Radioactivity

Lecture 26

Radioactivity and Homeland Security

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

- Roman Army: 1st to 3rd century
- Mongol Armies: 13th to15th century

- German Navy: unrestricted submarine warfare in WW1
- Japanese Army: Manchuria, China, Philippines, …
- Spanish Army: Civil War in Spain
- German Armies: occupation policies in WWII
- British Air Force: Bomb War against cities in WW2
- US Air Force: Bomb War against civilian targets Germany & Japan in WW2,
Hiroshima & Nagasaki
Vietnam
- Israeli Army: Palestine population
- Yugoslav Army: Muslims, Croats, Albanians
- Indonesian Army: East Timor

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 Jugoslavian partisans against German Armies
- o French Resistance against German Occupation
- o Kuomintang & Red Army against Japanese Occupation

Strictly against military occupation forces and collaborators

- 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 East Timor against Indonesian occupation

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

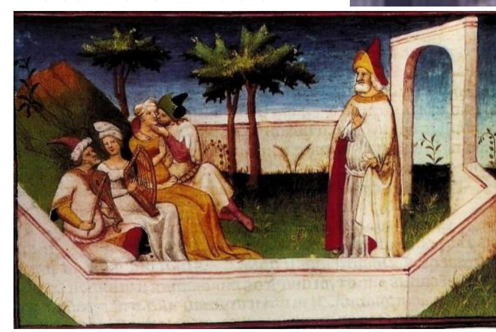
Second category often depicted as terrorist acts against legal government institutions!

Terrorist Movements

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

- o Assassins in 9^{th}-13^{th} century middle east
- o Anarchist terror in 19^{th} century Europe
- o Ku Klux Clan in the US
- o IRA in Ireland and Great Britain
- o Irgun Zvai Leumi & Lehi movement in Israel
- o Al Fatah in Israel, Jordan, Palestine
- o Red Army Fraction in Germany
- o Red Brigades in Italy
- 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)
- o Right to life movements
- o Islamic Al Qaeda
- o ISIS

Timothy McVeigh
Osama bin Laden



The old Man of the Mountain

Present and future generations

“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.

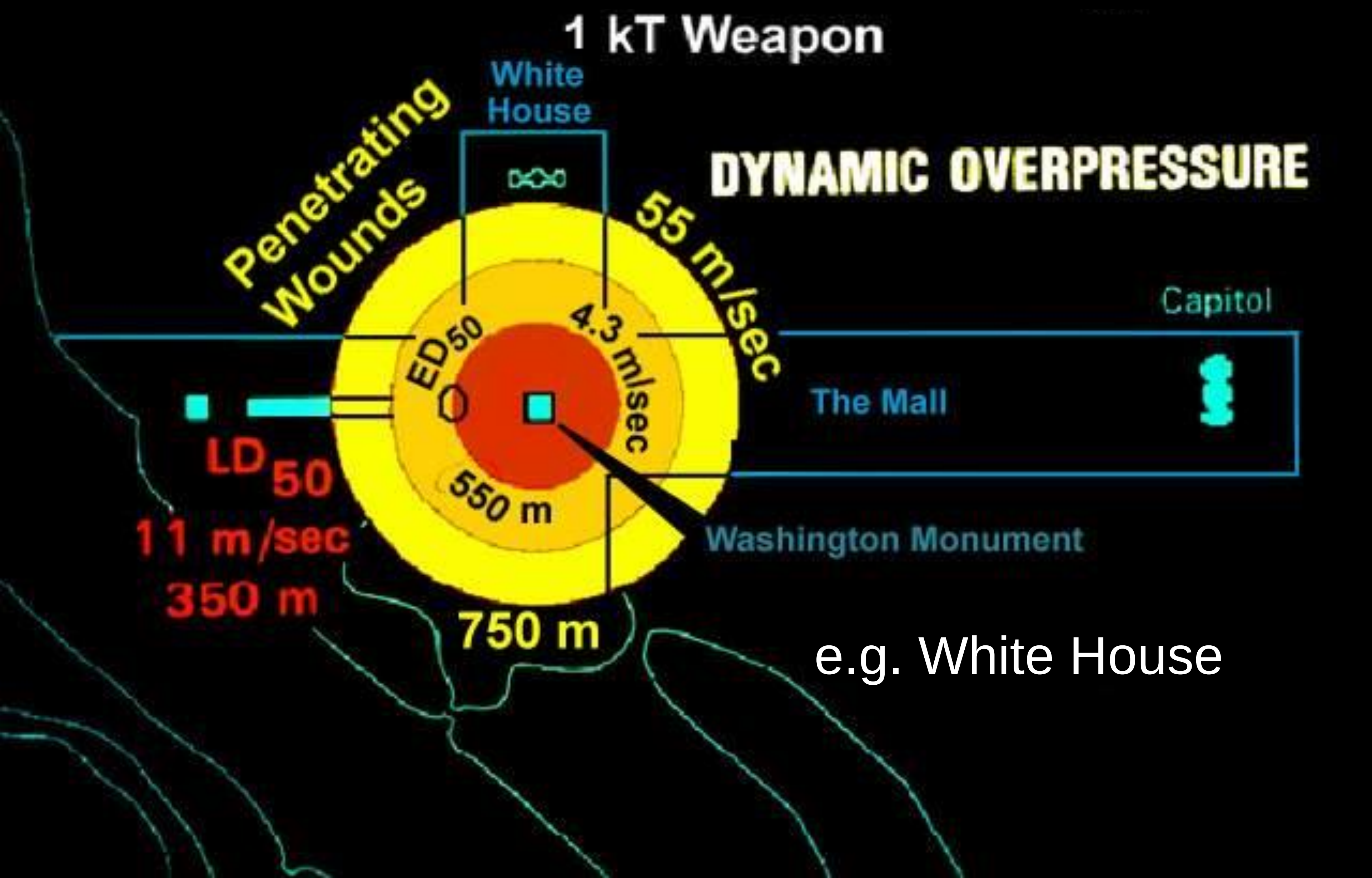
Logistical problems include:
Generating nuclear material (^{235}U, ^{239}Pu); huge industrial effort requires breeder reactor and diffusion or centrifugal based separation facilities (~10-20 years), requires hosting state resources

Provision of nuclear bomb material (^{235}U, ^{239}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!

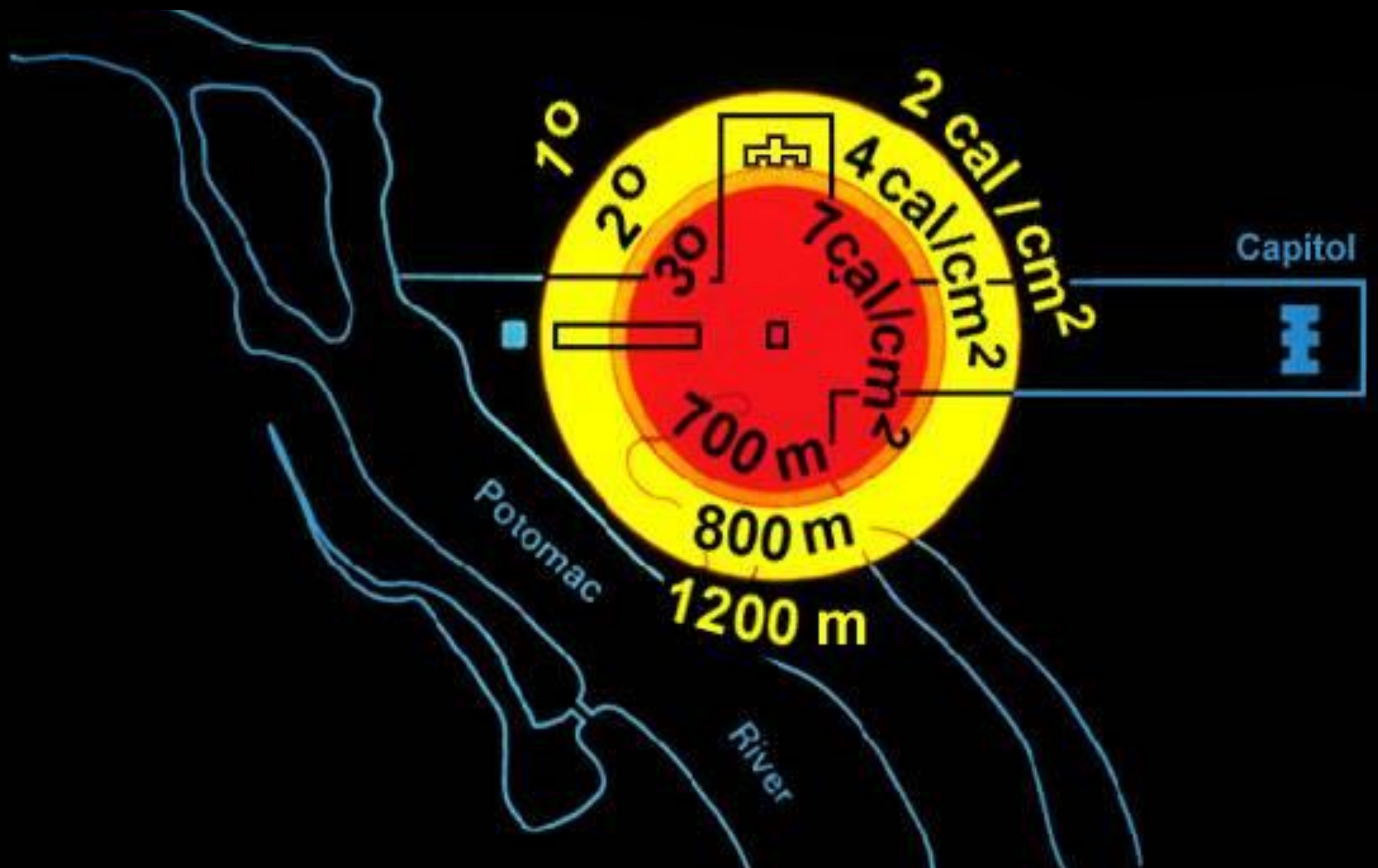
Smaller scale destruction by transportable nuclear device

Preferred Target - High Visibility Object

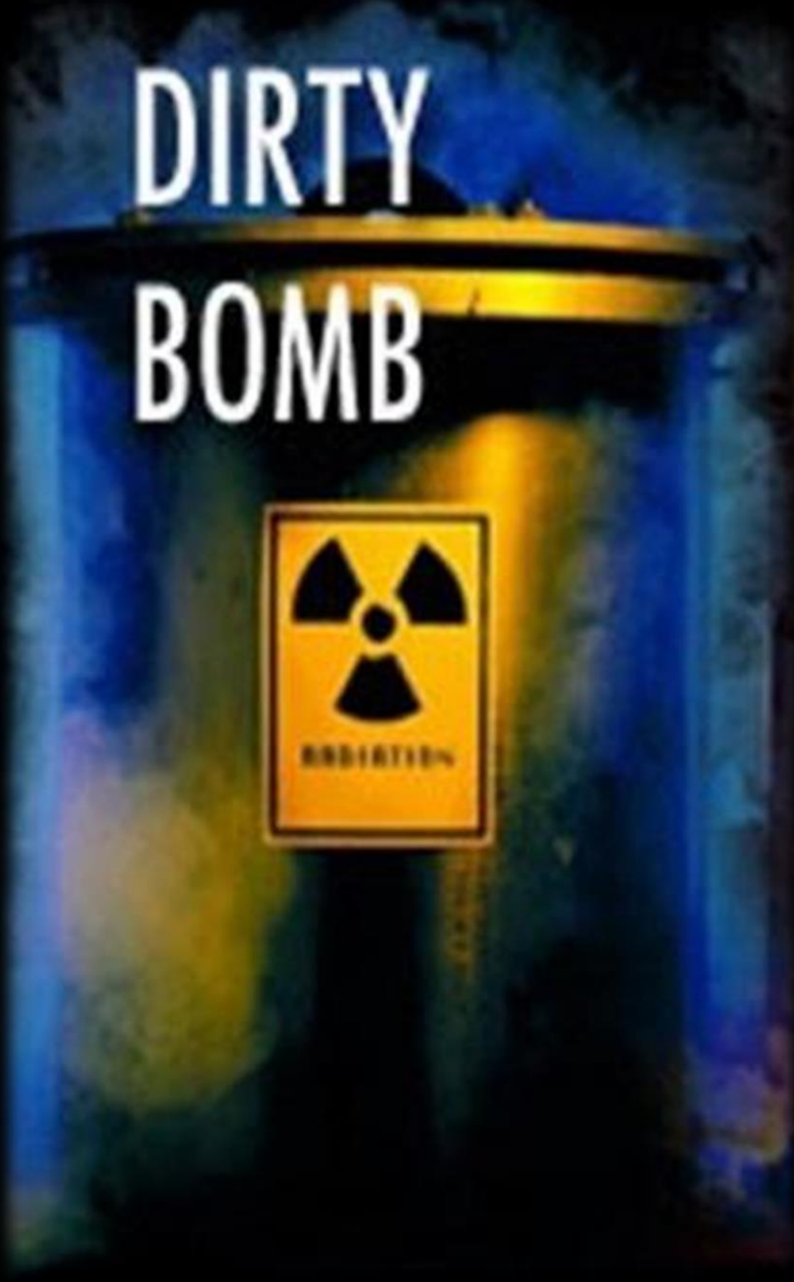


e.g. White House

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. $^{59}Co(n,\gamma)^{60}Co$ – 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}Co, which has a half-life of 5.26 y and produces energetic (and thus penetrating) γ rays. The half-life of ^{60}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.

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}Cs or ^{60}Co from a university lab or more likely from a hospital radiology department).

To contaminate an area of 10,000m^2 (circle of ~60 m radius) with ~1 Ci/m^2 (<1 rad dose for by-passer) from material transported in a regular suitcase you need an initial source of ~10.000 Ci radioactive material in your explosive device. If the material is ^{60}Co this activity corresponds to ~90g of pure ^{60}Co. The dose rate is ~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 γ radiation from ^{60}Co radioactive decay.
(A regular laboratory ^{60}Co source has an activity of $<10^{-5}$ Ci.) An “effective” dirty bomb provides substantial logistical problems on the delivery side!

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
^{60}Co	0.03	0.8
^{137}Cs	0.10	3.0
^{192}Ir	0.08	2.0
^{241}Am	0.06	2.0

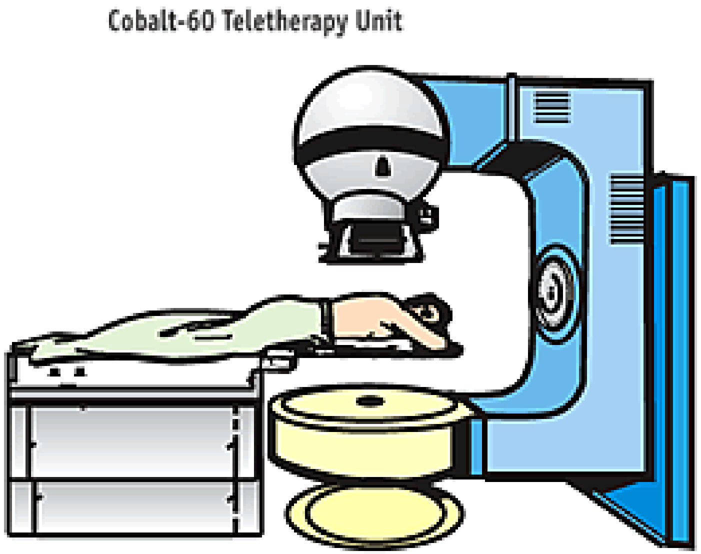
IAEA category of Dangerous Activity

A/D > 1 is dangerous

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	$0.01 > A/D \geq$ exempt/D

Highest risk is in “unprotected” medical facilities

Medical Sources



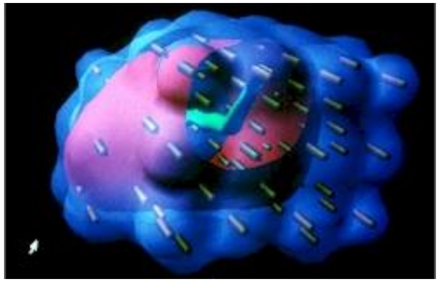
Sources are mainly designed for the radiation treatment of cancer patients

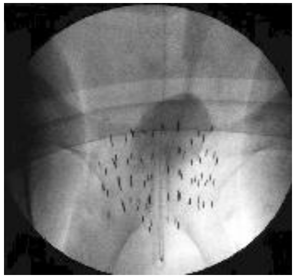
Theletherapy units

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

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

Brachytherapy units





Brachytherapy sources are more abundant but have lower individual radioactivity: ^{226}Ra, ^{137}Cs, and ^{192}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. …

Homeland Security Tasks

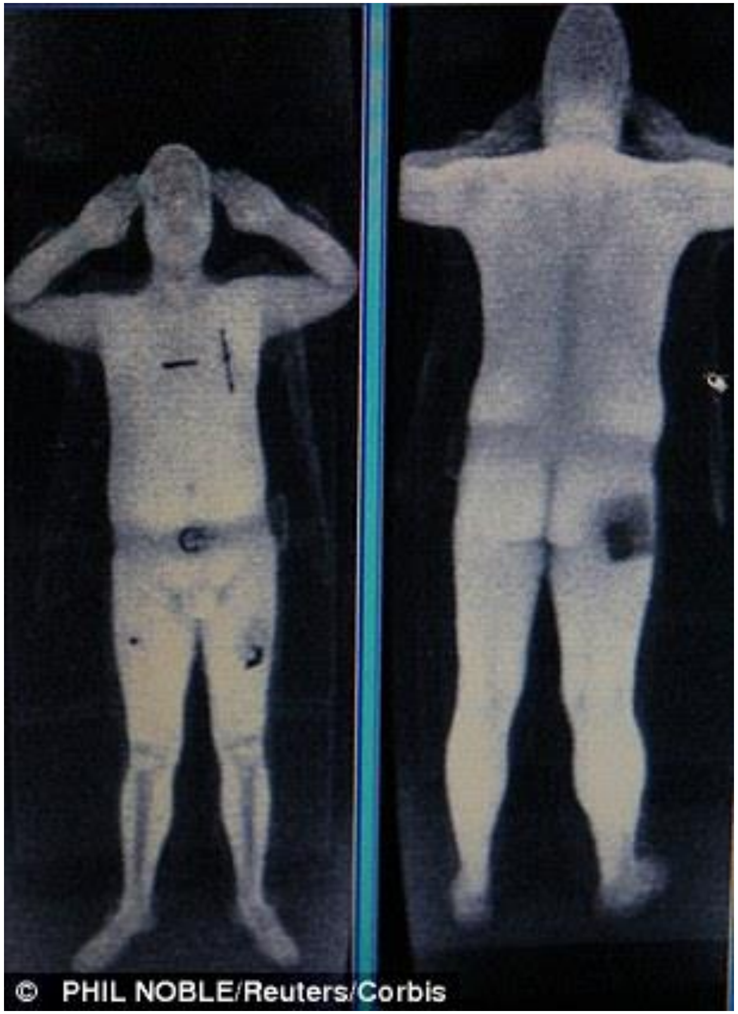
- Border Control Applications
- Detector developments
- Radiation Detection and Monitoring
- Nuclear Forensics
- Terrorist Attacks
- Radiological Emergency and Response

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.
7
8
3 Smart camera scans the area looking for suspicious faces or movements.
Departure lounge
Air conditioning
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.
Detector
5
6
5 Archway detector seeks out metal and can 'sniff' for other suspect substances.
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, 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.
1 Passenger arrives at check-in to deposit hold luggage before going through security with or without carry-on hand baggage.
Battery

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 µSv over a 12-month period. The effective dose estimates from a single scan range from 0.015 µSv to 0.88 µSv. To put these numbers into perspective, air travel can expose a passenger to 0.04 µSv 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 µSv per year, which is well below the Occupational Safety and Health Administration's occupational safety health limit of 50,000 µSv 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

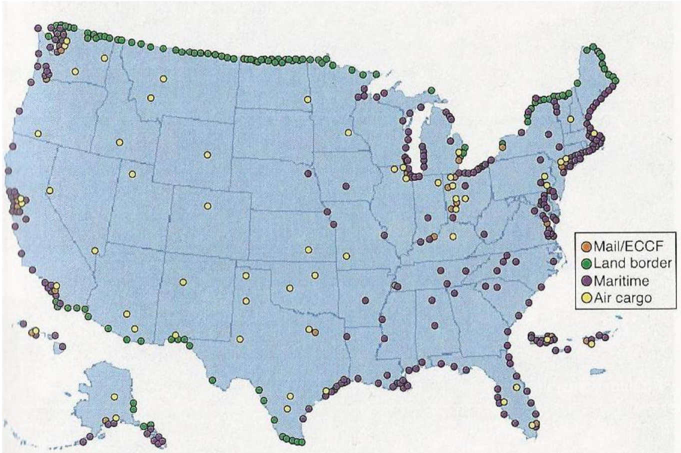
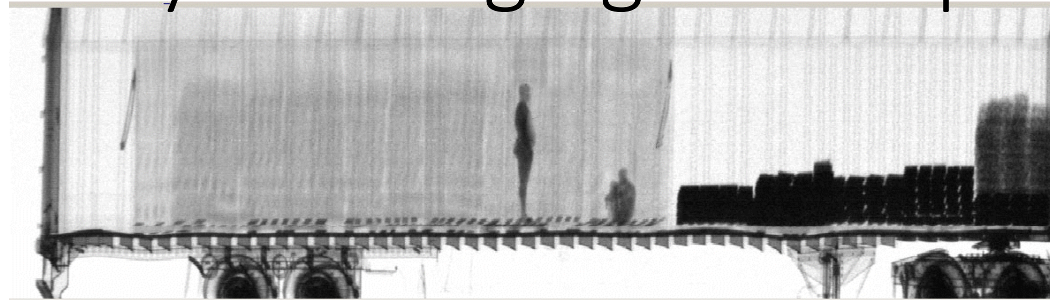
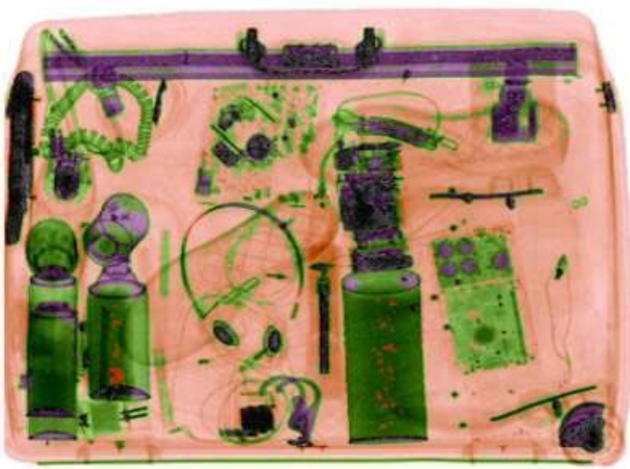


FIGURE 1.1 *The 307 U.S. ports of entry representing 621 crossings (2002 data). Over 300,000 vehicles, 2,500 aircraft, and 600 ships pass through these ports every day.*

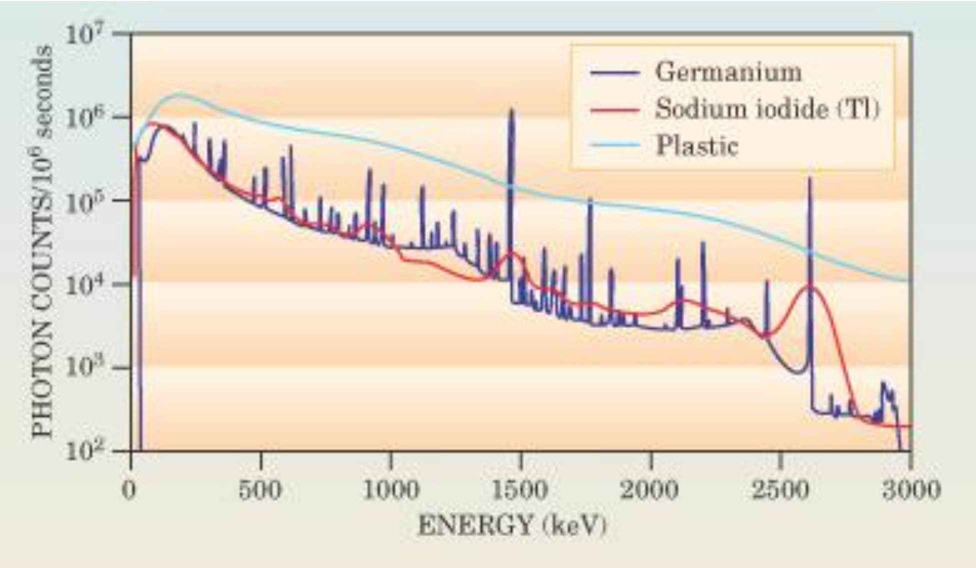




- Signature identification,
- Detector array development
- Sensitivity analysis

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

Monitoring Radioactivity

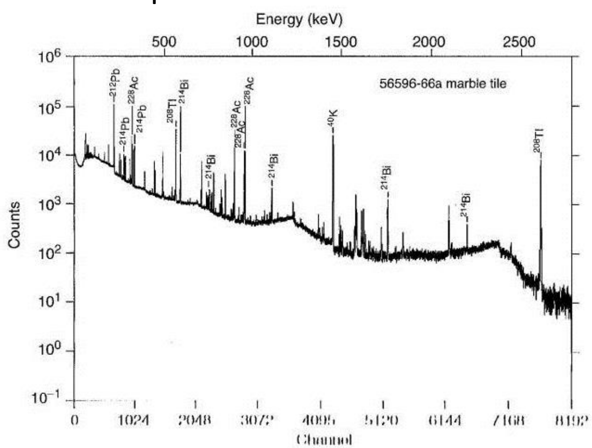


Efficiency of 10^{-4} limits the detection to activities in the milli-Curie range

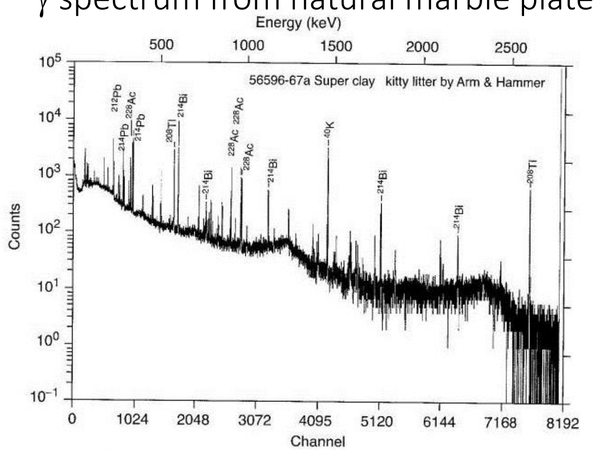
Problem with on-line radioactivity monitoring device is the number of false alarms due to natural activities and medical activities (patients after treatment)

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[a]		
	^{226}Ra	^{238}U	^{232}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

[a] The column marks (x) indicate the presence of the three isotopes ^{226}Ra, ^{238}U, and ^{232}Th.

New medical related background

Radionuclide	Half-Life	Organ	Estimated Percent of 2001 Dosages at Local Hospital (2797 Total)	Percent of Procedures Administered in U.S.A. During 2001 (14,390,000 Total) [a]	Annual Procedures in U.S.A. Per 10,000 Population for 2001
^{14}C	5730 yr	Kidneys, bladder, stomach	1.07	1.89	9.7
^{57}Co	271.8 day	Bladder, liver, kidneys, marrow	0.61	1.07	5.5
^{51}Cr	27.7 day	Marrow, liver	0.25	0.35	1.8
^{18}F	109.8 min	Brain, heart, bladder	1.43 (estimated)	2.02	10.3
^{67}Ga	78 hr	Intestines, marrow	0.11	0.19	1.0
^{123}I	13.3 hr	Thyroid, kidneys	0.86	0.03	0.2
^{125}I	59.41 day	Thyroid, spleen, lungs	0.00	Insufficient data	Insufficient data
^{131}I	8 day	Thyroid, kidneys	8.54	0.34	1.7
^{111}In	67.32 hr	Liver, marrow, spleen	0.89	1.40	7.2
^{153}Sm	46.27 hr	Skeleton, marrow	0.04	0.39	2.0
^{89}Sr	50.5 day	Skeleton, marrow	0.04	0.39	2.0
^{99m}Tc	6 hr	Heart, liver, spleen, marrow, kidneys, bladder, stomach, bones	87.06	91.51	468
^{201}Tl	72.91 hr	Heart, lungs	0.36	0.42	2.2
^{133}Xe	5 day	Lungs	0.00	Insufficient data	Insufficient data
^{90}Y	64.1 hr	Skeleton, marrow, liver, testes	0.00	Insufficient data	Insufficient data

[a] Frost and Sullivan Healthcare Group (2002).

The number of radiation based medical diagnostics and treatment procedures have multiplied over the last decade, due to number of applications and intensity of radiation level, which raises the overall exposure