A regular laboratory  $^{60}\text{Co}$  source has an activity of  $<10^{-5}$  Ci.) An “effective” dirty bomb provides substantial logistical problems on the delivery side! Possible sources are hospital radiation devices.

# Identification of possible sources for larger amounts of radioactive material

Categorization of danger in terms of Activity/Dangerous activity A/D activity: D

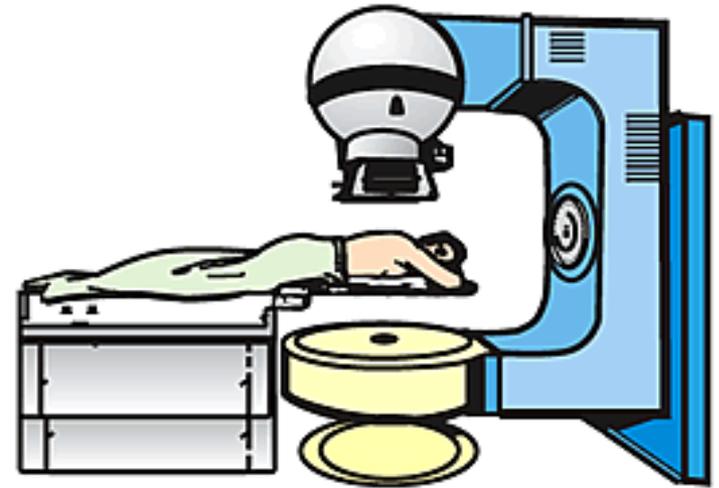
radionuclide	TBq	Ci	IAEA category of Dangerous Activity	A/D > 1 is dangerous
<sup>60</sup> Co	0.03	0.8		
<sup>137</sup> Cs	0.10	3.0		
<sup>192</sup> Ir	0.08	2.0		
<sup>241</sup> Am	0.06	2.0		

Category	Practice	Activity ratio (A/D)
1	Radioisotope thermoelectric generators; irradiators; teletherapy; gamma knife	$A/D \geq 1,000$
2	Gamma radiography; brachytherapy (high/medium dose rate)	$1,000 > A/D \geq 10$
3	Fixed industrial gauges (e.g., level, dredger, conveyor gauges); well logging	$10 > A/D \geq 1$
4	Brachytherapy (low-dose rate except eye plaques and permanent implants); thickness/fill-level gauges; portable gauges, static eliminators, bone densitometers	$1 > A/D \geq 0.01$
5	Brachytherapy (eye plaques and permanent implants); x-ray fluorescence devices; electron capture devices	$0.01 > A/D \geq \text{exempt/D}$

Highest risk is in “unprotected” medical facilities

# Medical Sources

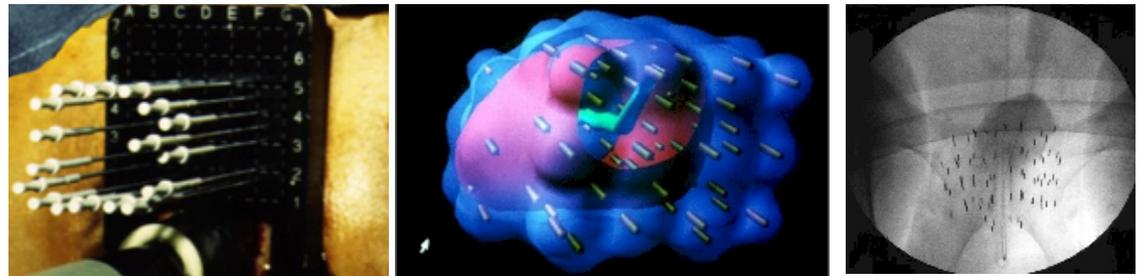
Sources are mainly designed for the radiation treatment of cancer patients



## Theletherapy units

More than 10,000 medical sources of  $^{60}\text{Co}$  ( $T_{1/2} \approx 5\text{y}$ ),  $\sim 100 \text{ TBq} \approx 3000\text{Ci}$  each. Each capsule contains 10,000 pellets with each pellet 100 GBq

Third world countries prefer the less expensive  $^{137}\text{Cs}$  sources ( $T_{1/2} \approx 30\text{y}$ ) which comes as highly dispersible CsCl salt. Each unit contains  $\sim 100 \text{ TBq} \approx 3000\text{Ci}$ .



## Brachytherapy units

Brachytherapy sources are more abundant but have lower individual radioactivity:  $^{226}\text{Ra}$ ,  $^{137}\text{Cs}$ , and  $^{192}\text{Ir}$ , with typical activity levels of 0.1-1.0GBq. The half-life of the radioactive elements is typically shorter than the ones used for Theletherapy.

# Example for careless handling: Goiania, Brazil

A radiotherapy unit had been abandoned in a clinic which was being demolished. The unit had a source consisted of 1,375 Curies of cesium-137 in the form of cesium chloride salt, sealed within two nested stainless steel containers to form a 5-cm diameter capsule. Two individuals dismantled the unit and extracted the source. Both began vomiting on the 13. September. The unit material was sold to a junkyard, a blue glow from the source container was observed that night; a number of people came to view the capsule. On the 21. of September the source material was removed and distributed among several people, some of whom spread it on their skin. Around the 23. of September several junkyard employees were exposed while further dismantling parts of the unit. ...



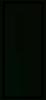
# Dirty Bomb Scenario #1 (~2500 Ci)



# Dirty Bomb Scenario #2 (~2500 Ci)

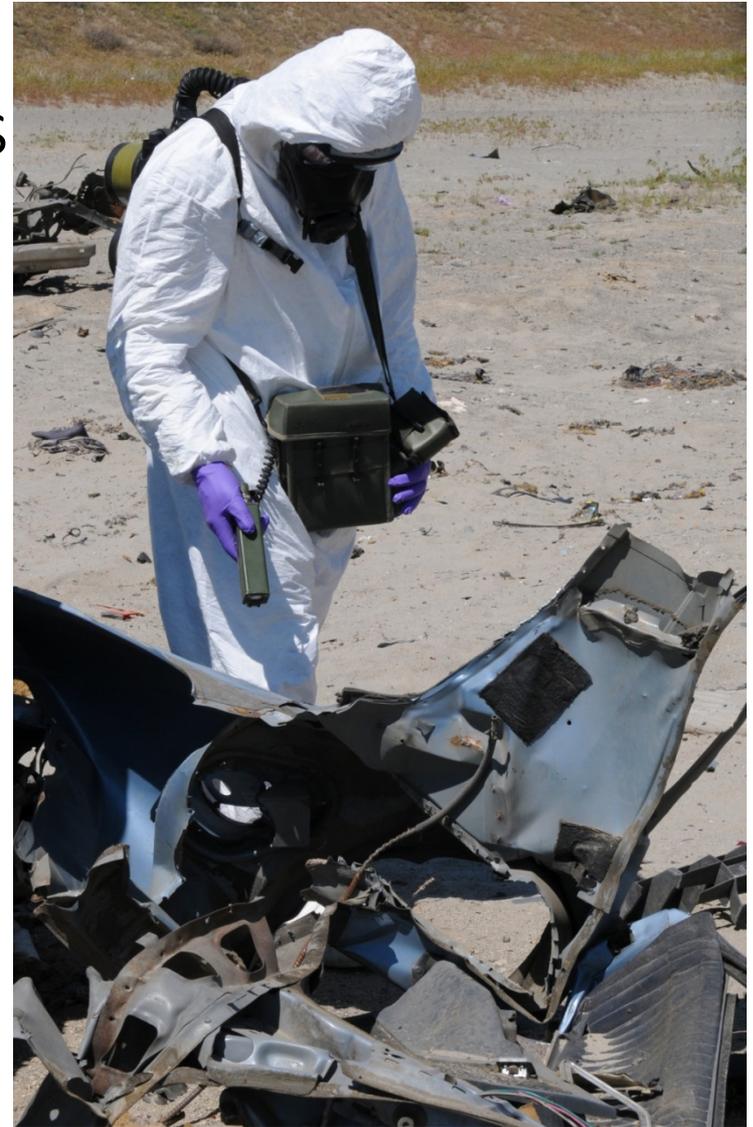


# Requirements for being prepared for possible Al Qaeda dirty bomb threats



# Homeland Security Applications

- Border Control Applications
- Detector developments
- Radiation Detection and Monitoring
- Nuclear Forensics
- Terrorist Attacks
- Radiological Emergency and Response



# Border Security

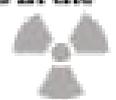
Over 7 million cargo containers enter U.S. ports each year. Less than 2% of the actual containers are surveyed for the presence of radioactive materials. The U.S. Department of Commerce anticipates the number of cargo containers entering the U.S. to quadruple over the next 20 years. This high volume of material movement is a significant challenge because a balance between security and commerce must be established. Radiation portal monitors (RPMs) used in ports are mostly comprised of plastic scintillation detectors and some have additional neutron detectors that monitor containers by looking for counts that exceed a threshold.



# AIRPORT SECURITY 2012 AND BEYOND



**2** Radiation detectors disguised as security barrier poles scan passengers for traces of radioactivity. A radiation detector sits just under the pole's roll-out extendable belt mechanism. The battery sits in the base. It can send warnings wirelessly to a central control unit.



**Detector**

**Battery**



**1** Passenger arrives at check-in to deposit hold luggage before going through security with or without carry-on hand baggage.

**Air conditioning**

**6**

**6** Hand luggage scanner checks for explosives, dangerous liquids, drugs. New portable scanners take a swab from skin or bags to check for traces of suspect materials.



**7** Biological threat Aerosol detectors monitor the air for airborne biological threats such as anthrax,

**7**



plague bacteria, smallpox viruses or deadly ricin poison, shutting down the air conditioning system and sealing off rooms to contain the toxic threat and prevent it spreading across an entire airport or being carried onto planes.



**8** Command and control centre, receives data from all the scanners, cameras and radar detectors giving an overview of whole airport security.

**3** Smart camera scans the area looking for suspicious faces or movements.

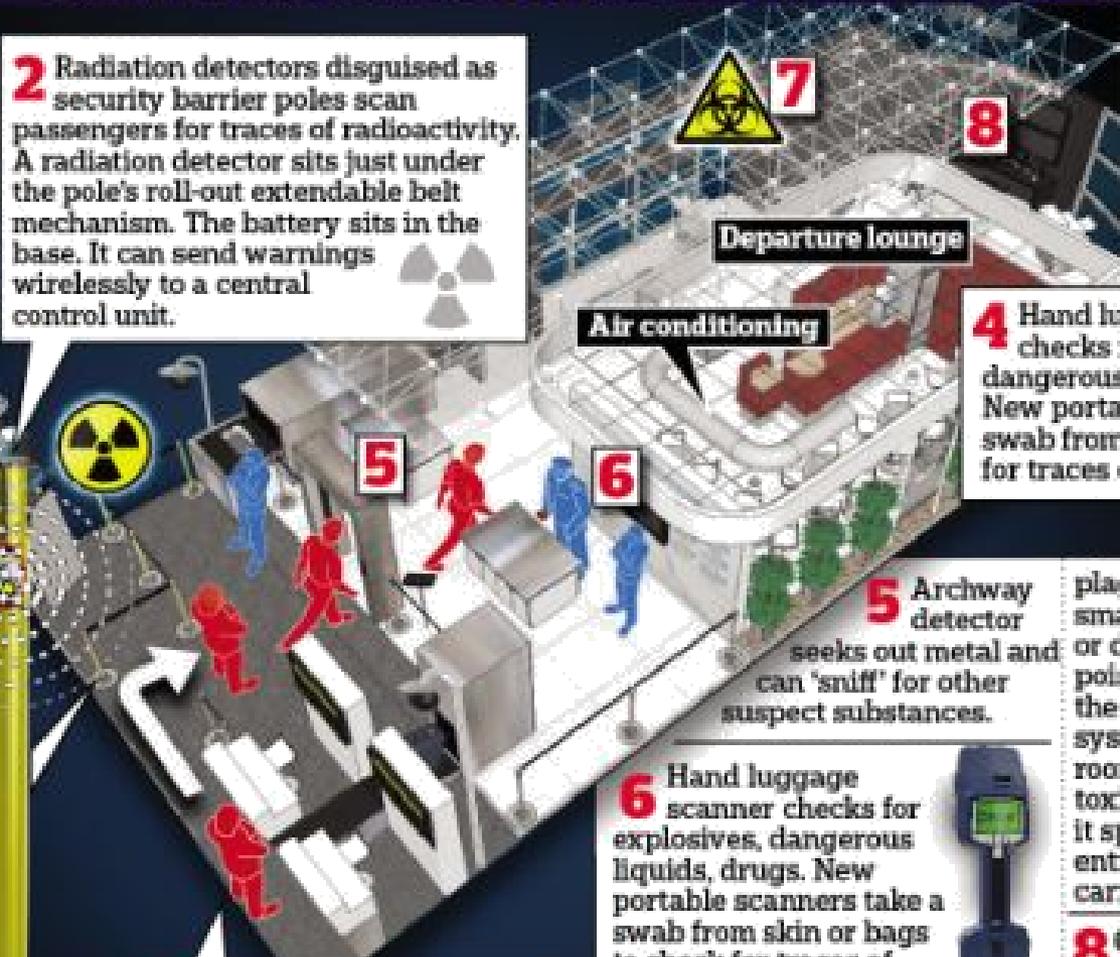


**4** Hand luggage scanner checks for explosives, dangerous liquids and drugs. New portable scanners take a swab from skin or bags to check for traces of suspect materials.



**Departure lounge**

**8**



# Full body scans are now common



Before the scanners were introduced to airports, radiation safety studies were conducted by a number of government and private health institutions. Each assessment proved the effective dose rate to be below the American National Standards Institute standard annual dose limit of  $250 \mu\text{Sv}$  over a 12-month period. The effective dose estimates from a single scan range from  $0.015 \mu\text{Sv}$  to  $0.88 \mu\text{Sv}$ . To put these numbers into perspective, air travel can expose a passenger to  $0.04 \mu\text{Sv}$  per minute from cosmic radiation. To look at this from another perspective, a passenger would have to pass through a scanner 1000–2000 times to equal the dose from a medical chest X-ray, which is also equivalent to the dose from 3 to 9 min of daily living. The TSA operators typically receive less than  $100 \mu\text{Sv}$  per year, which is well below the Occupational Safety and Health Administration's occupational safety health limit of  $50,000 \mu\text{Sv}$  per year.

# Radiography Techniques at Border Control

Active interrogation techniques utilize both neutron and gamma ray sources and includes nuclear resonance fluorescence, neutron and gamma ray multiplicity, neutron radiography, and neutron and gamma ray induced fission. These systems can be utilized to inspect cargo in shipping container at seaports and border crossings, air transport containers, or to be deployed as mobile inspection systems.

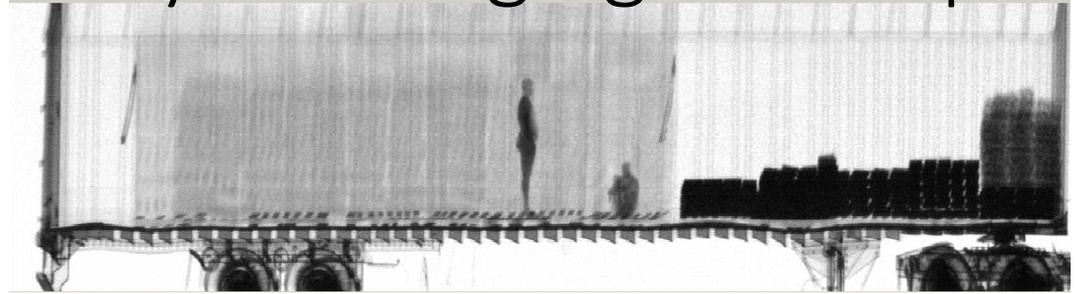
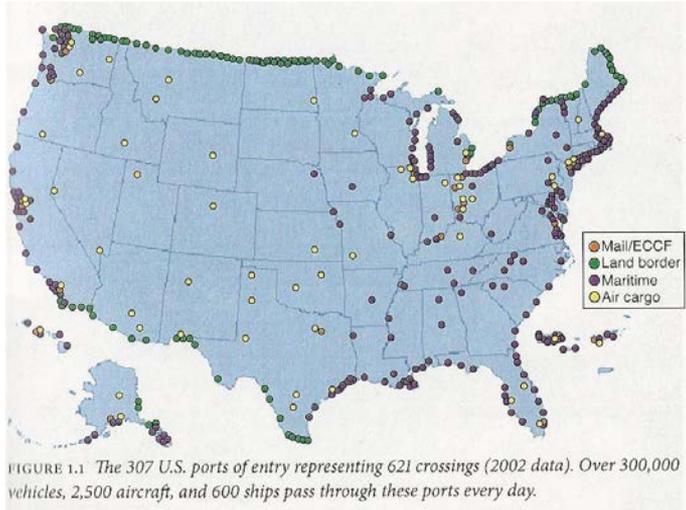


Radiation Portal Monitor for cargo screening.



Mobile x-ray transmission radiography screening measurements

# Modern X-ray or neutron scanning technologies rely on imaging techniques

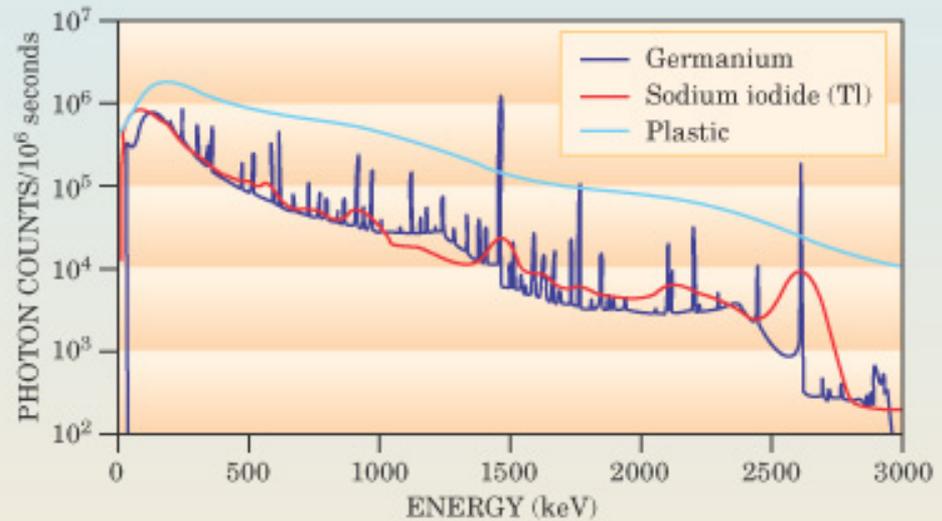


- Signature identification,
- Detector array development
- Sensitivity analysis



High-density rail cargo imager scans fully loaded trains, tankers and double-stacked cars in a single pass using X-rays.

# Monitoring Radioactivity



Efficiency of  $10^{-4}$  limits the detection to activities in the milli-Curie range

Problem with on-line radioactivity monitoring device is the number of false alarms due to natural activities and medical activities (patients after treatment)

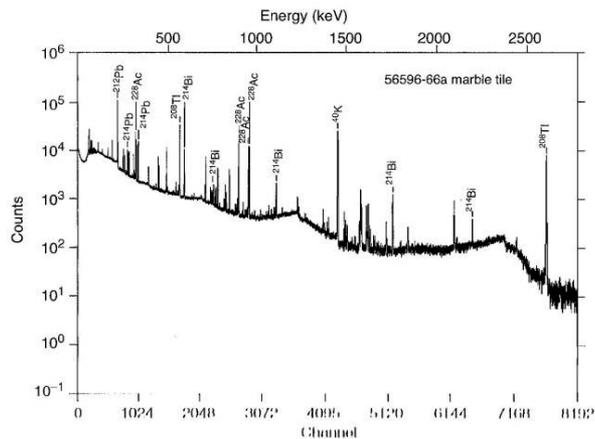


# Shortcomings and Limitations

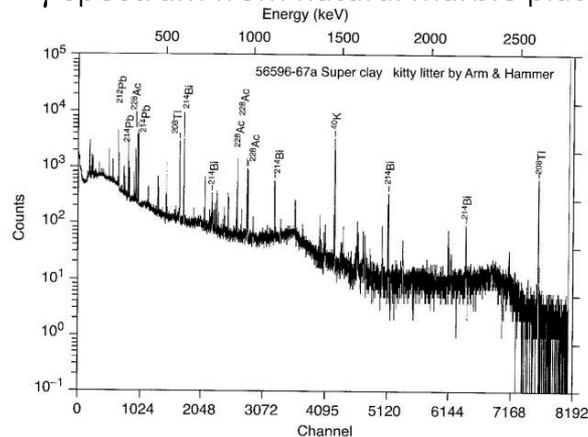


# Naturally occurring background from industry products

The increase in industrial and medical radioactive material in our society makes the work of homeland security more challenging since distinguishing between NORM radiation sources is close to impossible



γ spectrum from natural marble plate



γ spectrum from kitty litter

Other cargo items known to contain significant levels of naturally occurring radioactive material and technologically enhanced naturally occurring radioactive material

Item	Isotope <sup>a</sup>		
	<sup>226</sup> Ra	<sup>238</sup> U	<sup>232</sup> Th
Aircraft counterweights		X	
Camera lenses and other optical glass			X
Cloisonné jewelry	X	X	
Colored ceramic glazes	X	X	
Dental ceramics		X	
Firebrick			X
Fluorescent lamp starters	X		
Gas lantern mantles			X
Gyroscope rotors		X	
Magnesium-thorium alloys (aircraft parts)			X
Manufactured anhydride (by-product gypsum)	X	X	X
Oilfield scrap metal; natural gas containers and pipes	X		
Phosphogypsum	X	X	
Polishing powder			X
Specialty glass (colored)	X	X	
Strike plates for flint-lock muskets		X	
Thoriated tungsten welding electrodes (welding rods)			X
Tundish nozzles used in steel making and smelting			X
Zirconium sand			X

<sup>a</sup> The column marks (x) indicate the presence of the three isotopes <sup>226</sup>Ra, <sup>238</sup>U, and <sup>232</sup>Th.

