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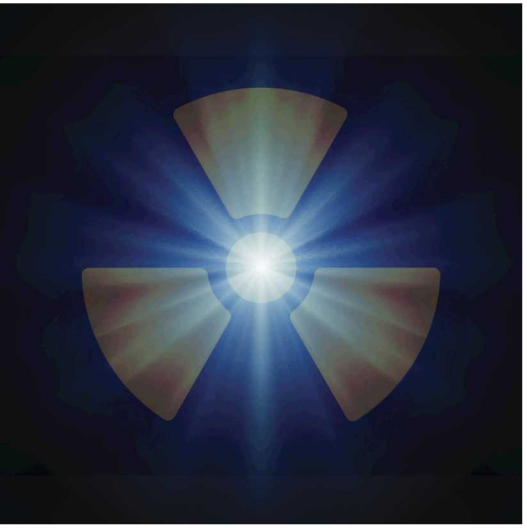

Radioactive Source Use and Options to Reduce Security Risk

Briefing to WINS Workshop on Alternative Technologies to High Activity Radioactive Sources Used in Medical Applications

April 28-29, 2015 – Rio De Janeiro, Brazil

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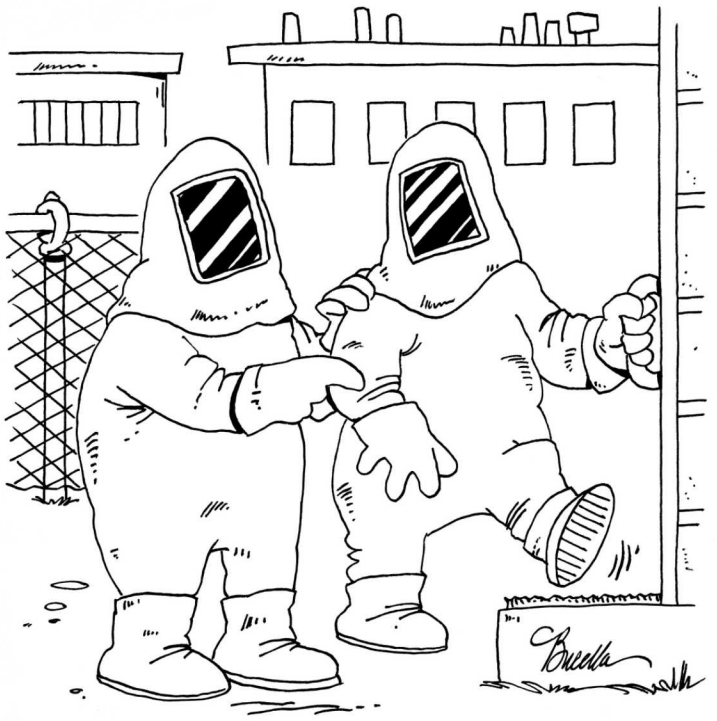
Outline

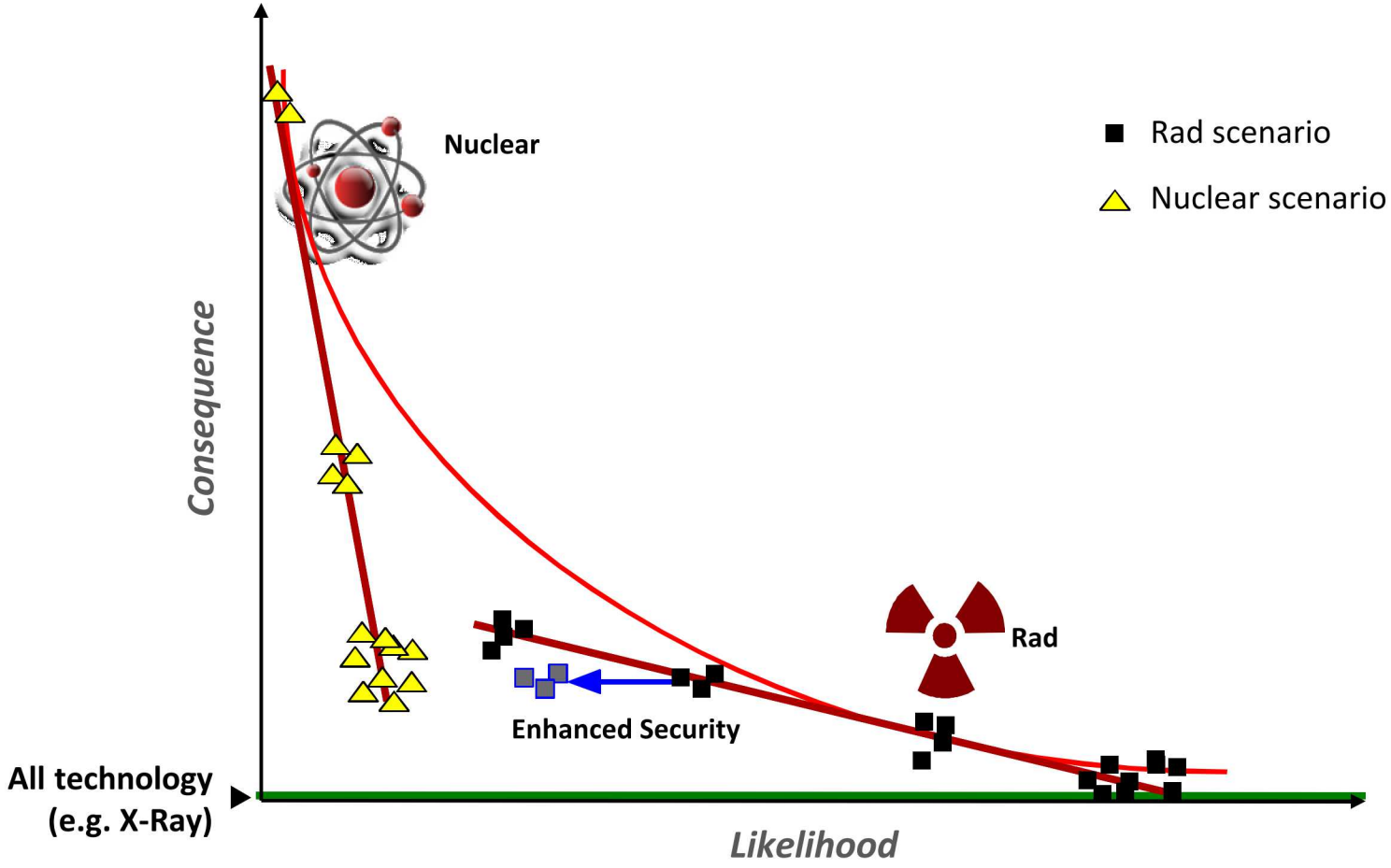
- Risk Context for High Activity Sources
  - Consequences
  - Likelihood of Attack
- US NAS Study Summary
- Options to Reduce Risk
- Summary & Conclusions



"Remember, before entering, make sure you wipe your feet on the hazmat."

Rad Terrorism Risk In Context

Alternative technology reduces risk to zero.



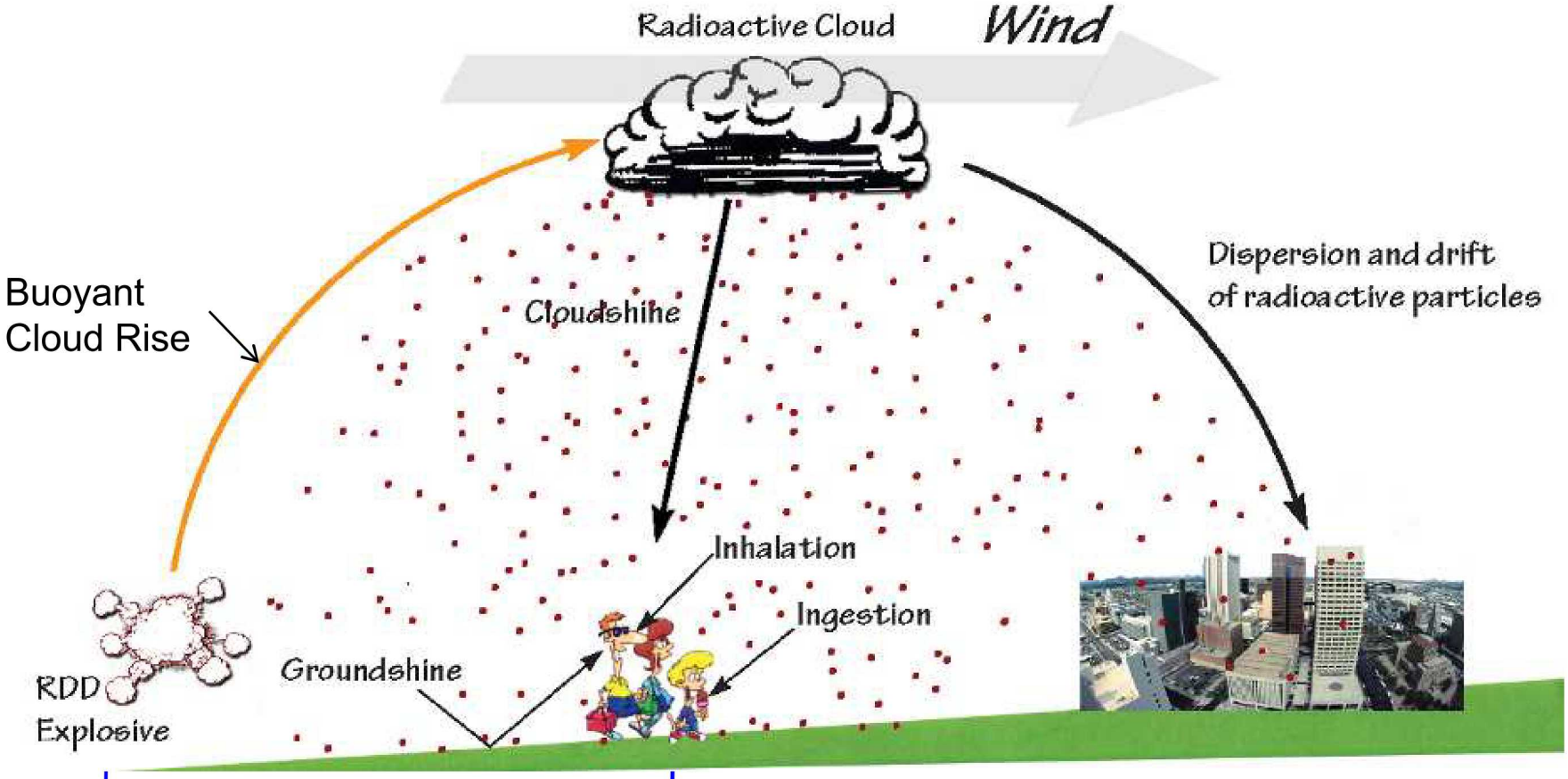
Rad Terrorism Scenarios

RDD is of most concern due to "area denial."

Device Type	Dispersal Form	Economic Effects	Health Effects	Comments
Radiation Exposure Device (RED)	N/A	Low to Medium	Medium: Deterministic and stochastic health effects	No lasting economic impact
Rad-Food Dispersal (RFD)	Dissolve or mix	Medium to High	Medium to High: Deterministic and stochastic health effects	Other poisons more readily available?
Radiation Dispersal Device (RDD)	Many	Medium to Very High "Area Denial"	Low: Latent cancer risk (stochastic) drives population relocation	Could impact ~ 10,000's; Area Denial--Unique aspect of radiological material

The Explosive RDD

Lofted material falls and can create a large contamination area.



Radionuclide Area Denial Properties

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CsCl poses unique concerns as a salt powder.

Radionuclide and emission	Half-life	Typical Form	Power to Contaminate*	Typical Use and Activity
Co-60 (b,g)	5.3 yr	Metal	0.4 TBq/km^2	**Irradiators/Telethe rapy (≥40 TBq)**
Cs-137 (b,g)	30 yr	Salt, Powder (CsCl)	1.5 TBq/km^2	**Irradiators (≥40 TBq)**
Sr-90 (b)	29 yr	Ceramic	4 TBq/km^2	RTGs (≥400 TBq)
Ir-192 (b,g)	74 d	Metal	4 TBq/km^2	Radiography (~4 TBq)
Am-241 (a,g)	430 yr	Oxide, Powder	1.5 TBq/km^2	Well Logging (~ 0.4 TBq)

Cs-137 & Co-60 used in high activity medical devices.

*Radionuclide ground contamination level that would trigger EPA Relocation Protective Action Guide (PAG) of 20 mSv/yr

Experience with Cs-137 Contamination

Accidents depict significant consequences from rad dispersion.

Goiania, Brazil Sept. 1985

5 mSy/first year Threshold

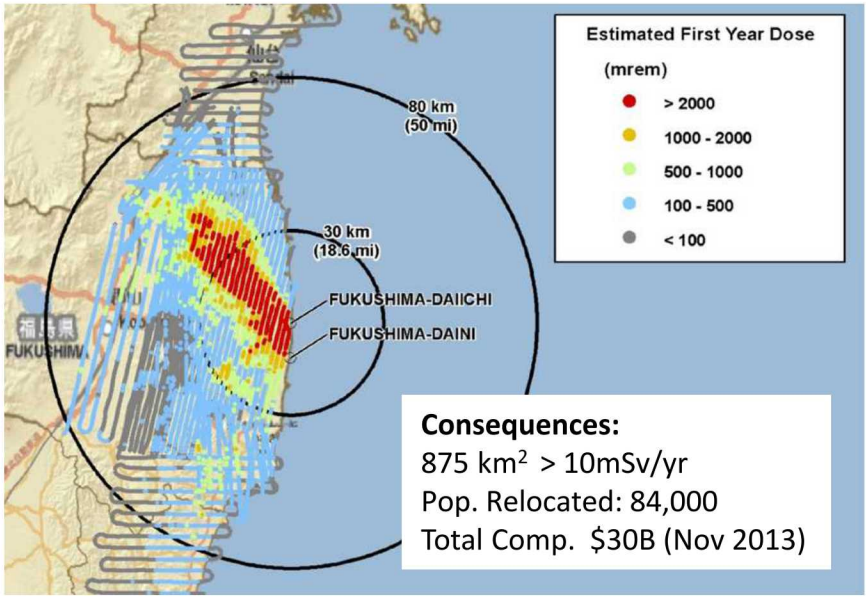
Cs-137 teletherapy machine source

Consequences:
4 Deaths
200 People Relocated
112,000 People Monitored
3500 m^3 rad-waste.
Decon Costs: $10's Million (1988)

Source: The Radiological Accident in Goiania, IAEA 1988

Fukushima, Japan March 2011

10 mSv/yr Threshold



Consequences:
875 km^2 > 10mSv/yr
Pop. Relocated: 84,000
Total Comp. $30B (Nov 2013)

Source: DOE/NNSA Nuclear Incident Team

- US PAG/Chernobyl 20 mSv/yr threshold

RDD Plume Modeling and the 20-mSv PAG

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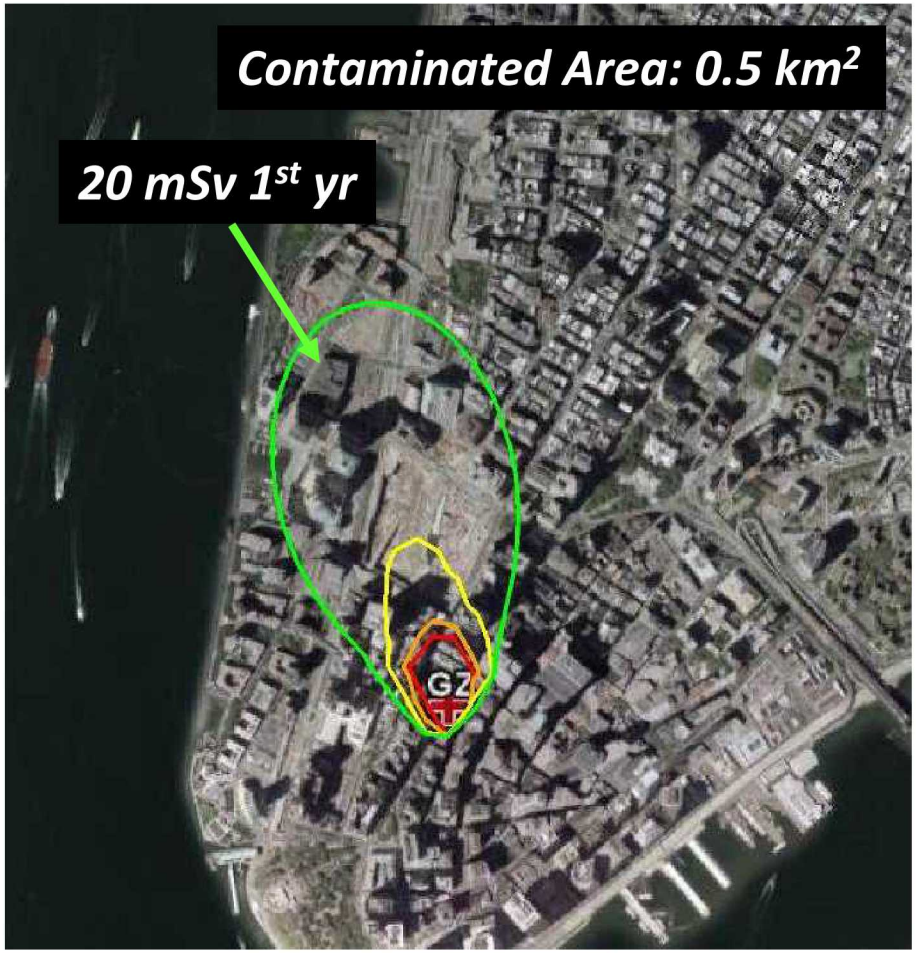
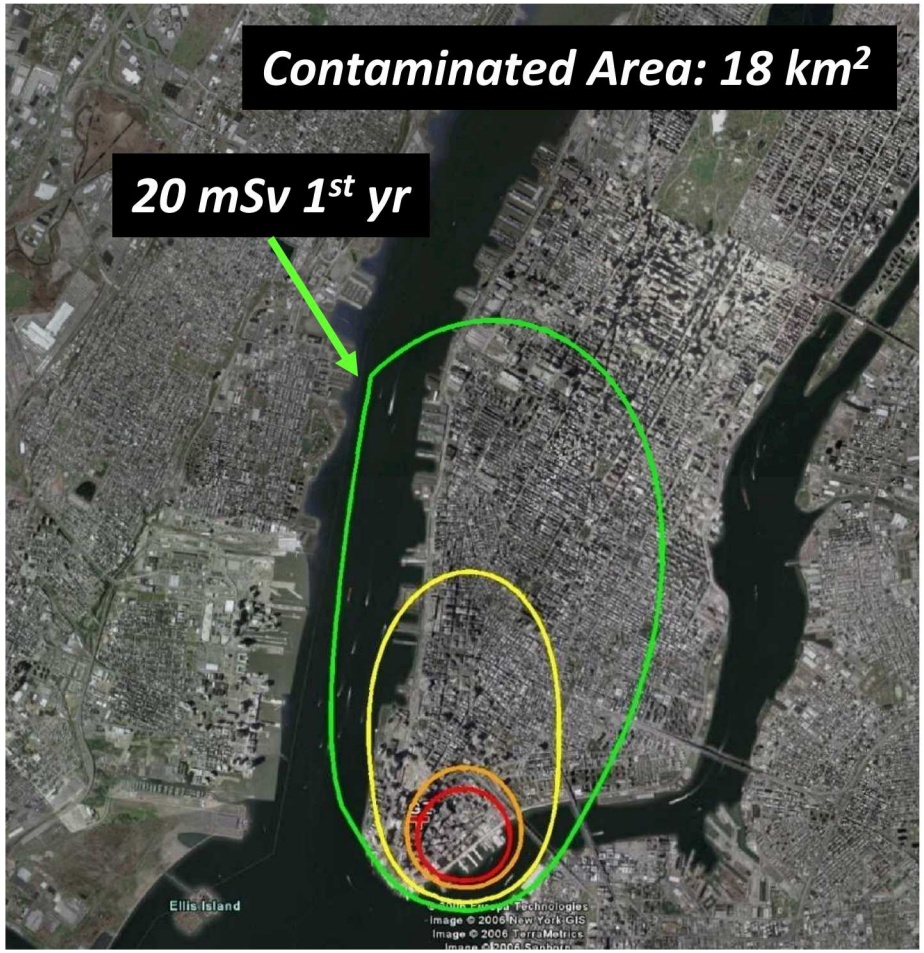
RDD consequences will depend on many factors such as adversary capability





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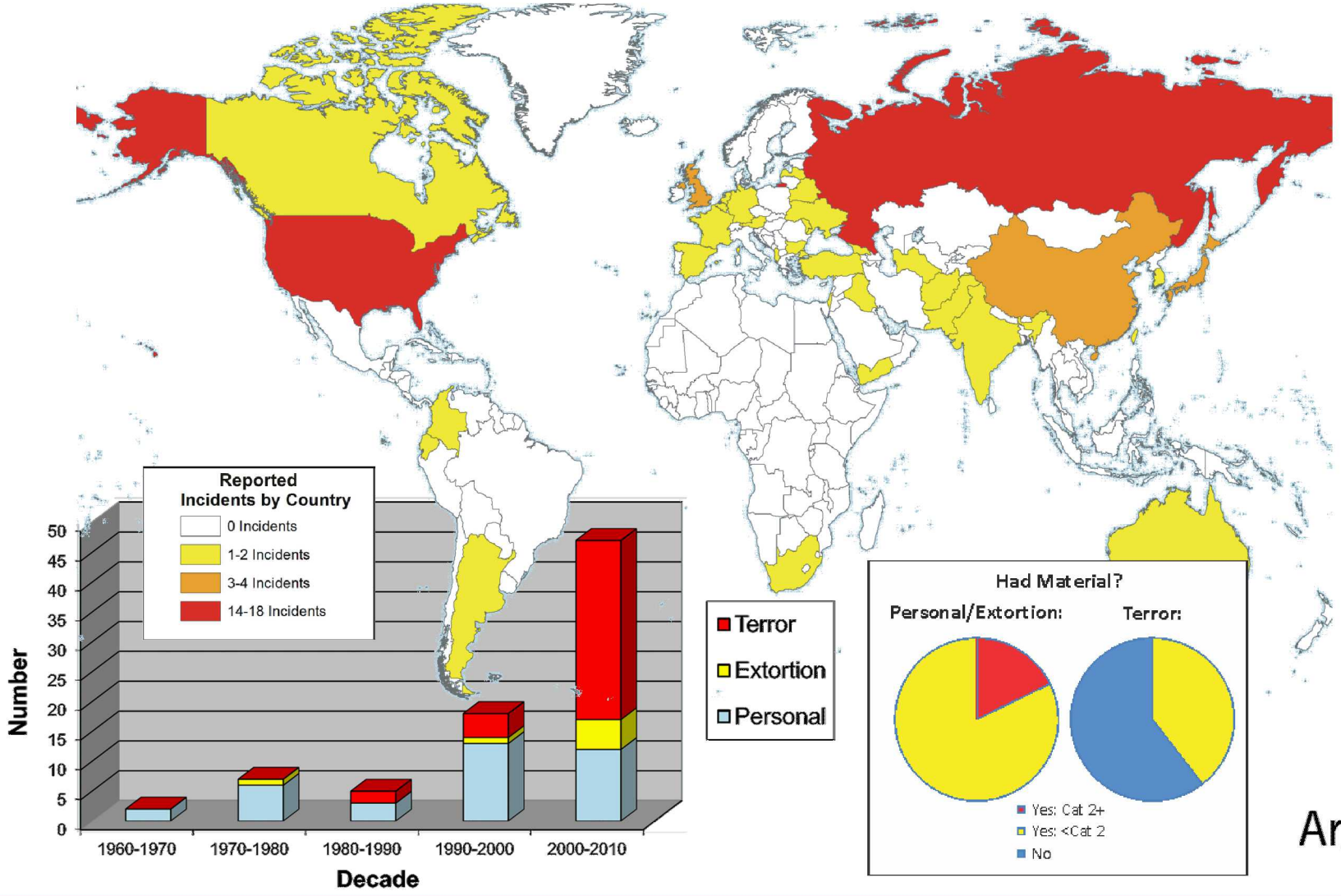
LIKELIHOOD

Intent: Historical Malicious Use Plots Involving Radioactive Material

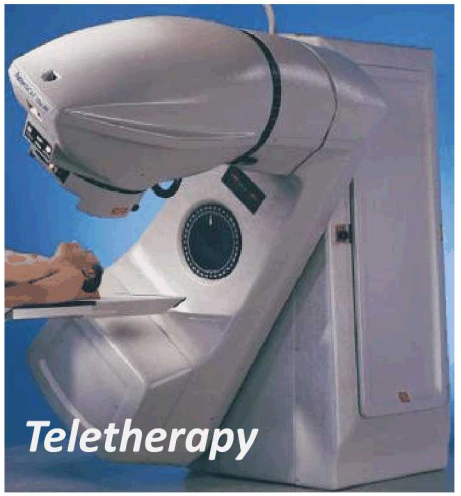


Material Availability

Is it too hard to remove the source?

- Difficulty of attack key part of risk assessment for self contained irradiator.
- Threat Capability
  - Technologist used for attack assessment.
  - Required radiation effects and mechanical knowledge.
- US interagency consensus to move forward with security enhancements.


JLSA Mark I

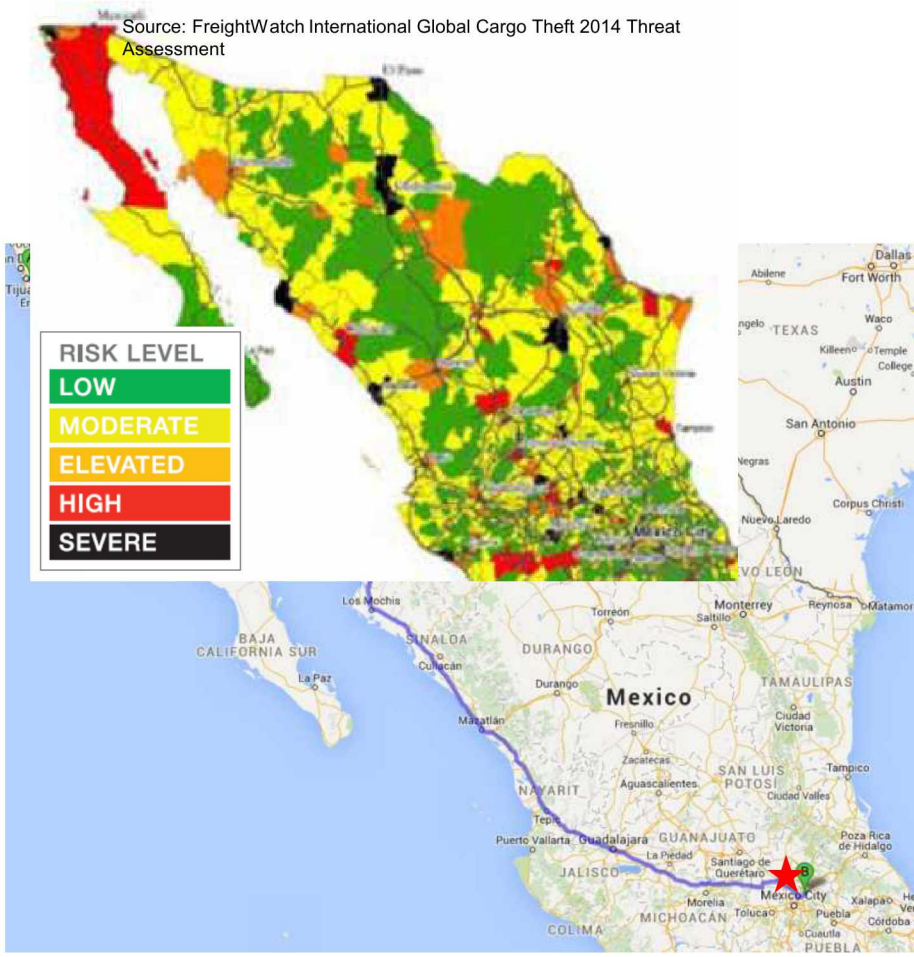

Teletherapy

MDSN GC 3000

Material Availability:

2013 Mexico Co-60 Theft

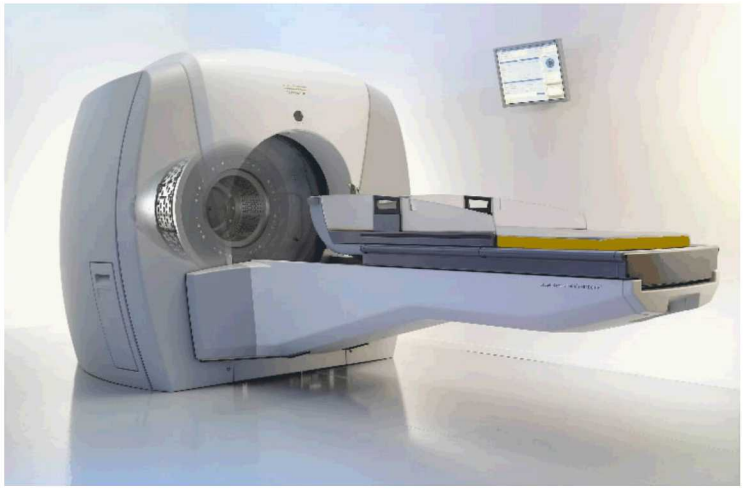
- December 2013 a truck carrying a teletherapy unit for disposition with ~ 110 Tb (~3,000 Ci) of Co-60 was hijacked north of Mexico City
- Overland ~2,800 km trip from Tijuana to waste repository north east of Mexico City
- Truck had no operational security associated with it
- Hijacking appeared to conducted by an organized ring specializing in truck thefts
- Just one of more than an estimated 60 truck hijackings a week that occurred across Mexico in 2013



Material Availability:

Abandoned Sources

- 2008 (Before NRC Enhanced Controls) Abandoned Gamma Knife in USA
- Gamma knife facility in a Pennsylvanian strip mall shuttered in 2008
- Machine contained 3,000 curies Co-60
- Regulator not informed
- Unit left unprotected for an indeterminate amount of time until discovered by PDEP



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NAS Study 2008

NAS Radiation Source Use and Replacement Tasking

- Review radiation sources to identify those that can be replaced by
  - Alternative technology
  - Lower risk radioisotopes
- Explicitly consider technical and economic feasibility and risks to workers from such replacements.

NAS Committee Members

Assessment requires diverse set of stakeholders.

THEODORE L. PHILLIPS (*chairman*), University of California, San Francisco

EVERETT BLOOM, University of Tennessee—Knoxville

DAVID R. CLARKE, University of California, Santa Barbara

LEONARD W. CONNELL, Sandia National Laboratories

ROBIN GARDNER, North Carolina State University, Raleigh

C. RICHARD LIU, University of Houston

RUTH MCBURNEY, Conference of Radiation Control Program Directors

ERVIN B. PODGORSAK, McGill University

TOR RAUBENHEIMER, Stanford Linear Accelerator Center

STEPHEN WAGNER, American Red Cross

DAVID L. WEIMER, University of Wisconsin at Madison

STAFF

Micah Lowenthal, Study Director
Federico San Martini, Staff Officer
Mandi Boykin, Sr. Program Asst
Tracey Bonner, Program Asst
Marili Ulloa, Sr. Program Asst

NAS Study Recommendations Summary

- Replacement of some radionuclide sources with non radionuclide radiation generators should be done with caution.
  - Applications of radionuclide sources are important and beneficial.
  - Need an avenue for permanent disposal of CsCl sources.
- U.S. NRC should consider a radiation sources' potential to cause contamination of large areas.
  - Discontinue licensing of new CsCl irradiator sources.
  - Use incentives for decommissioning existing CsCl sources.
  - Prohibit the export of CsCl sources to other countries, except for purposes of disposal in an appropriately licensed facility.

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OPTIONS

Risk Reduction Options – Using Radionuclides

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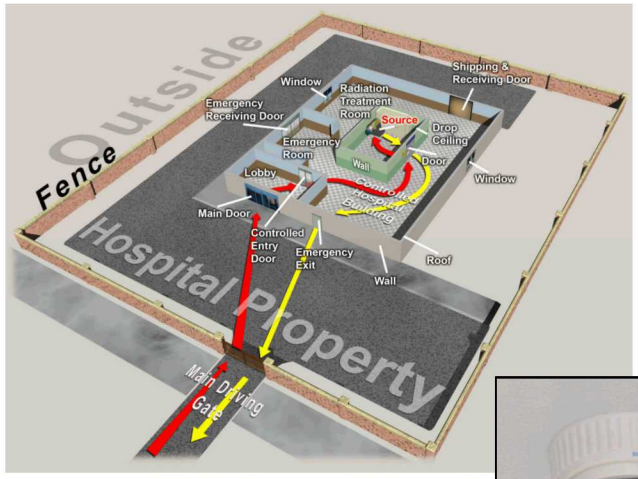
Increase attack difficulty and mitigate consequences.

- Enhanced Security
  - Facility Upgrades:
    - Detect-Delay-Respond
    - Access Control
  - Local law enforcement coordination & exercises
  - Challenges
    - Enhance security culture at public access facilities
    - Insider threat
    - Cost and sustainability
- Use less dispersible radionuclide chemical or physical forms



Non Radionuclide Alternatives (NAS Study)

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Alternative technology reduces risk to zero.

Application	Current Radionuclide	Non Radionuclide Alternative	Comments
Self-Contained Irradiators	Cs-137 (Co-60)	X-ray Irradiators	Roadblocks: Database (research), inertia, lack of competition (blood), operational (blood).
Teletherapy	Co-60	LINAC	Roadblocks: Developing countries use.
Radiography	Ir-192 (Co-60)	Ultrasound Portable X-ray	Roadblocks: Trained personnel; regulatory factors.
Well Logging	Am-241/Be	Neutron Generator	Roadblocks: Database, inertia.

Improvements in X-Ray Technology

Improved sustainability and less infrastructure needed.

- Ferris-wheel-type geometry allows uniform exposure with single tube (US FDA approved).
- External water hook-up no longer required for blood irradiator.
- Increased throughput in many cases.
- Technology also used for SIT and available for other applications.
  - SIT application requires external cooling system.

Rad Source RS3400 X-Ray Blood Irradiator

Study comparing use of X-ray and gamma rays

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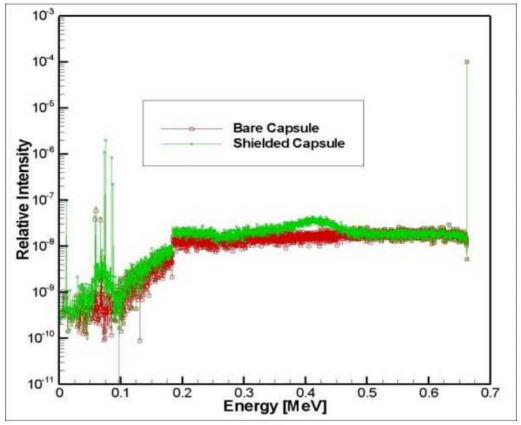
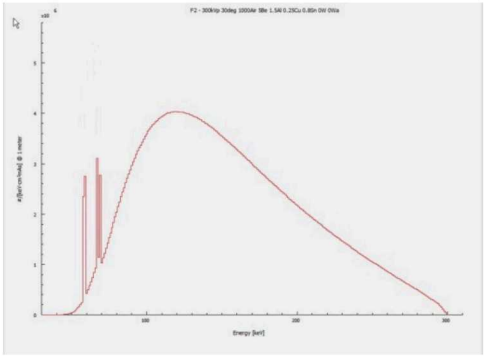
Showed promise for cancer research.



Gammacell® 1000

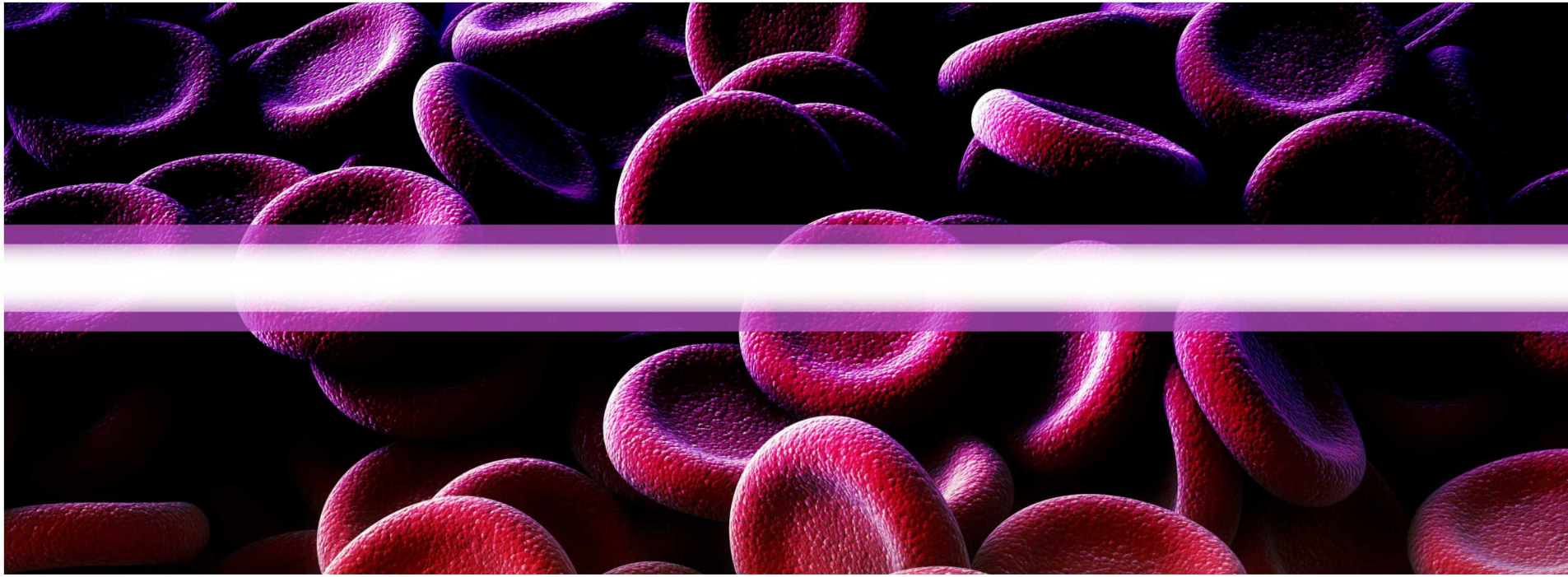
- Do you achieve the same biological effects?
  - Cancer cells.
  - Mouse bone marrow.
- Conclusions
  - Cancer cell response correlates.
  - Mouse study showed reconstitution of bone marrow.
- Three articles published in dosimetry journals.

X-RAD 320



Photochemical (Rb-UV) option used for blood treatment outside US

- White blood count inactivation equivalent to gamma irradiation*
- Licensed in Europe, the Middle East, and Russia**



Treatment of whole blood with riboflavin plus ultraviolet light, an alternative to gamma irradiation in the prevention of transfusion-associated graft-versus-host disease?, Transfusion, 2013

***Promoting Alternatives to High-Risk Radiological Sources: The Case of Cesium Chloride in Blood Irradiation*, CNS, 2014

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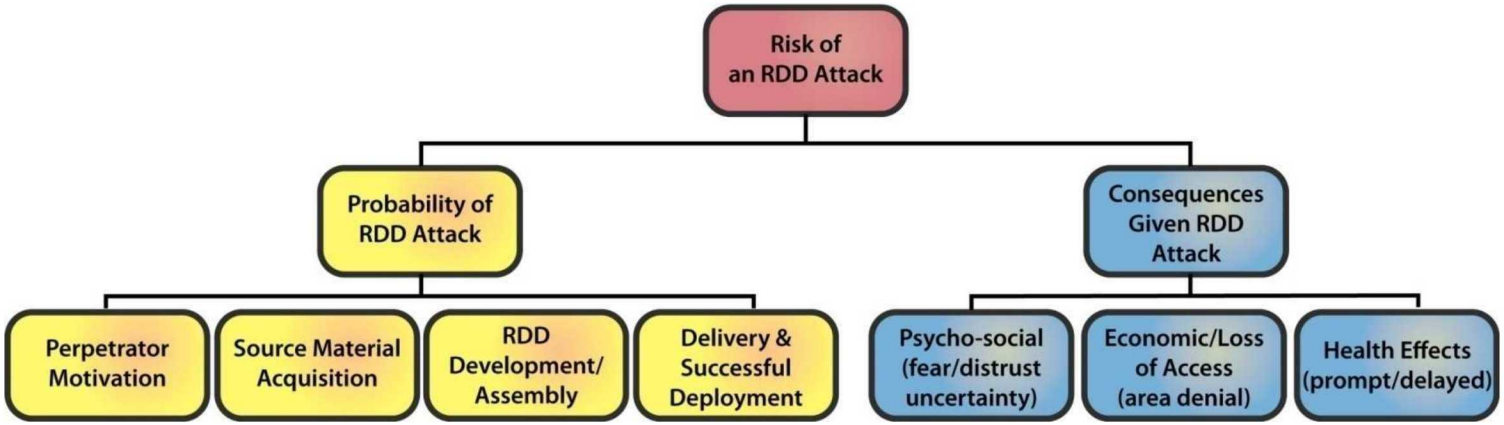
SUMMARY & CONCLUSIONS

Summary

- Terrorist RDD poses a significant security risk and composed of various elements:



- Viable alternative technology reduces the security risk to zero.
  - X-ray and Rb-UV technology viable for blood/research irradiation (Cs-137/Co-60).
  - LINAC viable for Teletherapy (Co-60).

Conclusions: HEU Case Study*

- Government efforts to phase out the use of HEU in research reactors and medical isotope production.
  - Push back: lack of creditable threat, use enhanced security, lack of feasible alternatives.
  - Success: Alternatives developed and being used minimizing non-military use of HEU.
- Success Factors:
  - Establish clarity and certainty of government commitment for change.
  - R&D of new technologies.
  - Establish incentives and restrictions.
- We're on the right path for the radiological risk.

**Promoting Alternatives to High-Risk Radiological Sources: The Case of Cesium Chloride in Blood Irradiation*, CNS, 2014

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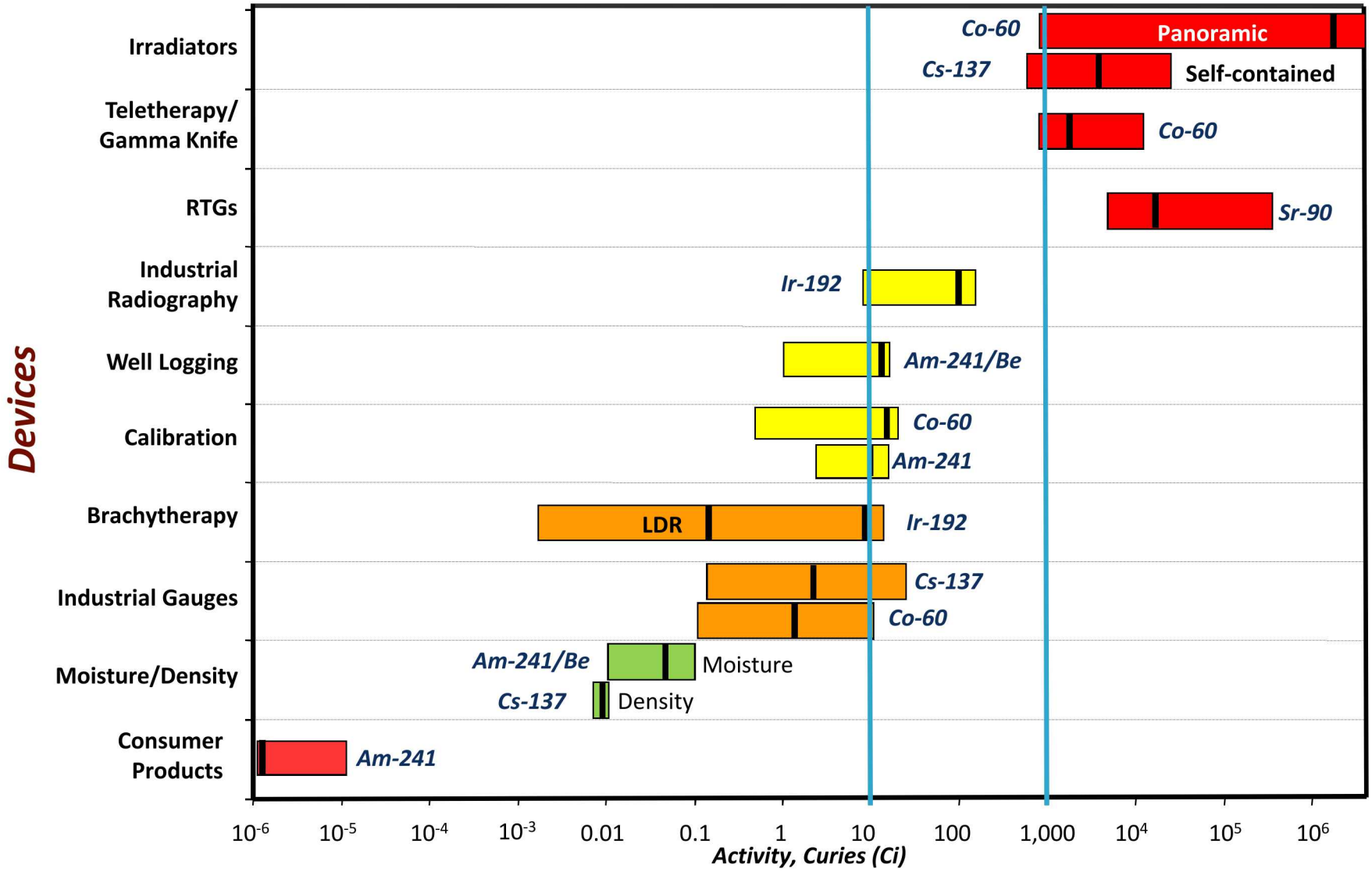
BACKUPS

Radiation Devices & Activity Ranges†



† Derived from IAEA Categorization of Sources

Historical Cases Demonstrate RDD/RED Possibility

Cs-137 Attack, 1972
Texas petroleum engineer obtained an oil exploration device containing Cs-137 and used it to irradiate his estranged son, causing the child significant bodily harm.

Cs-137/Ir-192 Attack, 1998
South Korean medical doctor stole Cs-137 and Ir-192 brachytherapy sources and attempted to murder his mistress by hiding them in her car.

Co-60 Attack, 1993
Unknown perpetrator murdered the manager of a Russian packaging company using a Co-60 industrial source hidden in his chair.

Ir-192 Attack, 2001
Chinese radiation technologist obtained Ir-192 radiography sources, fashioned a necklace, and attempted to murder a former girlfriend. Several individuals suffered from radiation exposure.

Co-60 Attack, 1997
Chinese phosphate plant employee stole a Co-60 industrial source and used it to murder his plant manager by hiding it in his office.

Ir-192 Attack, 2003
Chinese nuclear medicine researcher illegally obtained an Ir-192 radiography source and attempted to murder a colleague by hiding it in his office. 74 people suffered from exposure before it was discovered.

Cs-137/Am-241 Extortion, 1998
Am-241 and Cs-137 oil exploration sources were stolen at gunpoint while in transit to Colombian job site. The thieves, who included a company employee, threated to disperse the material if not paid.

Cs-137 Attack, 2006
Unknown perpetrator attempted to murder a Chinese university professor by hiding a Cs-137 source in his office.

Radiation Sources in the United States

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- Approximately 5,000 devices containing nearly 55,000 Category 1 and 2 ("high-risk") radiation sources are licensed for use today in the United States.
- The devices are used for applications that are important to society: cancer therapy, sterilization of medical devices, irradiation of blood for transplant patients and of laboratory animals for research, non-destructive testing of structures and industrial equipment, and exploration of geologic formations to find oil and gas deposits.

RECOMMENDATION:
Replacement of some radionuclide sources with non radionuclide radiation generators should be done with caution.

Security Risks and Area Denial

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- Security and safety risks motivated the request for this study.
- Radiation sources can be significant risks for individuals, but are unlikely to cause deterministic health effects to large numbers of people.
- The widest ranging and most long lasting consequences from an RDD may be the economic and social disruptions resulting from contamination that leads to area denial.
- IAEA source categories are based on deterministic health effects. U.S. NRC & U.S. DOE's contamination criterion does not sufficiently account for differences in consequences of RDDs using different sources.

RECOMMENDATION:
For prioritizing its efforts to reduce security risks, the U.S. NRC should consider a radiation sources' potential to cause contamination of large areas resulting in area denial.