MODULE 7: EVALUATING A SYSTEM (PATH ANALYSIS)
1. System Approach evaluates each element of the PPS and how it contributes to overall system effectiveness
2. Elemental contribution helps define performance requirements which can then be measured
3. There is a qualitative and quantitative aspect to measuring PPS performance at the elemental level
4. Path analysis is a tool that allows analysts to combine to evaluate qualitative and quantitative data simultaneously
Systematic Approach To Design & Analysis

3 Step Process

1. Define System Objectives
   - What are we protecting?
   - Who are we protecting it from?
   - What technology tools do we have to protect it?
   - What controls/procedures do we have to protect it?

2. Design/Characterize System
   - What path will the adversary follow?

3. Evaluate System
   - When will security neutralize threat?
Systematic Approach To Design & Analysis

**Risk Formula**

\[ R = P_O \cdot C \cdot (1 - P_E) \]

- **System Risk**
- **Probability Of System Effectiveness** \( P_I \cdot P_N \)
- **Probability Of Interruption**
- **Probability Of Neutralization**

Diagram:
- **Adversary Task Time**
- **Total MPC&A Response Time**
- **Detection**
  - **Assessment Time**
  - **Response Force Time**
- **Adversary Begins Task**
- **Adversary Completes Task**

*Image credit: National Nuclear Security Administration*
Evaluating A system

**Vulnerability Assessment Process**

1. Facility Characterization
2. Target Identification
3. Threat Definition
4. Upgrade System
5. Results Unacceptable?
6. Results Acceptable?
7. Continuous Improvement

**System Characterization**
- Detection
- Delay
- Response

**Performance Metrics**
- Qualitative
- Quantitative

**Pathway Analysis**
- Qualitative
- Quantitative

**Neutralization Analysis**
- Qualitative
- Quantitative

**Defeat Tactics**

**Scenario Analysis**
- Qualitative
- Quantitative

**Interruption Analysis**
- Quantitative

**System Effectiveness**
- \( P_i \times P_n \)

- Performance Requirements will be measured based on predetermined metrics
Detection Metrics

- Detection Performance evaluated for:
  1. Function (Probability of detection $P_D$)
     - Will the sensor function correctly
     - Will the sensor communicate the alarm to the system
  2. Time
     - Alarm Signal Communication Time ($T_{AC}$)
Detection Metrics

- $P_D$ function depends on numerous factors
  - Sensor hardware design
  - Installation conditions
  - Sensitivity setting
  - Weather conditions (exterior sensors)
  - Maintained condition
  - Target (adversary) size and speed
Assessment Metrics

• Assessment is evaluated for:

  1. Function
     • Will the video sync with the alarm
     • Will the video feed be processed by the system to the operator
     • Will the operator correctly assess the alarm

  2. Time
     • How long does it take the operator to correctly assess the alarm
     • How long does it take the operator to communicate the alarm to the guard forces

\[ H_{FOV} = W_1 D/FL \]
Delay Metrics

• Performance measures (Function & Time)
  1. Time to penetrate or bypass barriers
  2. Time to travel across areas
• Delay must occur after detection
  • Delay before detection is deterrence
• Can be composed of
  • Passive Barriers
  • Active Barriers
  • Response ( Interruption)
  • Traversal time
Response Metrics

- Response is evaluated for:
  1. **Interruption (Time)**
     - Will a sufficient number of guards arrive in time to halt adversary progress
     - Interruption results in the extension of the adversary timeline
  2. **Neutralization (Function)**
     - Will the guards permanently eliminate/neutralize the adversary ability to make additional progress in their attack/theft
     - How many guards will arrive
     - What are the capabilities of the guards
     - Evaluations are scenario specific
Path Analysis

• Evaluation of an ordered series of actions an adversary must follow to steal/sabotage identified target

Penetrate Fence

Penetrate Outer Door

Penetrate Wall

Penetrate Inner Door

Storage Bin

System Characterization
• Detection
• Delay
• Response

Performance Metrics
• Qualitative
• Quantitative

Interruption Analysis
• Quantitative

Pathway Analysis
• Qualitative
• Quantitative

Scenario Analysis
• Quantitative

Neutralization Analysis
• Qualitative
• Quantitative

System Effectiveness
\[ P_i \times P_n \]
Combining The Metrics: Path Analysis

Path Analysis performance measures are:

1. Probability of Detection
2. Probability of Assessment
3. Probability of Interruption

<table>
<thead>
<tr>
<th>Description</th>
<th>PD</th>
<th>PA</th>
<th>PI</th>
<th>Score</th>
<th>Time</th>
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<tbody>
<tr>
<td>Penetrate Fence</td>
<td>VL</td>
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<td>VL</td>
<td>VL</td>
<td>30 sec</td>
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<tr>
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<td>H</td>
<td>VH</td>
<td>VL</td>
<td>VL</td>
<td>45 sec</td>
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<tr>
<td>Penetrate Wall</td>
<td>H</td>
<td>VH</td>
<td>VL</td>
<td>VL</td>
<td>90 sec</td>
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<tr>
<td>Penetrate Inner Door</td>
<td>H</td>
<td>VH</td>
<td>VL</td>
<td>VL</td>
<td>30 sec</td>
</tr>
<tr>
<td>Storage Bin</td>
<td>H</td>
<td>VH</td>
<td>VL</td>
<td>VL</td>
<td>30 sec</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
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<td>195 sec</td>
</tr>
</tbody>
</table>

Response Time = 210 seconds
Path Analysis

**Critical Path**

- Multiple adversary paths into a facility
  - Critical Path
    - Path with the lowest $P_i$
    - Critical path characterizes the effectiveness of the overall system in detecting, assessing, interrupting and neutralizing the adversary threat.
  - Balanced System
    - Provides adequate protection against all paths leading into a facility
Path Analysis

**Critical Path**

<table>
<thead>
<tr>
<th>Delay and Time Element (working backwards)</th>
<th>Cumulative Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 seconds to exit over fence</td>
<td>10</td>
</tr>
<tr>
<td>30 seconds to cross area to fence</td>
<td>40</td>
</tr>
<tr>
<td>10 seconds to exit through emergency exit</td>
<td>50</td>
</tr>
<tr>
<td>60 seconds to defeat tie downs</td>
<td>110</td>
</tr>
</tbody>
</table>
No time counts before detection

Response Force Time (RFT) doesn’t begin until detection and assessment
Path Analysis Process

Adversary Minimizes Detection

- Minimum Chance For Guards To Create Interruption
- Minimum Time Delay Remaining Along Adversary Path For Interruption

Adversary Minimizes Delay

- Response Time (100 sec)

Timeline:
- Begin Attack
- Fence (10 sec)
- Cross Area (30 sec)
- Building Door (20 sec)
- Alarmed Vault Door (30 sec)
- Alarmed Tie Downs (60 sec)
- Emergency Exit
- Cross Area (30 sec)
- Fence (10 sec)
- Escape
Path Analysis Example

Path Analysis Process
1. Characterize the Target
2. Characterize the Adversary
3. Characterize the Facility
4. Break each barrier into a step (detection opportunities)
5. Analyze $P_D \ P_A \ P_I \ P_N$ for each step
6. Create a step score for each barrier
7. The highest step score is the system effectiveness as a whole
Target Description
- 4 cylinders containing 5kg of HEU 80% enriched
- Canisters weight 6kg empty
- Total weight per canister = 11kg
- Dimensions h=20cm, r=8cm

Threat Description
- 6 adversaries
- 1 insider (active/ non-violent)
- Automatic Weapons
- 20kg of explosives

Facility Characterization
- Detection & Assessment
  - Site Perimeter
    - Passive Fence with ECP/Lighting
    - Guard Building
  - Protected Area Perimeter
    - Passive Outer Fence
    - Active Inner Fence (Pd = 70%)
  - MAA/MBA/Vault
    - All doors sensored.
Facility Characterization

- **Response**
  - 2 guards at site ECP
  - 3 guards at Protected Area ECP
  - 2 guards randomly patrol protected area fence line
  - 8 guards in guard building
  - All guards armed with:
    - Automatic Weapons

- **Response Time**
  A. Assessment = ?
  B. Communication to Guard force commander = ?
  C. Assessment by guard force commander = ?
  D. Deployment Orders Communicated = ?
  E. Muster Time = ?
  F. Transit Time = ?

A+B+C+D+E+F = Total Response Time

- Repeat for each deploy force
Path Analysis Example

Adversary Sequence Diagram

1. Off-Site
   - Gate
   - Fence
   - Building

2. Limited Area
   - Gate
   - Fence
   - Building

3. Protected Area
   - Door
   - Walls
   - Roof

4. Material Access Area
   - Door
   - Walls
   - Roof

5. MBA
   - Door
   - Walls
   - Roof

6. Vault
   - Container

7. Target

Limited Area
- Passive Outer/Active Inner (Vibration)

Protected Area
- Material Access Area
  - Lab (MBA1)
  - Vault (MBA 2)

All Active Fence Lines Have Adequate CCTV

Guard Building

Vehicle & Pedestrian ECP
- Prox/Pin Required
  - Guard Building

Off-Site
Path Analysis Example

Adversary Sequence Diagram

# | Description
---|---
1 | Off-Site
   | Gate | Fence | Building
2 | Limited Area
   | Fence | Gate | Building
3 | Protected Area
   | Door | Walls | Roof
4 | Material Access Area
   | Door | Walls | Roof
5 | MBA
   | Door | Walls | Roof
6 | Vault
   | Container
7 | Target

P_D

Limited Area
- Passive Outer/Active Inner (Vibration)

Protected Area
- Material Access Area
  - Lab (MBA1)
  - Vault (MBA 2)
- All Active Fence Lines Have Adequate CCTV

Off-Site
- Low

Passive Fence
- Vehicle & Pedestrian ECP
  - Prox/Pin Required
  - Guard Building
### Adversary Sequence Diagram

<table>
<thead>
<tr>
<th>#</th>
<th>Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Off-Site</td>
</tr>
<tr>
<td></td>
<td>Gate</td>
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<tr>
<td></td>
<td>Fence</td>
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<td>4</td>
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<td>Roof</td>
</tr>
<tr>
<td>6</td>
<td>Vault</td>
</tr>
<tr>
<td></td>
<td>Container</td>
</tr>
<tr>
<td>7</td>
<td>Target</td>
</tr>
</tbody>
</table>

**Path:**
- Off-Site
  - Limited Area
    - Material Access Area
      - Vault
        - Target

**Security Measures:**
- All Active Fence Lines Have Adequate CCTV
- Passive Outer/Active Inner (Vibration)

**Protection:**
- Low
- High
Path Analysis Example

**Adversary Sequence Diagram**

<table>
<thead>
<tr>
<th>#</th>
<th>Off-Site</th>
<th>Limited Area</th>
<th>Protected Area</th>
<th>Material Access Area</th>
<th>MBA</th>
<th>Vault</th>
<th>Target</th>
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<tbody>
<tr>
<td>1</td>
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<td>Walls</td>
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<td>7</td>
<td>Target</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

- **P**
- **D**
- **PD**
- **Low**
- **High**
- **Limited Area**
- **Material Access Area**
- **MBA**
- **Vault**
- **Target**

**Diagram Details**

- Off-Site
- Limited Area
- Protected Area
- Material Access Area
- MBA
- Vault
- Target
- All Active Fence Lines Have Adequate CCTV
- Passive Outer/Active Inner (Vibration)
- Low
- High
- Gate
- Fence
- Building
- Door
- Walls
- Roof
- Lab (MBA1)
- Vault (MBA 2)
- Guard Building
- Passive Fence
- Low P
- High P
- Container
- Gate & Pedestrian ECP
- Prox/Pin Required
- Guard Building
- Low P
- High P
- Vehicle & Pedestrian ECP
- Low P
- High P
- Container
- Gate & Pedestrian ECP
- Prox/Pin Required
- Guard Building
- Low P
- High P
- Vehicle & Pedestrian ECP
Path Analysis Example

Adversary Sequence Diagram

1. Off-Site
   - Gate
   - Fence
   - Building
   - PD
   - Low

2. Limited Area
   - Fence
   - Gate
   - Building
   - PD
   - High

3. Protected Area
   - Door
   - Walls
   - Roof
   - PD
   - High

4. Material Access Area
   - Door
   - Walls
   - Roof
   - PD
   - High

5. MBA
   - Door
   - Walls
   - Roof

6. Vault
   - Container

7. Target

Off-Site
Limited Area
Protected Area
Material Access Area
Lab (MBA1)
Vault (MBA 2)
All Active Fence Lines Have Adequate CCTV

Guard Building
Prox/Pin Required
Vehicle & Pedestrian ECP
Path Analysis Example

Adversary Sequence Diagram

#   Location
1   Off-Site
2   Limited Area
3   Protected Area
4   Material Access Area
5   MBA
6   Vault
7   Target

P_D
Low: Gate, Fence, Building
High: Door, Walls, Roof

Limited Area
Passive Outer/Active Inner (Vibration)
Protected Area
Material Access Area
Lab (MBA1)
Vault (MBA 2)

All Active Fence Lines Have Adequate CCTV

Guard Building

Container

Gate
Fence
Building

Walls
Roof
Path Analysis Example

Adversary Sequence Diagram

#   | Off-Site                  | Limited Area              | Protected Area             | Material Access Area |
---  |---------------------------|---------------------------|---------------------------|----------------------|
1    | Gate                      | Fence                     | Building                  |                      |
2    | Limited Area              | Fence                     | Gate                      | Building             |
3    | Protected Area            | Door                      | Walls                     | Roof                 |
4    | Material Access Area      | Door                      | Walls                     | Roof                 |
5    | MBA                       | Door                      | Walls                     | Roof                 |
6    | Vault                     | Container                 | High                      |                      |
7    | Target                    | High                      | All Active Fence Lines Have Adequate CCTV

Guard Building
Lab (MBA1)
Vault (MBA 2)
Low
Prox/Pin Required
Passive Outer/Active Inner (Vibration)

Path: Off-Site → Limited Area → Protected Area → Material Access Area → MBA → Vault → Target
Path Analysis Example

Adversary Sequence Diagram

How do you get out?

1. Off-Site
   - Gate
   - Fence
   - Building
   - P
   - Off-Site
   - Limited Area
   - Protected Area
   - Material Access Area
   - MBA
   - Vault
   - Container
   - Target

2. Limited Area
   - Fence
   - Gate
   - Building
   - Low

3. Protected Area
   - Door
   - Walls
   - Roof
   - High

4. Material Access Area
   - Door
   - Walls
   - Roof
   - High

5. MBA
   - Door
   - Walls
   - Roof
   - High

6. Vault
   - Container
   - High

7. Target
   - High

Limited Area
- Passive Outer/Active Inner (Vibration)

Protected Area
- Lab (MBA1)

Material Access Area
- Vault (MBA2)

Off-Site
- All Active Fence Lines Have Adequate CCTV
- Gate
- Building
- Passive Fence
- Prox/Pin Required
- Guard Building
- Low

How do you get out?
Path Analysis Example

Adversary Sequence Diagram

<table>
<thead>
<tr>
<th>#</th>
<th>Off-Site</th>
<th>Limited Area</th>
<th>Protected Area</th>
<th>Material Access Area</th>
<th>MBA</th>
<th>Vault</th>
<th>Target</th>
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<tbody>
<tr>
<td>1</td>
<td>Gate</td>
<td>Fence</td>
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<tr>
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<td>3</td>
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<td>Walls</td>
<td>Roof</td>
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</tr>
</tbody>
</table>

P_D:
- Low
- High

Protected Area:
- Limited Area
- Material Access Area
- MBA
- Vault
- Target

All Active Fence Lines Have Adequate CCTV
Adversary Sequence Diagram

1. Off-Site
   - Gate
   - Fence
   - Building

2. Limited Area
   - Fence
   - Gate
   - Building

3. Protected Area
   - Door
   - Walls
   - Roof

4. Material Access Area
   - Door
   - Walls
   - Roof

5. MBA
   - Door
   - Walls
   - Roof

6. Vault
   - Container

7. Target

When Does Interruption Occur?
- Off-Site
- Limited Area
- Protected Area
- Material Access Area
- Vault
- Target
- Container

Path Analysis Example
Path Analysis Example

Adversary Sequence Diagram

<table>
<thead>
<tr>
<th>#</th>
<th>P_D</th>
<th>Adversary Step Time</th>
<th>Cumulative Time</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Off-Site</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>Limited Area</td>
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<td>60</td>
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<td>15</td>
<td>135</td>
</tr>
<tr>
<td>6</td>
<td>Vault</td>
<td>30</td>
<td>150</td>
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<tr>
<td>7</td>
<td>Target</td>
<td>45</td>
<td>180</td>
</tr>
</tbody>
</table>

Total Task Time is 440 seconds
1. 340 Seconds to get to material & prepare material for transport
2. 100 Seconds to escape (use times listed in barriers)

What are the response times?
Can interruption be achieved?
**Path Analysis Example**

<table>
<thead>
<tr>
<th>Location</th>
<th>Response</th>
<th>Response Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site ECP</td>
<td>2 Guards @ _ seconds</td>
<td>Assessment Time = Muster Time = Transit to Specific Location =</td>
</tr>
<tr>
<td>Protected Area ECP</td>
<td>3 Guards @ _ seconds</td>
<td>Assessment Time = Muster Time = Transit to Specific Location =</td>
</tr>
<tr>
<td>Patrol Squad</td>
<td>2 Guards @ _ seconds</td>
<td>Transit to Specific Location =</td>
</tr>
<tr>
<td>Guard Building</td>
<td>8 Guards @ _ seconds</td>
<td>Assessment Time = Muster time = Transit to Specific Location =</td>
</tr>
</tbody>
</table>

**Total Adversary Task Time = 440**

**Analysis**
- When interruption occurs, what happens?
- Can the interrupting forces kill or capture adversary?

![Adversary Sequence Diagram](image-url)
<table>
<thead>
<tr>
<th>Step</th>
<th>Step Time</th>
<th>Cuml Time</th>
<th>Response Time</th>
<th>Description</th>
<th>( P_D )</th>
<th>( P_A )</th>
<th>( P_I )</th>
<th>( P_N )</th>
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Step Score = Probability of Effectiveness
Probability of Interruption factor is the starting point for scenario analysis

- *Scenario Analysis* determines whether the system can be exploited by adversaries

- The end result of a scenario analysis is a Probability of Neutralization factor

\[ \text{Probability of Neutralization} = \text{Probability of Interruption} \times \text{Probability of Neutralization} \]
Briefing Summary

1. Performance metrics lay a foundation for analysis
2. In the VA Process each security element should have a purpose that can be measured
3. Analysis includes the synthesis of qualitative and quantitative data
4. Synthesized results drive overall system effectiveness