ORS
Office of Radiological Security
Protect · Remove · Reduce

SAND2018-1352C

Security by Design

NICSTAR 2018

Michal Kuca, Sandia National Laboratories

National Nuclear Security Administration

Global Material Security

ORS
Office of Radiological Security
Protect · Remove · Reduce

Outline

- Introduction
- Threat of Theft
- Radiation Dose Calculations
- Physical Protection System Considerations
- Security by Design Project Layout

Introduction

- Security by Design supports the US Department of Energy Office of Radiological Security's Protect mission by partnering with manufacturers to incorporate security enhancements into device or facility designs.
- Radioactive material is an attractive target.
  - Terrorist groups
  - Criminal groups
- Data shows incidents of loss and theft of radioactive material in many areas of the globe.
- Theft of material is a high-consequence event.
  - Human consequences
  - Regulatory consequences

ORS
Office of Radiological Security
Protect · Remove · Reduce

Incidents of Theft or Loss

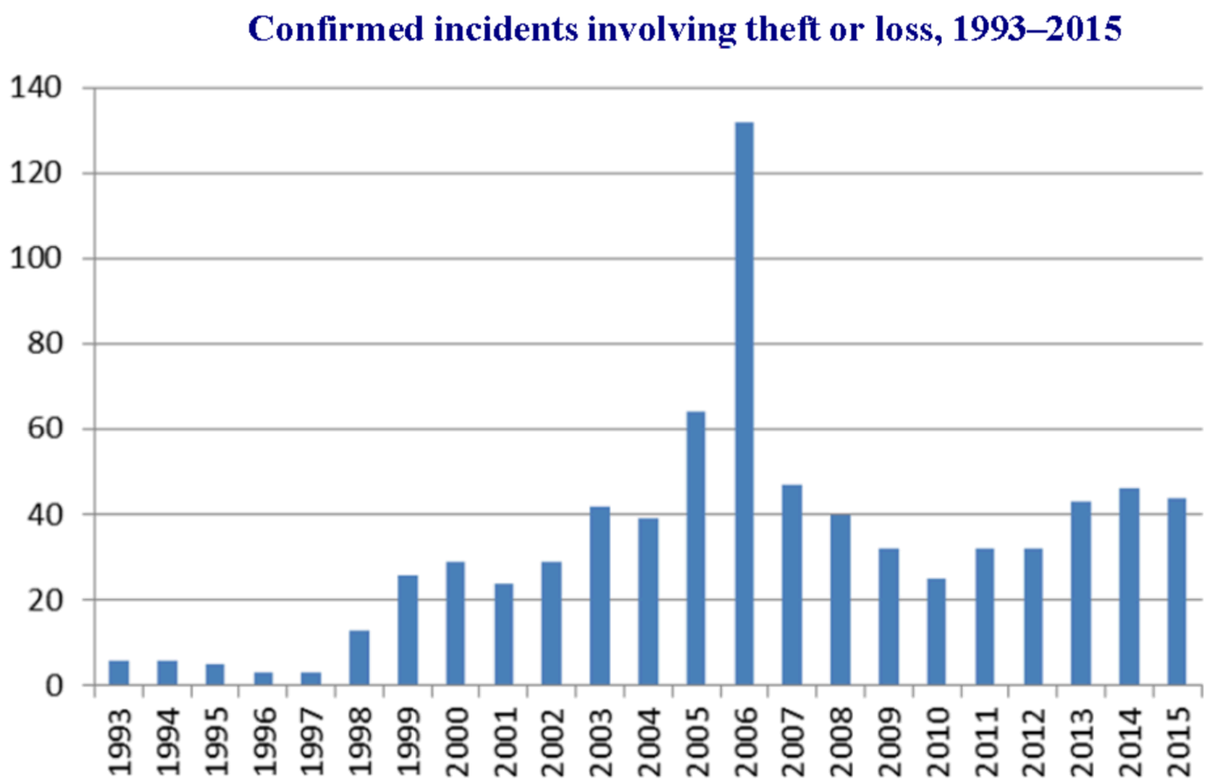


Figure 2. Incidents reported to the ITDB involving theft or loss, 1993–2015.

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

National Nuclear Security Administration

Global Material Security

Source: IAEA Incident and Trafficking Database

Office of Radiological Security
Protect · Remove · Reduce

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.

National Nuclear Security Administration
Global Material Security

ORS
Office of Radiological Security
Protect · Remove · Reduce

Threat Examples: French Jewel Heist, 2015

- Between Paris and Lyon
- Highly coordinated
- Involved ~12 well-armed attackers
- Used enhanced breaching
- $9.5 million in jewels stolen

National Nuclear Security Administration
Global Material Security

Threat Examples: Organized Crime

- Drug Trafficking Organizations: Sinaloa Cartel—Revenue $3 billion
- Mafia: Solntsevskaya Bratva—Revenue: $8.5 billion
- Gangs: Prison and Street

Radiation Dose Considerations: Worst Case

- Assumption has been that industrial irradiator sources are self-protecting due to incapacitating radiation doses.
- If a single source can be removed from the device while the source is in its storage position, radiation will likely be considerably lower.
- Convention on the Physical Protection of Nuclear Material and INFCIRC/225 provide general recommendations that 1 Gray per hour (1 Gy/hr) is self-protecting.
- To be an effective deterrent to theft, incapacitation must occur within minutes.
  - What dose is necessary to achieve rapid or immediate incapacitation?

ORS
Office of Radiological Security
Protect · Remove · Reduce

Radiation Dose Considerations: Worst Case

- Incapacitating dose actually may be much higher than 1 Gy/hr.
- Data about early effects of high-radiation doses comes from nuclear accidents, clinical irradiations, Hiroshima and Nagasaki detonations, and laboratory animal studies.
- Doses exceeding 20 Gy result in disorientation, confusion, prostration, loss of balance, and seizures.
- Timing and extent of recovery depends on the total dose and the 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

ORS Office of Radiological Security Protect · Remove · Reduce

2005 ORNL Dose Evaluation

- Incapacitation generally begins with emesis (vomiting), followed by further functional impairment from central nervous system damage leading to reduced cognitive capability and routine task skills.
- Temporary improvement in performance often occurs within the next 30 minutes (extent and duration of improvement depends on dose).
- Initial decrease in performance (before temporary improvement) referred to as Early Transient Incapacitation (ETI).
- Early onset (within minutes) of emesis and incapacitation appears to occur in essentially all exposed individuals at levels >25 Gy, with initial delays and recovery periods becoming more abbreviated at higher exposures.
- 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)."

Office
Protec

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

Dose (Gy)[a]	Probability of nausea	Time to emesis[b] (h) Mean	Time to emesis[b] (h) Range	Potentially lethal effects[c]	Chance of survival[d]	Time to death (d)	Index of incapacitation[c,e]
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)

ORS
Office of Radiological Security
Protect · Remove · Reduce

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.

ORS
Office of Radiological Security
Protect · Remove · Reduce

Time to Incapacitation Calculations

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.
- Dose for source pencil removal estimated by treating it as a line source.
- Arms-length distance to body conservatively estimated at 30 cm.
- Remote handling tool distance to body estimated at 1 meter.

Physical Protection Systems

Effective Physical Protection Systems should consist of three elements:

- **Detection**
  - The adversary's presence and intentions must be detected, preferably early in the attack.
- **Response**
  - A force of sufficient size and capability must arrive to stop the adversary before he completes his objective.
- **Delay**
  - Barriers are used to force the adversary to spend more time conducting their attack and to give the response time to act.

ORS Office of Radiological Security
Protect · Remove · Reduce

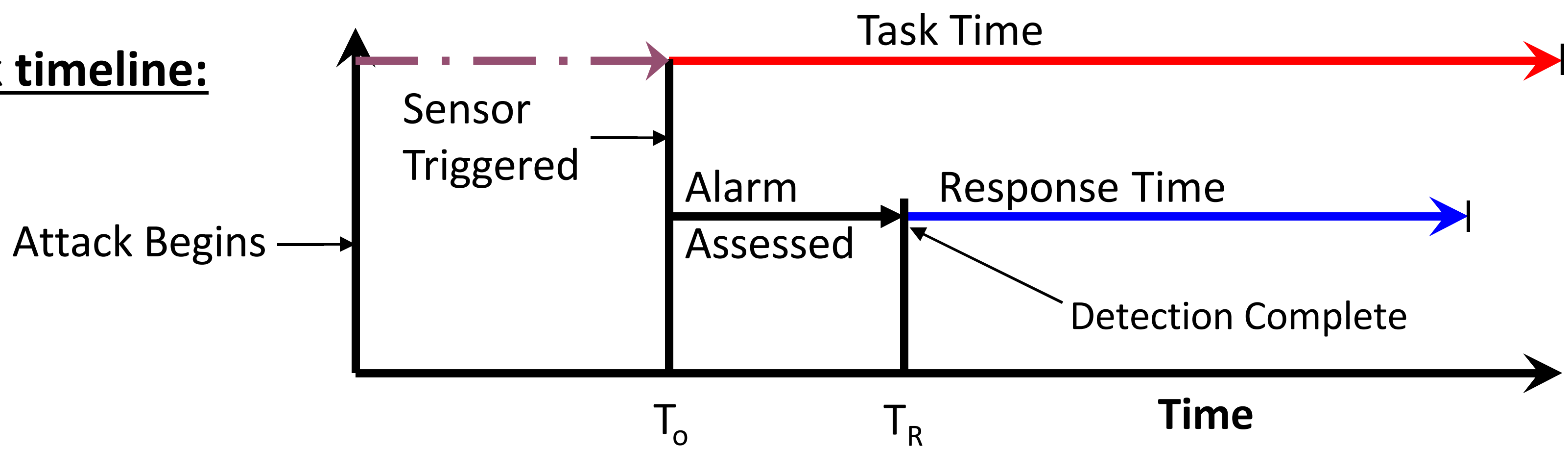
Physical Protective System Elements

Three key elements:

1. Intrusion Detection and Assessment
2. Access Delay
3. Response

NOTE:
Radiation safety measures rarely provide delay!

Attack timeline:



Ways to ensure total *Response Time* < *Adversary Task Time*:

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

National Nuclear Security Administration
Global Material Security

ORS Office of Radiological Security Protect · Remove · Reduce

Define the Threat

- Who are the attackers (protestors, terrorists, etc.)?
- How many attackers?
- What tools can the attackers use?
  - Hand tools vs. power tools vs. thermal tools
- Are there any toolkit weight or volume limits?
- What knowledge and skills do the attackers possess?
- What open source knowledge is available?
  - Operating manuals, journal articles, common user knowledge
  - Photographs of device or enhancements (whatever would be visible during maintenance procedures)
- Sensitivity analysis: how does performance change as an adversary has full knowledge of enhancements?

National Nuclear Security Administration Global Material Security

ORS
Office of Radiological Security
Protect · Remove · Reduce

Physical Protection System Design Principles

- Detection occurs before delay – Delay before detection does not count.
- Balanced design – A physical protection system should equally protect all possible paths to the asset.
- Designed to meet threat – A designated threat is used to design the physical protection system elements.
- Assessment – Detection should incorporate some means of assessing an alarm to determine validity.

Office of Radiological Security
Protect · Remove · Reduce

Physical Protection System Design Principles

- Low nuisance and false alarm rates.
- Minimal impact to operations.
- No impact to safety (radiation or other).
- **Security is often most effectively designed into a device or facility from the beginning, rather than added on afterwards.**

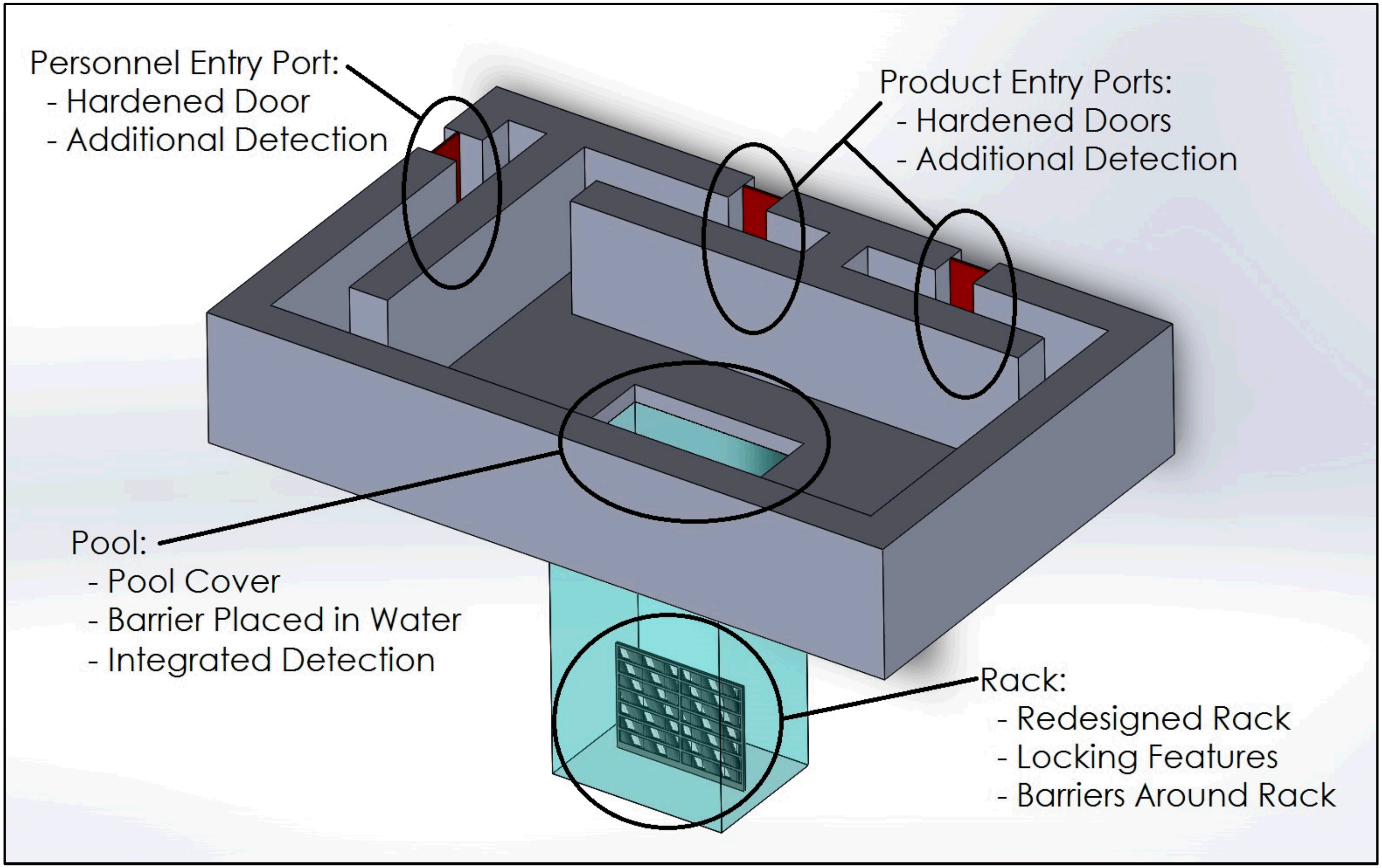
Security System: Layered Approach

Physical Protection Systems can be implemented into modern industrial gamma irradiation facilities at several different layers:

- Rack
  - Redesigned, more robust modules and/or rack
  - Locking features incorporated into modules
  - Barriers placed around rack at bottom of pool
- Pool
  - Pool cover
  - Barriers placed in pool over rack
- Maze
  - Hardened doors at entry and exit points
- Facility
  - Hardened entry points

ORS
Office of Radiological Security
Protect · Remove · Reduce

Security System: Layered Approach



NNSA National Nuclear Security Administration

Global Material Security

Common Enhancement Methods

- Add delay along the attack path and concentrate delay at the source.
- Choose barrier materials that are difficult to cut with a variety of tools.
  - Use multiple barriers/delay materials together to create synergy
- Add detection elements early in the attack path.
- Use delay elements to enhance detection.
- Integrate tamper detection sensors into delay barriers.
- Incorporate two-person control when possible.
- Remove components/tools that aid an adversary.

ORS
Office of Radiological Security
Protect · Remove · Reduce

Security by Design Project Objective

- Collaborate with the manufacturer to identify and develop low-cost detection and delay enhancements that can be incorporated into future facility designs to help mitigate the risk of source theft.

Security by Design Project Steps

- Review facility or device design information (drawings, photographs, operations)
- Conduct site assessments to characterize the facility or device, operations, and equipment
- Conduct adversary "path analysis" to identify source removal methods and timeline estimates
- Conduct baseline attack testing
- Develop initial Security-by-Design concepts
- Collaborate with manufacturer to develop prototype security upgrade designs

ORS Office of Radiological Security
Protect · Remove · Reduce

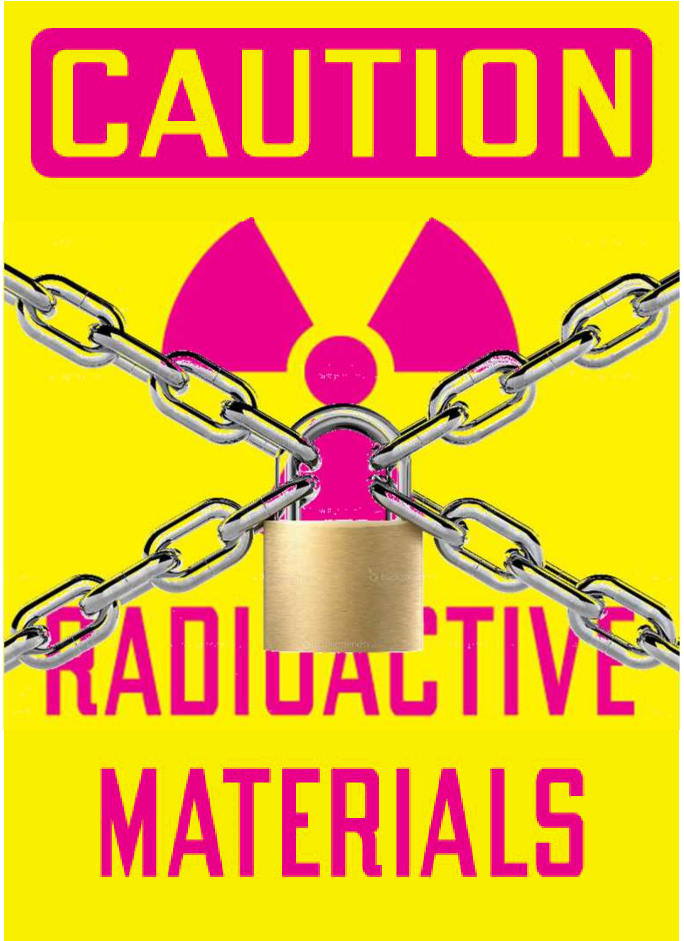
Security by Design Project Steps

- Attack test prototype security upgrade designs and refine design based on results
- Obtain necessary permit or license needs to address security upgrades
- Perform pilot installation(s) and refine security upgrade design based on pilot installation(s)
- Adopt final design of security upgrades
- Create retrofit version of security upgrades for existing facilities/devices

NNSA National Nuclear Security Administration
Global Material Security

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?