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Industrial Irradiator Security by Design

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National Nuclear Security Administration

Global Material Security

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Introduction

- The US National Nuclear Security Administration (NNSA) Office of Radiological Security (ORS) works with governments, law enforcement, and businesses across the globe to protect radioactive sources.

- The In-Device Delay (IDD) program supports ORS's mission by partnering with manufacturers to incorporate engineered security enhancements into device or facility designs.

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Incidents of Theft or Loss

Source: IAEA Incident and Trafficking Database

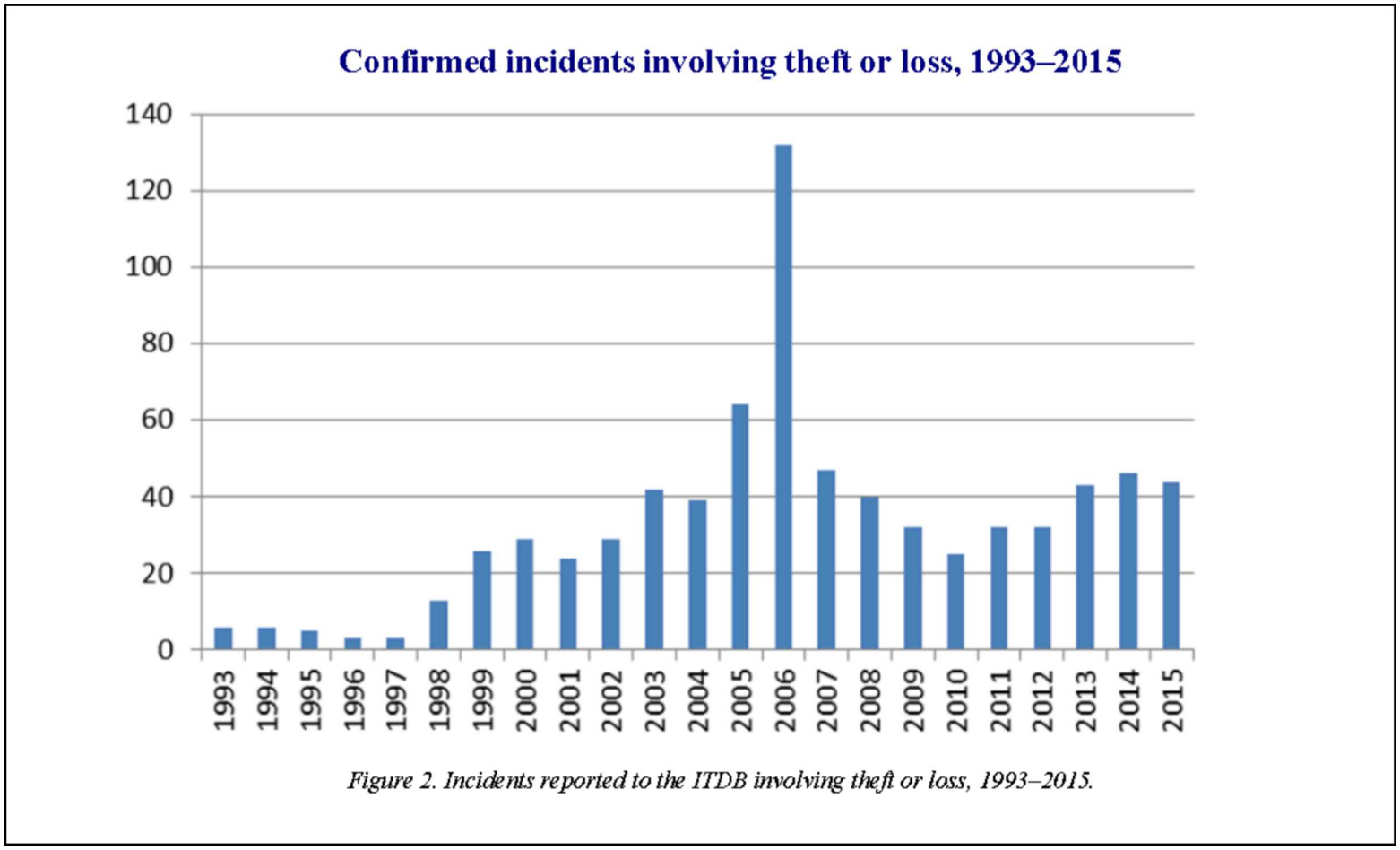

Figure 2. Incidents reported to the ITDB involving theft or loss, 1993–2015.

"The majority of thefts and losses reported to the ITDB involved radioactive sources that are used in industrial or medical applications"

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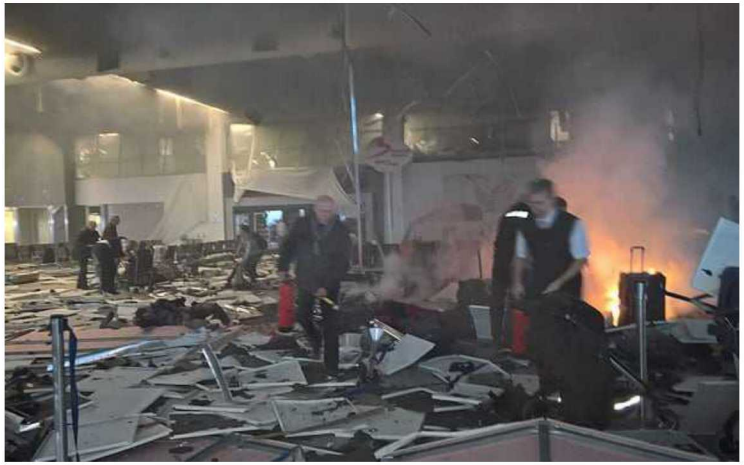
Threat Examples: Tihange Nuclear Power Plant

- Suspects in 2016 Brussels bombing attacks were interested in radioactive material to make a dirty bomb.
- Suspects were surveilling the home of a senior researcher at the Belgian Centre for Nuclear Energy.
- Police raids in Brussels disrupted the plot.
  - Led to the Paris Massacre and Brussels Airport and Metro bombings.



Threat Examples: French Jewel Heist, 2015

- Occurred between Paris and Lyon
- Highly-coordinated attack involving ~12 well-armed attackers
- Used enhanced breaching
- $9.5 million in jewels stolen

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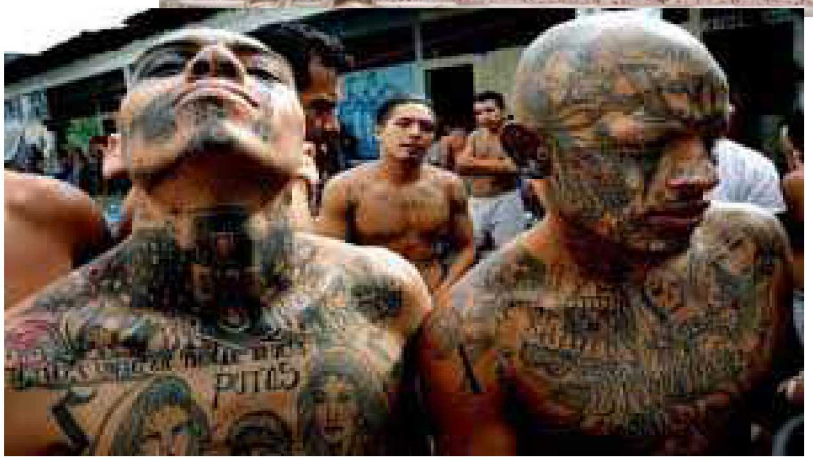
Threat Examples: Organized Crime

- Drug Trafficking Organizations: Sinaloa cartel revenue $3 billion with global reach
- Mafia: Solntsevskaya Bratva revenue: $8.5 billion
- Gangs: Prison and Street



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In-Device Delay (IDD) Security by Design

- Work with manufacturers of gamma irradiators and other devices containing high-activity radioactive sources to design enhancements that will make illicit removal of sources difficult.
- Incorporate detection components as well as delay where possible to increase time for local law enforcement to respond.
- Existing devices/facilities retrofitted with enhancements; new devices/facilities incorporate enhancements into manufacturing process.

IDD provides substantial delay time against an adversary that attempts to remove the source from the device, thus buying time for off-site responders to arrive at the site to contain the adversary.

Over 10 manufacturer partnerships since 2007

Industrial Irradiator Security

- Long assumed that industrial irradiator sources are self-protecting due to high, incapacitating radiation doses.
- Convention on the Physical Protection of Nuclear Material and INFCIRC/225 indicate that material with a dose rate of 1 Gy/hr at one meter does not need additional physical protection measures.
- This was seen as a deterrent to theft…however, to self-protect, the dose must be sufficient to incapacitate the adversary before the source can be removed from the facility.
- INFCIRC/225 Revision 5 (2018) now indicates that States should carefully consider whether or not the provision is an acceptable modification in determining their physical protection requirements.

Incapacitating Dose

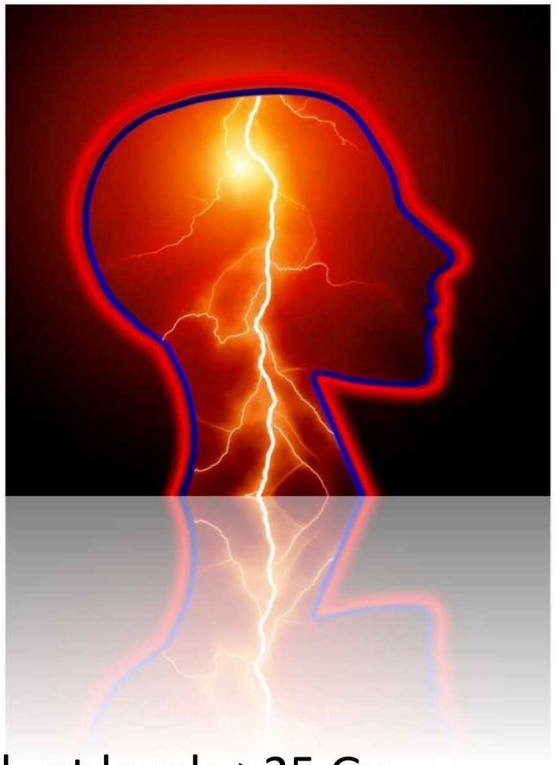
- Data about early effects of high-radiation doses comes from nuclear accidents, clinical irradiations, Hiroshima and Nagasaki detonations, and laboratory animal studies.

  - Doses > 20 Gy result in disorientation, confusion, prostration, loss of balance, and seizures.
  - Timing of symptoms and the extent of recovery depends on total dose and dose rate.

- Oak Ridge National Laboratory (ORNL) analyzed incapacitation due to radiation exposure:

  Radiation Effects on Personnel Performance Capability and a Summary of Dose Levels for Spent Research Reactor Fuels, December 2005

2005 ORNL Incapacitating Dose Evaluation



- Incapacitation generally begins with emesis, followed functional impairment from central nervous system damage, leading to reduced cognitive capability and routine task skills.
- Temporary improvement often occurs within 30 minutes – the extent of improvement a function of dose and dose rate.
- Initial decrease in performance before temporary improvement) referred to as Early Transient Incapacitation (ETI).
- ETI appears to occur in essentially all exposed individuals at levels >25 Gy.
- Dose rate of 100 Gy/hr at 1 meter determined to be "…the level that significantly affected performance of the perpetrator and offered limited self-protection (in the range of minutes)."

Table 4. Exposure effects on capability[2, 4, 11, 13, 18–26]

Dose (Gy)[a]	Probability of nausea	Time to emesis[b] (h)		Potentially lethal effects[c]	Chance of survival[d]	Time to death (d)	Index of incapacitation[c,e]
		Mean	Range				
0.5	15%	5	3–18	None	~100%	Unlikely	0.02 – Possible nausea or vomiting
1	30%	4	1.5–15	None	~100%	Unlikely	0.05 – Increased incidence and severity of nausea, vomiting
2	50%	3	0.8–12	Increased marrow damage	>90%	35–49	0.1 – Nausea, vomiting, reduced cognitive and routine task skills
3	70%	2	0.5–10	Extensive marrow damage	50%	28–42	0.15 – Same as above but more likely to occur and more intense
4	90%	1.5	0.3–8	Severe marrow damage	<40%	21–35	0.2 – Same as above but more likely to occur and more intense
6	~100%	1	0.1–6	Severe marrow damage; some GI and lung damage	Very low	14–21	0.25 – Depressed cognitive skills, task performance; animal studies show immediate depression in volitional performance
10	~100%	0.5	0.08–3	Combined GI, lung, and marrow damage	Very low	7–14	0.3 – Same as above but more likely to occur and more intense
15	~100%	0.4	0.08–2	GI damage	None	5–12	0.4 – Greater CNS involvement; ETI in many cases (animal data)
25	~100%	0.3	0.08–1.5	GI damage	None	2–5	0.7 - Substantial incapacitation for physical activity within 5 min in virtually all exposed persons (based on data for monkeys)
40	~100%	0.25	0.08–1	GI and CNS damage	None	2–3	1.0 - Increased frequency and intensity of incapacitation (humans and monkeys). Greatly reduced blood pressure in 5 min (monkeys)
100	~100%	Minutes	--	CNS damage	None	~2	1.0 – Incapacitation in minutes in most persons (humans, animals)

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US Centers for Disease Control: Acute Radiation Syndrome

Syndrome	Dose	Prodromal Stage	Manifest Illness Stage
Gastrointestinal (GI)	>10 Gy (> 1000 rads) some symptoms may occur as low as 6 Gy (600 rads)	• Symptoms are anorexia, severe nausea, vomiting, cramps, and diarrhea. • Onset occurs within a few hours after exposure. • Stage lasts about 2 days.	• Symptoms are malaise, anorexia, severe diarrhea, fever, dehydration, and electrolyte imbalance. • Death is due to infection, dehydration, and electrolyte imbalance. • Death occurs within 2 weeks of exposure.
Cardiovascular (CV) & Central Nervous System (CNS)	>50 Gy (5000 rads) some symptoms may occur as low as 20 Gy (2000 rads)	• Symptoms are extreme nervousness and confusion; severe nausea, vomiting, and watery diarrhea; loss of consciousness; and burning sensations of the skin. • Onset occurs within minutes of exposure. • Stage lasts for minutes to hours.	• Symptoms are return of watery diarrhea, convulsions, and coma. • Onset occurs 5 to 6 hours after exposure. • Death occurs within 3 days of exposure.

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Estimated Time to Incapacitation for Unshielded Co-60

Activity (Ci)	Time (min) @ 30 cm	Time (min) @ 60 cm	Time (min) @ 100 cm
750	20.2	63.5	163.2
1500	10.1	31.7	81.6
2500	6.1	19.0	49.0
3500	4.3	13.6	35.0
4500	3.4	10.6	27.2
5000	3.0	9.5	24.5
7500	2.0	6.3	16.3
11000	1.4	4.3	11.1

Assumptions:

- 25 Gy is a reasonably conservative incapacitation dose.
- Co-60 source pencil removal estimated by treating it as a line source.

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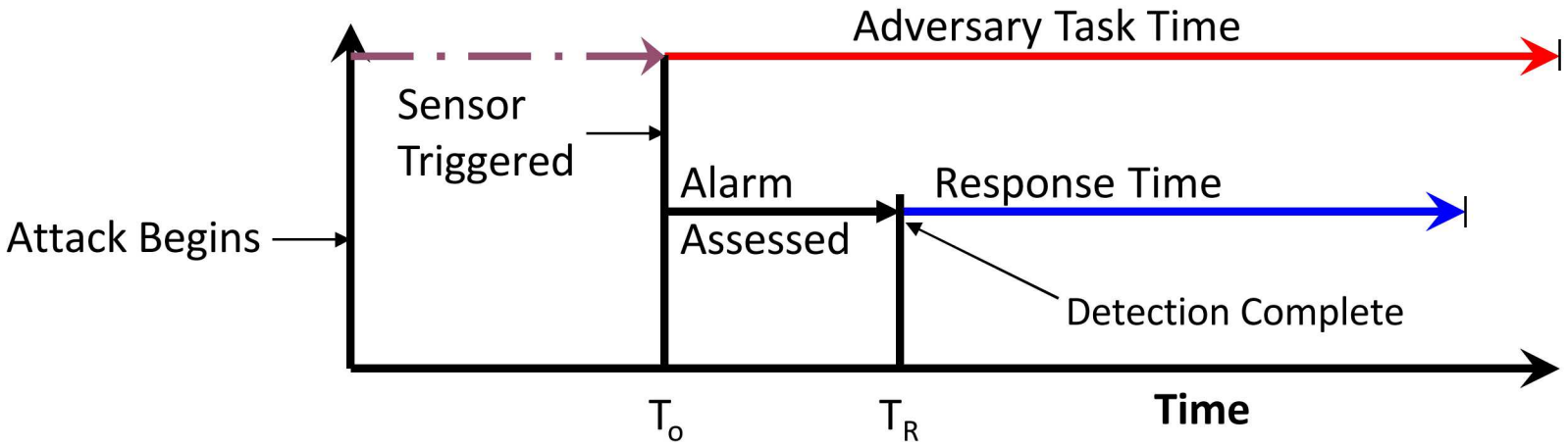
Physical Protective System Elements

Attack timeline:



To ensure total Response Time is less than Adversary Task Time:

- Sense attack earlier
- Increase delay
- Reduce response time
- Reduce detection/assessment times

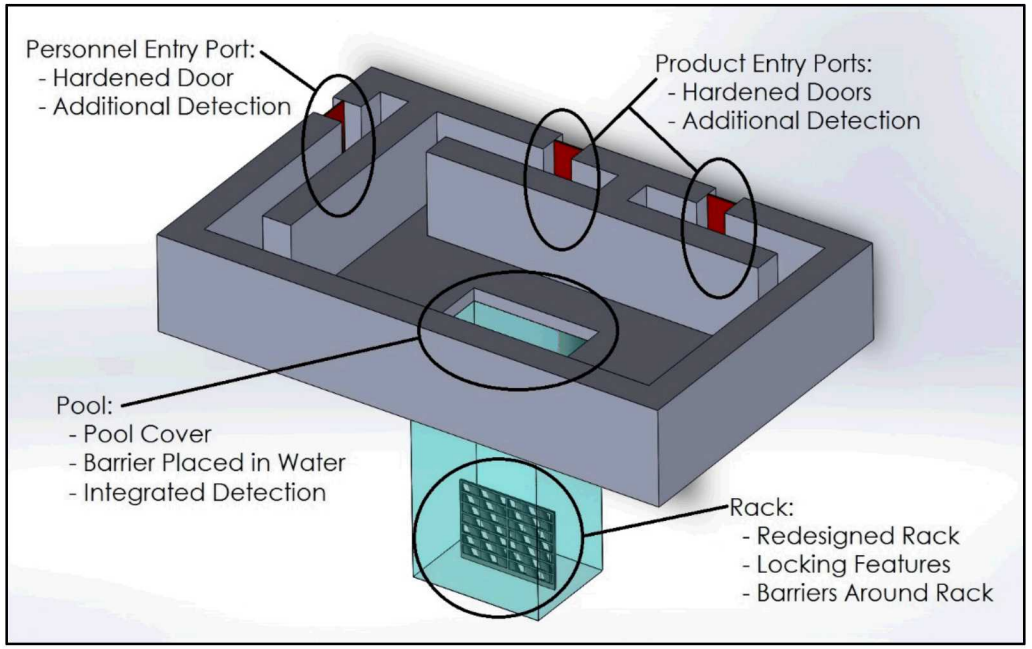
IDD Security by Design Process

- Understand the threat environment.
- Conduct vulnerability analysis.
  - Baseline attack testing
- Collaborate with partner to design a solution that will have:
  - Minimal impact to operations
  - No impact to safety (radiation or other)
  - Only a small percentage added to the overall product cost
  - Enough delay time to provide response forces time to arrive and thwart the attack
- Security is often most effectively designed into a device or facility from the beginning rather than added afterwards.

Security: Layered Approach

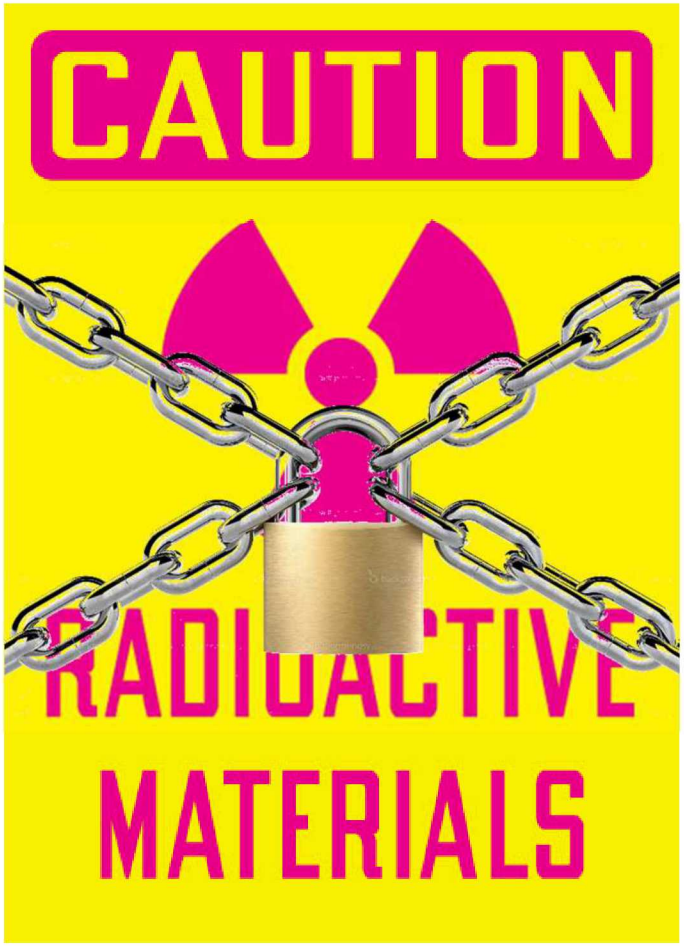
Security can be implemented into industrial irradiation facilities in a layered approach.

- Rack: Design more robust modules and/or racks; engineer locking features
- Pool: Improve pool cover; add barriers that block access to the rack
- Maze: Hardened doors at entry and exit points; add detection
- Facility: Hardened entry points; add detection



Conclusions

- Radioactive material is an attractive target.
- It is possible to steal a source from many existing radiological devices/facilities.
- Security by Design offers an opportunity to increase source security with relatively low-cost options that are designed into a facility or device.



Questions?