Mitigating Container Security Risk Using Real-Time Monitoring with Active Radio Frequency Identification and Sensors

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The Problem

• Global trade is on the rise
• ~90% of the world’s cargo is transported by container
• Large enough to hold multiple nuclear warheads, many tons of Anthrax, and other mass-destruction devices
• A terrorist attack could bring this trade to a halt
• The threat itself poses challenges that create inefficiencies in the global supply chain
Research

• Determine major global transport risks
• E-Container proposition
  – New angle on the e-seal
• Relation framework
  – Sensor-identified signatures and phenomena
  – Behaviors representing breaches in container security
• Theoretical model
  – Which sensors are required to identify breaches
• Goal → Mitigate global transport risk

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Four Major Container Categories

- Dry Freight
- Insulated
- Temperature Controlled
- Open Top

Source: Isocontainer.com

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Modes of Transportation

- Land (Chassis)
- Rail (Rail car)
- Sea (Ship)
- Handled (Individually)

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The Risks

- Stowaways & Human Smuggling
- Weapons Smuggling
- Injection of Chemical and Biological Agents
- Nuclear Materials
- Drug Smuggling
- Theft of Containers and their Contents (Piracy)
- Explosion or Leakage of Dangerous Materials
- Size of Maritime Vessels

Theft Cost Breakdown by Percentage

<table>
<thead>
<tr>
<th>Transportation Method</th>
<th>% of Total</th>
<th>$30 Billion Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Transport (Truck)</td>
<td>87%</td>
<td>$26.1 Billion</td>
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<tr>
<td>Maritime Cargo (Container Ship)</td>
<td>8%</td>
<td>$2.4 Billion</td>
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<td>Rail Cargo</td>
<td>4%</td>
<td>$1.2 Billion</td>
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<tr>
<td>Air Cargo</td>
<td>1%</td>
<td>$300 Million</td>
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</table>

Source: DeGeneste & Sullivan, 1994
Current Security Standard

Security Seals:
- Rubber and metal locks and/or bolts
- If broken, container will be inspected
- Known issues:
  - Rough treatment
  - Seals often damaged accidentally
- Causes unnecessary inspection

X-Ray Machines:
- Truck moves along side container
- Not proactive
- What can you actually detect?
  - Low-level radiation source penetrates cargo
  - Drugs, humans, dangerous cargo

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Picture taken at Intransit Rail Yards, December 2004
X-Ray Photo Source: http://www.copybook.com/images/publications/AirportInt/articleimages/L3detection3.jpg
Current Technology Standard
“e-Seal”

- Few Sensors
- Downloaded data
  - Not Real-Time
- Conspicuous
- Remove the hinge...
- Breach the side or roof...
- Proprietary software


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Available Sensors

- **Ambient Temperature**: Fahrenheit, Celsius, Kelvin
- **Light**: EM intensity
- **Humidity**: Moisture Density
- **Pressure**: Mass/Volume (typically air)
- **Vibration**: small-scale linear velocity, spatial displacement, acceleration
- **Sound**: decibels
- **Acceleration**: $\frac{d^2 x}{dt^2}$
- **Existence**: RFID tagged objects (RFID!)
- **Current Draw**: on the Tag
- **Motion**
- **Air Exchange**
- **Explosives**
- **Location**
- **Radioactivity**
Relate: Sensors to Behaviors

**Ambient Temperature:**
- Determine if a container has been opened
- Determine if a chemical reaction is occurring
- Determine if a person is moving in the container and generating heat

**Light:**
- Determine if a container door has been opened
- Determine if a fire has started
- Determine if lights are changing (electronic devices such as a timer)

**Humidity:**
- Determine if a person is breathing
- Determine if a liquid is leaking inside the container
- Determine if the container itself is leaking

**Pressure:**
- If a container is sealed air-tight, determine if the seal is broken
- Determine if pressure is building inside the container from heat etc.
Relate: Sensors to Behaviors

Vibration:
- Determine if something mechanical is running inside the container
- Determine if the container is being treated in a violent fashion

Sound:
- Determine if a person is speaking inside the container
- Determine if a machine is running inside the container
- Determine if items inside the container are banging or breaking

Acceleration:
- Determine shock and vibration

Existence:
- Determine if RFID tagged items are being added to the container
- Determine if RFID tagged items are being removed from the container
Relate: Sensors to Behaviors

Current Draw:
  – Determine if someone/something is tampering with the RFID tag

Motion:
  – Determine if someone/something is moving inside the container

Air Exchange:
  – Determine if a substance is being piped into or out of the container

Explosives:
  – Determine if there are explosives inside the container

Location:
  – Through GPS, determine the exact location of the container

Radioactivity:
  – Determine the existence of radioactive materials
  – Determine the intensity of the radioactive materials

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### Risk to Sensor Model

<table>
<thead>
<tr>
<th>Sensor Choice Model for Container Risk Mitigation</th>
<th>Ambient Temperature</th>
<th>Light</th>
<th>Humidity</th>
<th>Air Pressure</th>
<th>Vibration</th>
<th>Sound</th>
<th>Acceleration</th>
<th>RFID Existence</th>
<th>Current Draw</th>
<th>Air Exchange</th>
<th>Location</th>
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The e-Container

• Active RFID tags connected to sensors in the container
• Connect to a network and share real-time telemetry

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Architecture

RFID Middleware

Cellular Receiver Module
Wi-Fi/Wi-Max Receiver Module
Satellite Receiver Module

Cellular Network

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Centralized Data Center

Data Acquisition Unit

Satellite Receiver Module

Cellular Receiver Module

Wi-Fi/Wi-Max Receiver Module

RFID Middleware

ERP

WMS

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Communication

1. Heart Beat
2. Tampering Message
3. Threshold Break
4. Scheduled Scan
5. Manual Scan
Customs Technology Issues

• Searches are secret and random
• Evidence in prosecution
Additional Uses for the Technology

• Food perishability notices
  – Re-order

• Placement of Goods
  – Animal Hides & Food
  – Hot & Cold

• Unloading of Containers
Thanks

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