Module 7: Evaluating A System (Path Analysis)

National Nuclear Security Administration

Briefing Overview

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

❶ Define System Objectives

- What are we protecting?
- Who are we protecting it from?

❷ Design/Characterize System

- What technology tools do we have to protect it?
- What controls/procedures do we have to protect it?

❸ Evaluate System

- What path will the adversary follow?
- When will security neutralize threat?

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Systematic Approach To Design & Analysis

Risk Formula

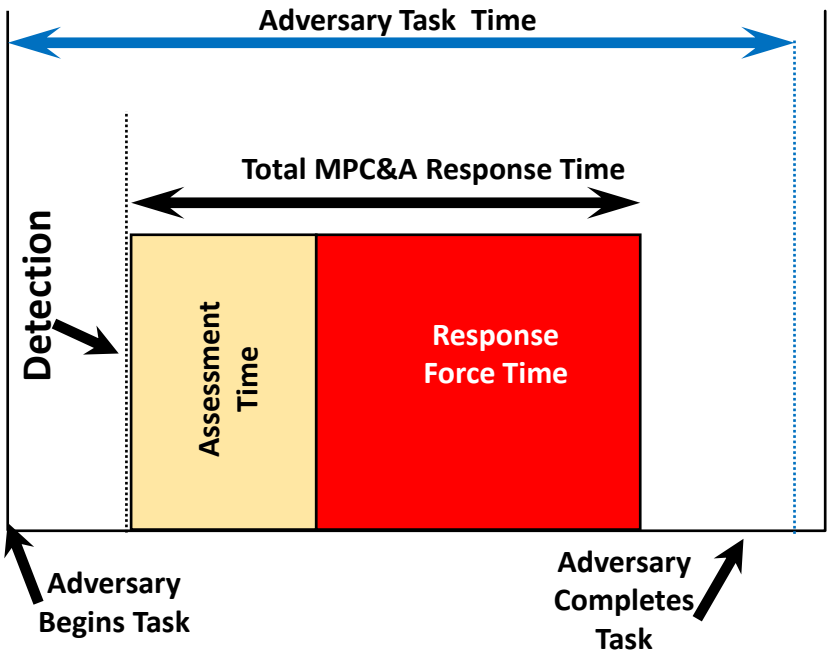
$$R = P_O * C (1 - P_E)$$

System Risk

Probability Of System Effectiveness
$P_I * P_N$

Probability Of Interruption

Probability Of Neutralization



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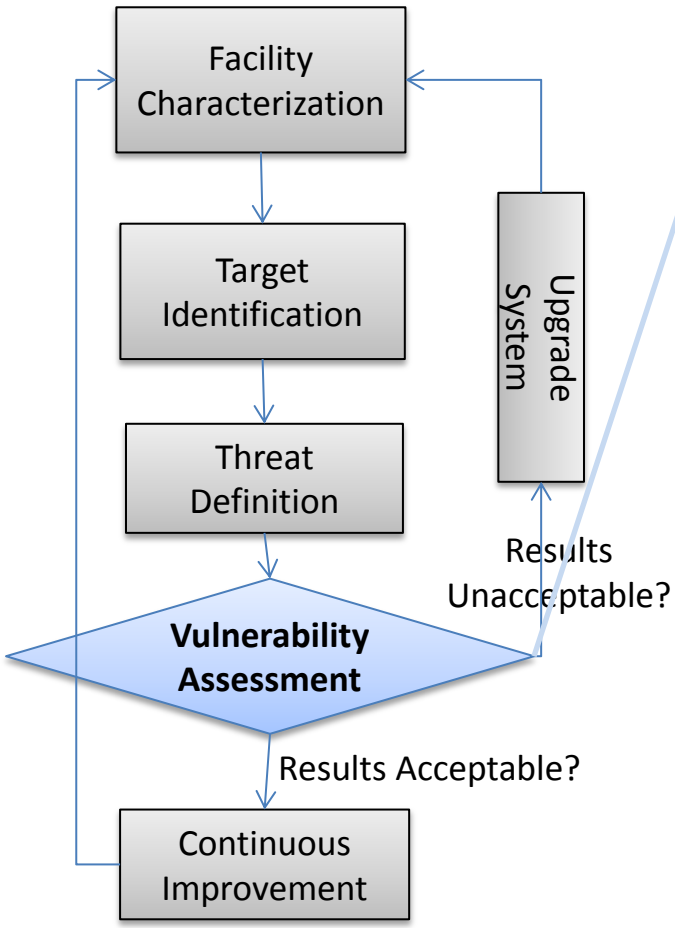
Evaluating A system

Vulnerability Assessment Process



System Characterization
- Detection
- Delay
- Response

Performance Metrics
- Qualitative
- Quantitative

Pathway Analysis
- Qualitative
- Quantitative

Interruption Analysis
- Quantitative

Scenario Analysis
- Quantitative
- Quantitative

Defeat Tactics

Neutralization Analysis
- Qualitative
- Quantitative

System Effectiveness
- $P_i * P_n$

- 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})

Alarm Sensor

Control Box

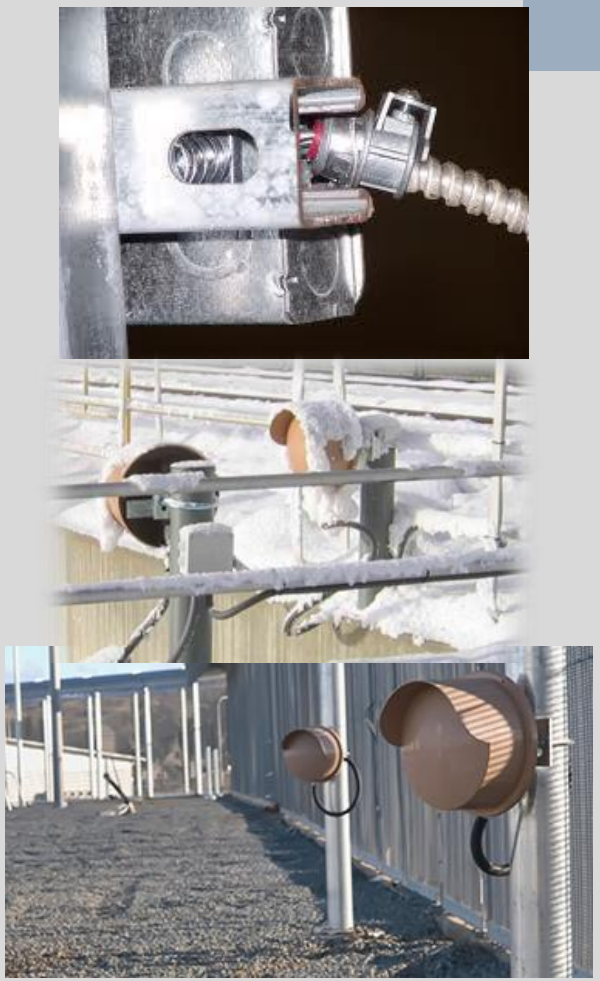
Network

Server → Assessment System

Central Alarm Station

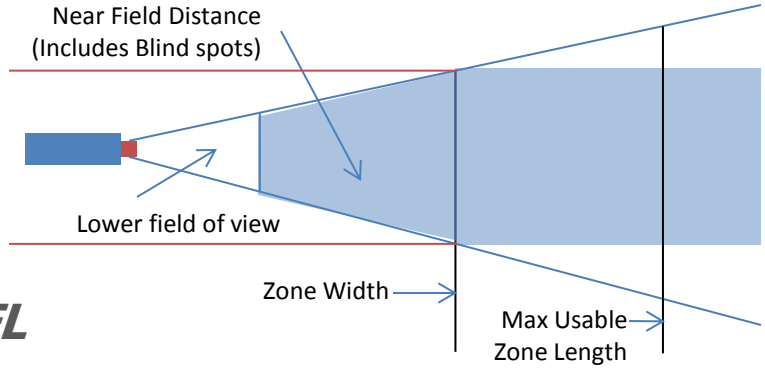
Detection Metrics

- 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 assessment 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



$$H_{FOV} = W_I D/FL$$

Delay Metrics

- Performance measures (Function & Time)
  1. Time to penetrate or bypass barriers
  2. Time to travel across areas
- Delay <u>must</u> 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

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

↓ **Pathway Analysis**
- Qualitative
- Quantitative

→ **Interruption Analysis**
- Quantitative

↓ **Scenario Analysis**
- Quantitative
- Quantitative

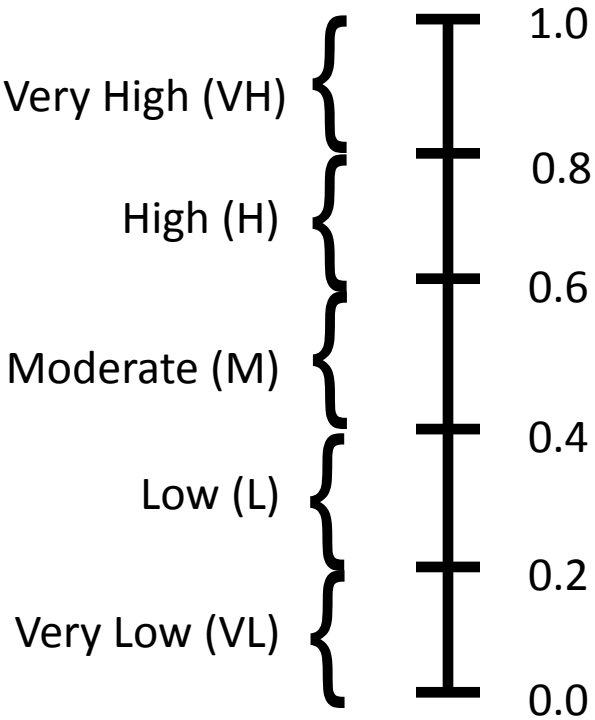
→ **Defeat Tactics** → **Neutralization Analysis**
- Qualitative
- Quantitative

→ **System Effectiveness**
- $P_i * P_n$

Combining The Metrics: Path Analysis

Path Analysis performance measures are:

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



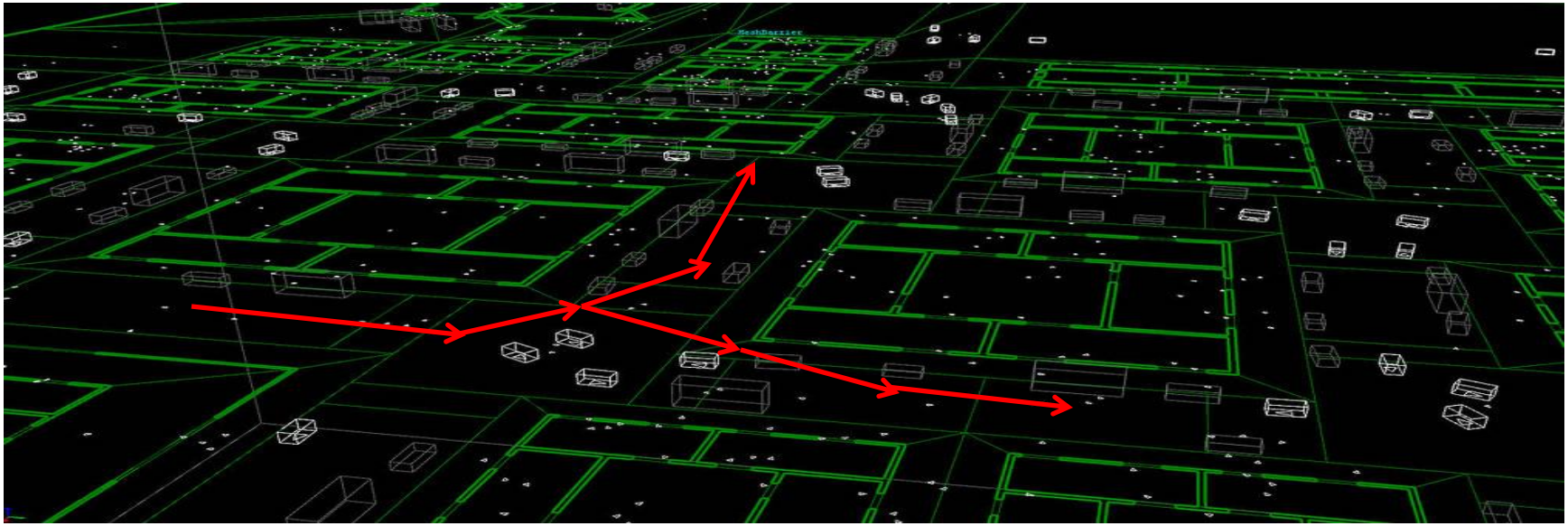
Description	P_D	P_A	P_I	Score	Time
Penetrate Fence	VL	VL	VL	VL	30 sec
↓					
Penetrate Outer Door	H	VH	VL	VL	45 sec
↓					
Penetrate Wall	H	VH	VL	VL	90 sec
↓					
Penetrate Inner Door	H	VH	VL	VL	30 sec
↓					
Storage Bin	H	VH	VL	VL	30 sec
Total				VL	195 sec

Response Time = 210 seconds

Path Analysis

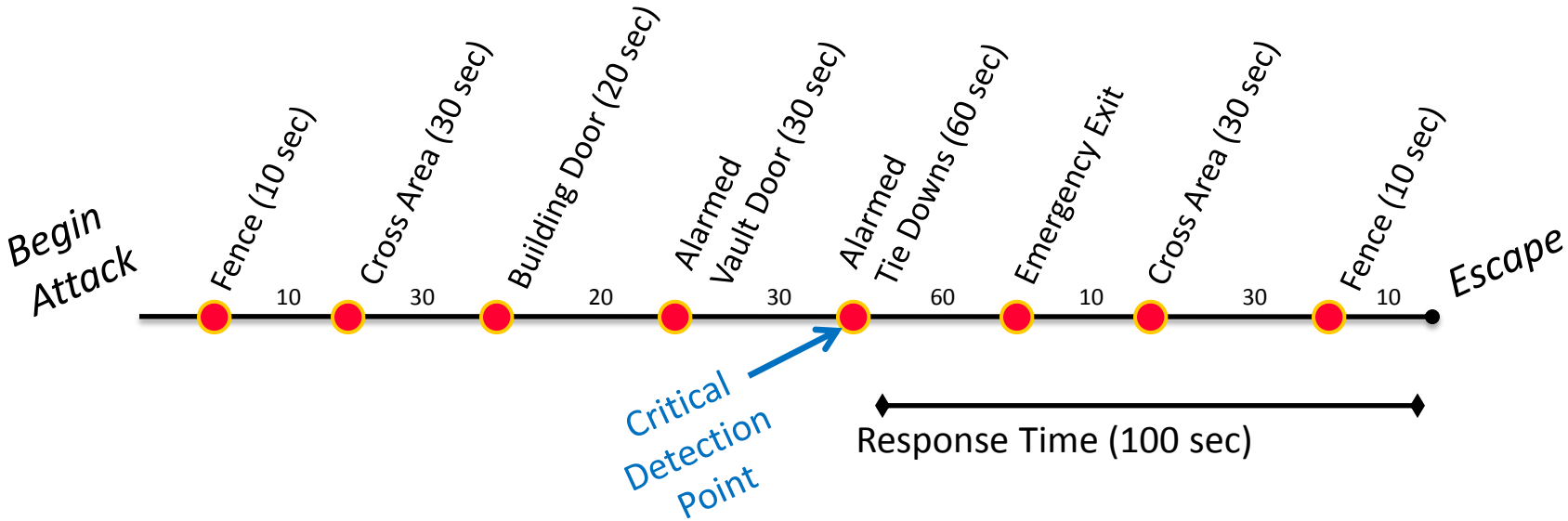
Critical Path

- 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

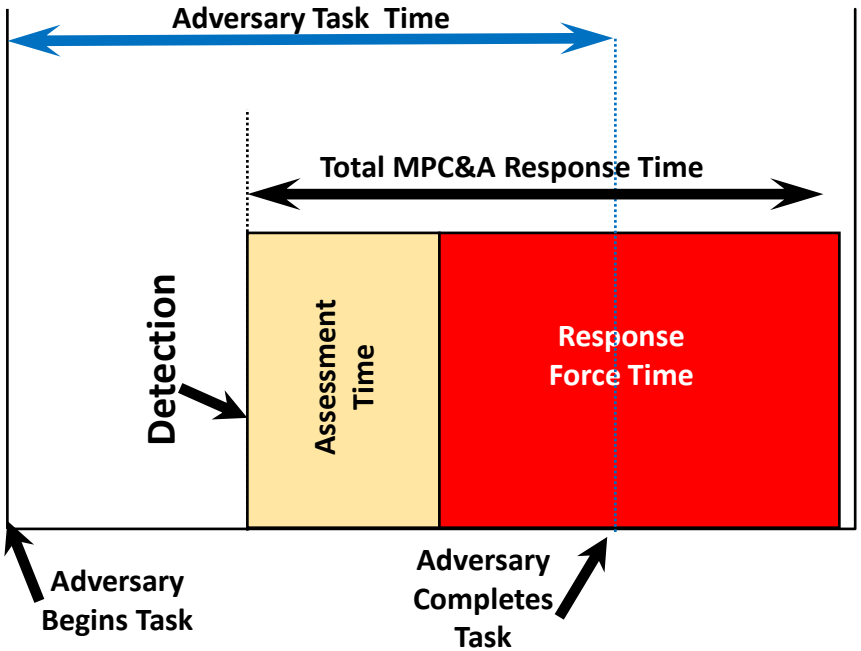
Critical Path

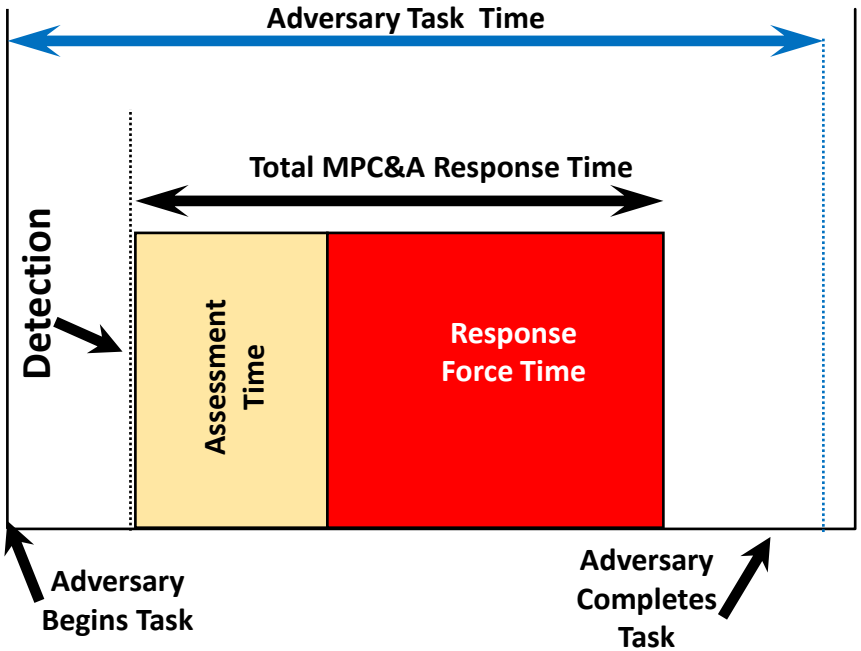


Delay and Time Element (working backwards)	Cumulative Time
10 seconds to exit over fence	10
30 seconds to cross area to fence	40
10 seconds to exit through emergency exit	50
60 seconds to defeat tie downs	110

Adversary Time Vs. PPS Time

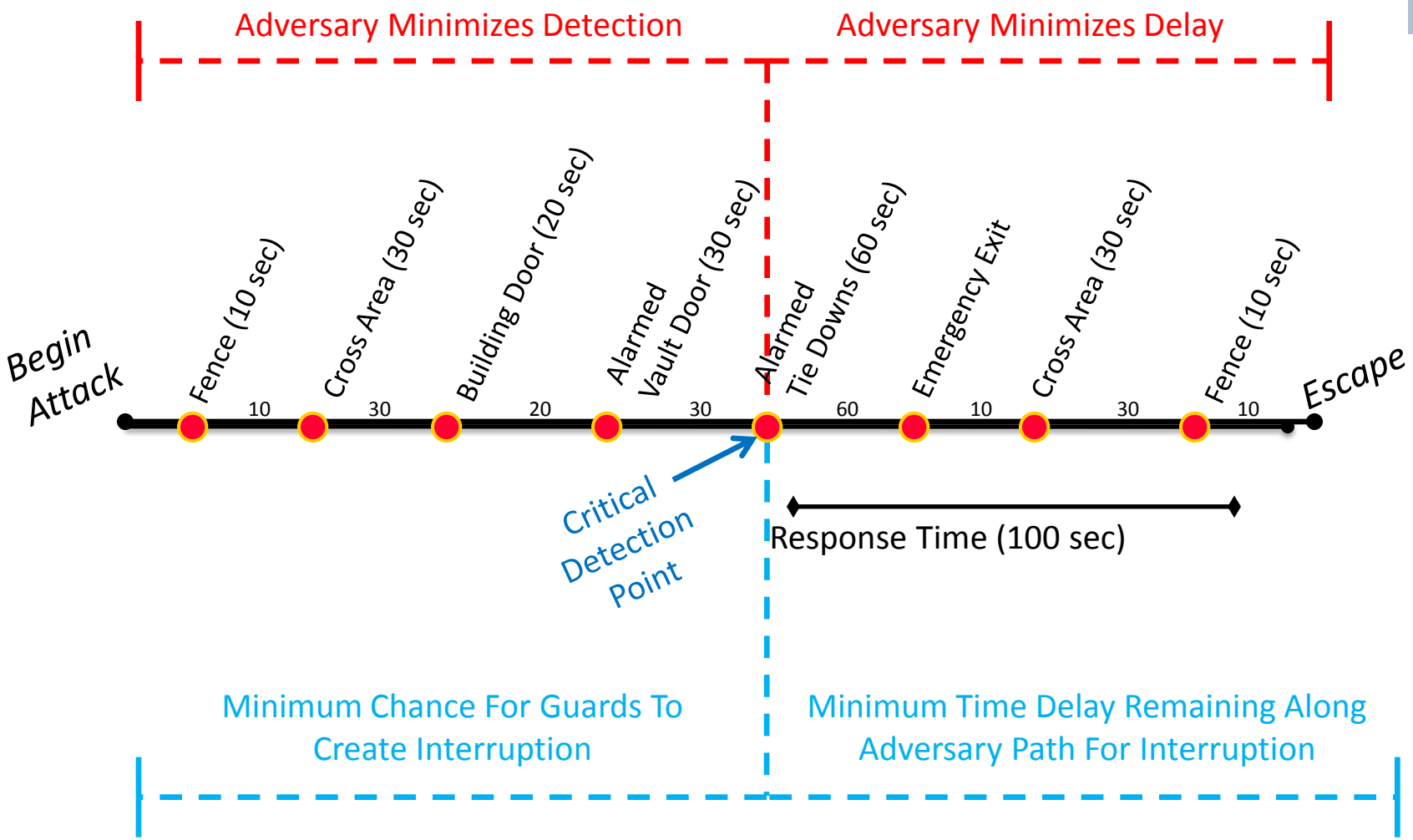
No time counts before detection





Response Force Time (RFT) doesn't begin until detection and assessment

Path Analysis Process



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

Path Analysis Example

Target Description

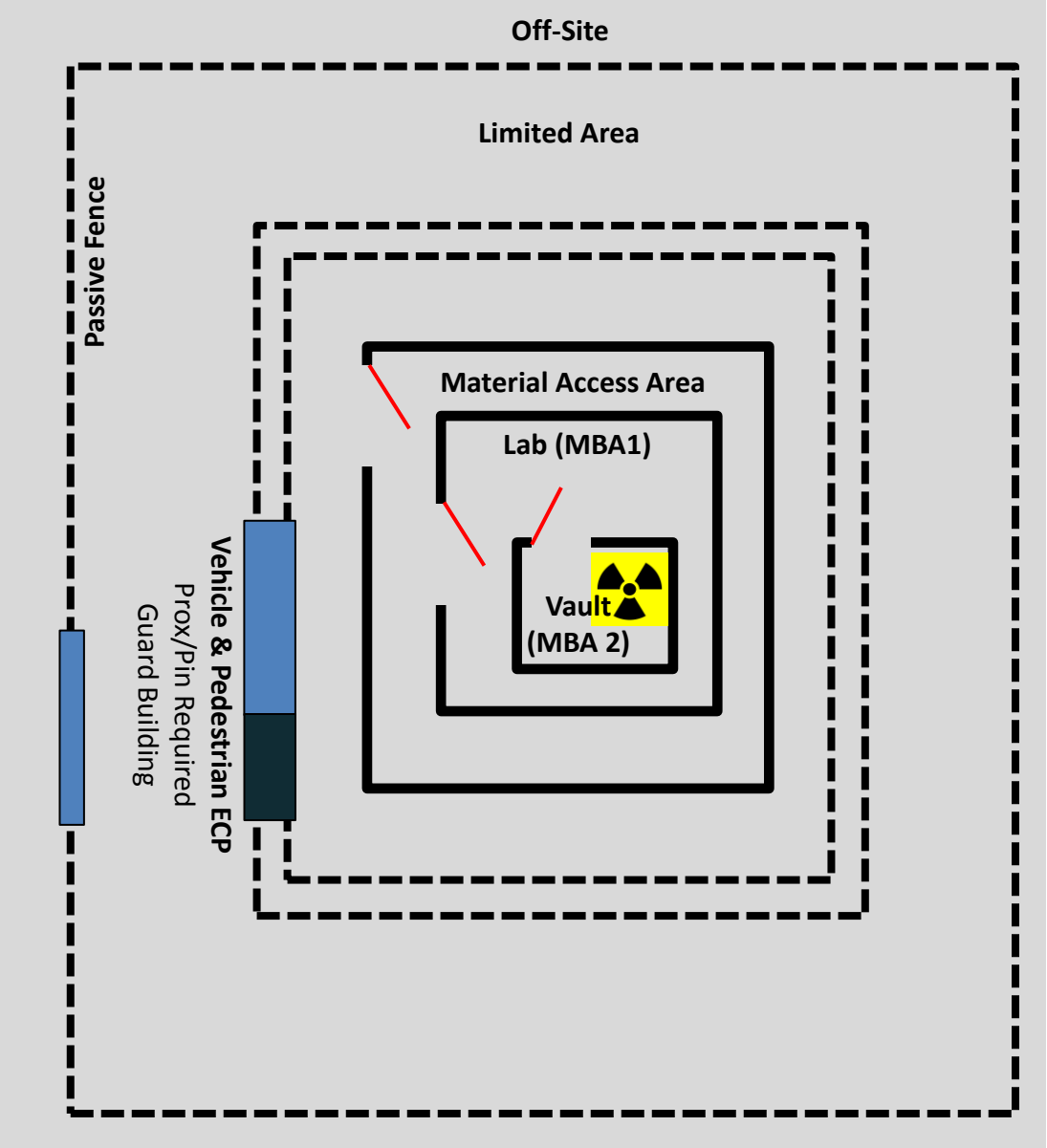
- 4 cylinders containing 5kg of HEU 80% enriched
- Canisters weight 6kg empty
- Total weight per canister = 11kg
- Dimensions h=20cm, r=8cm

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.



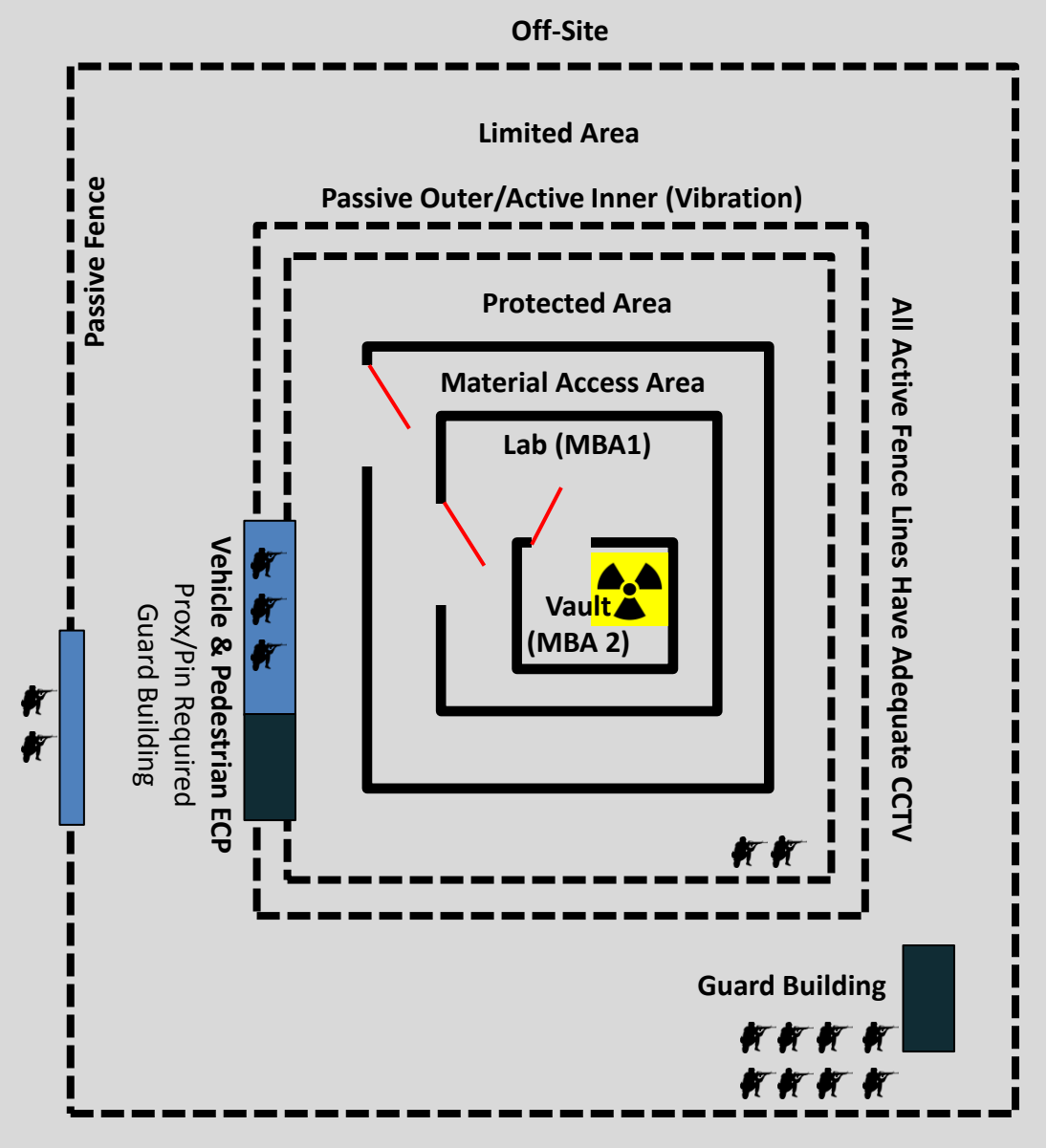
Path Analysis Example

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

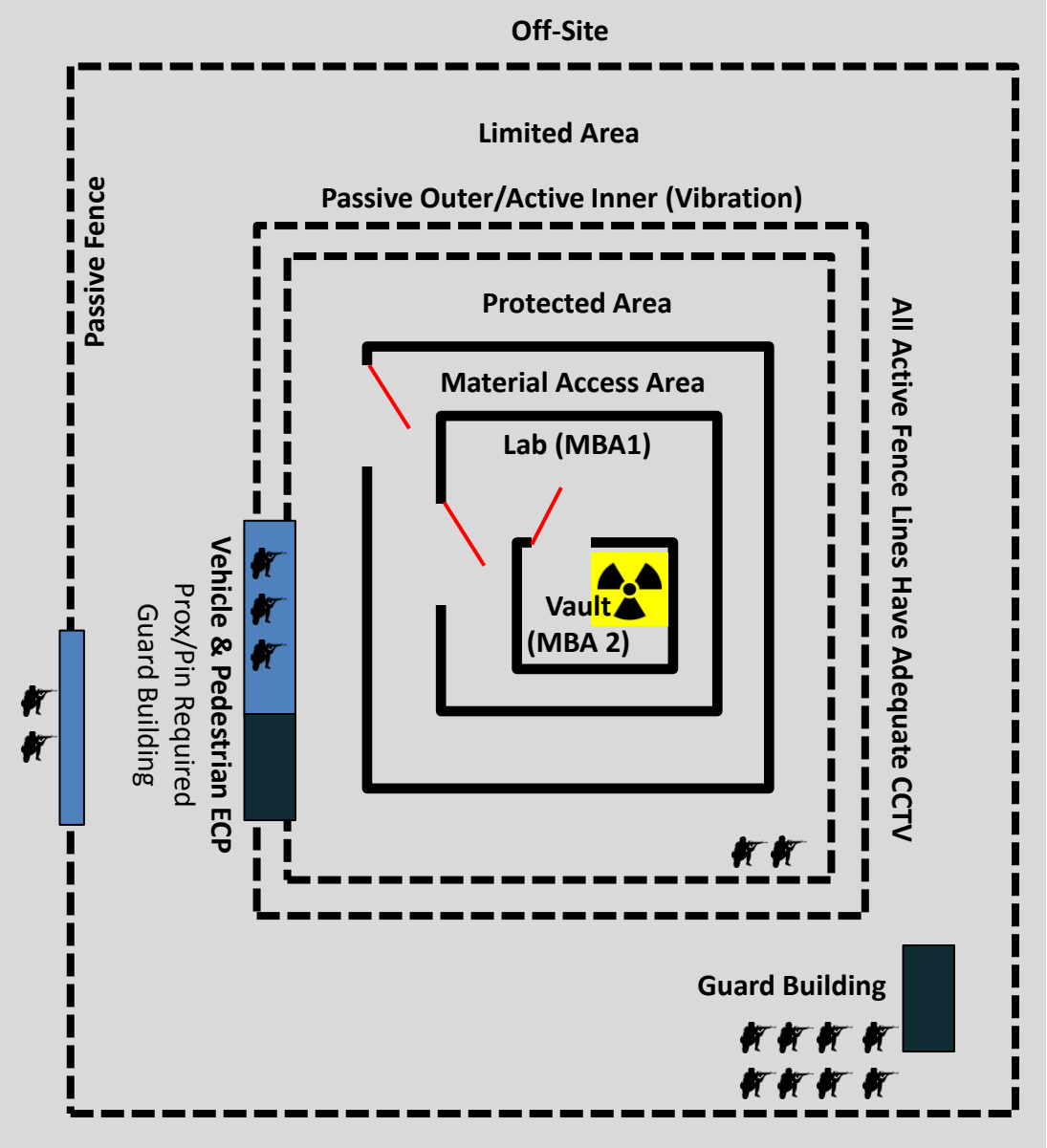
- Repeat for each deploy force



Path Analysis Example

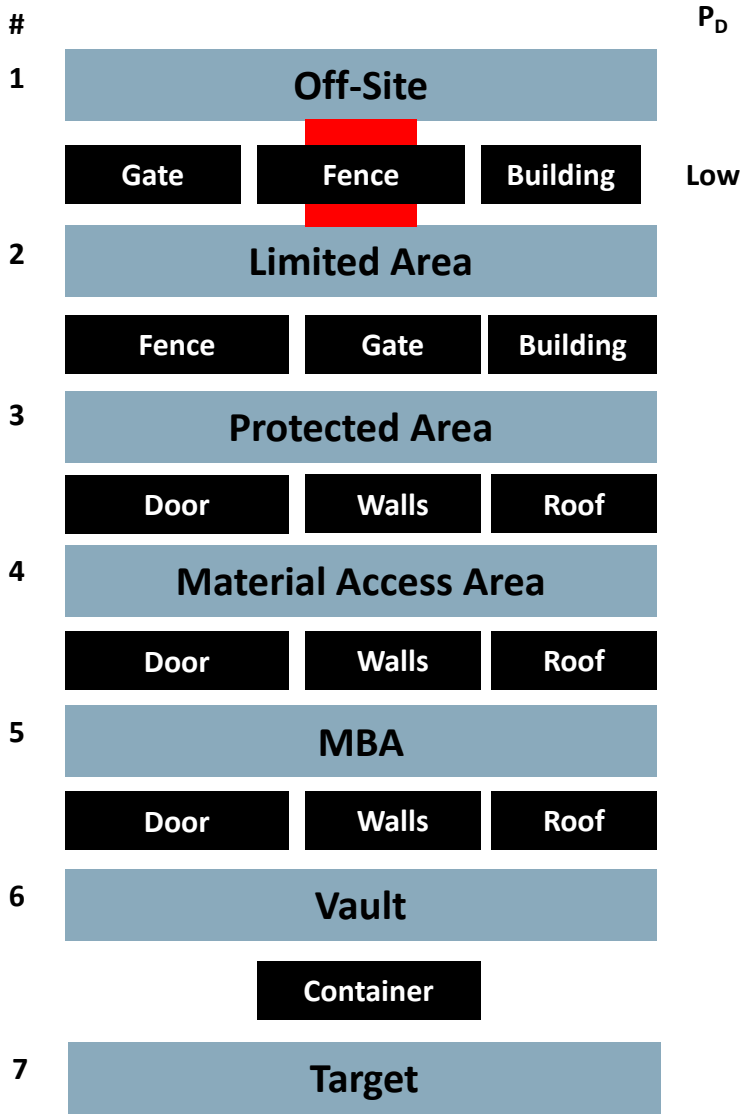
Adversary Sequence Diagram

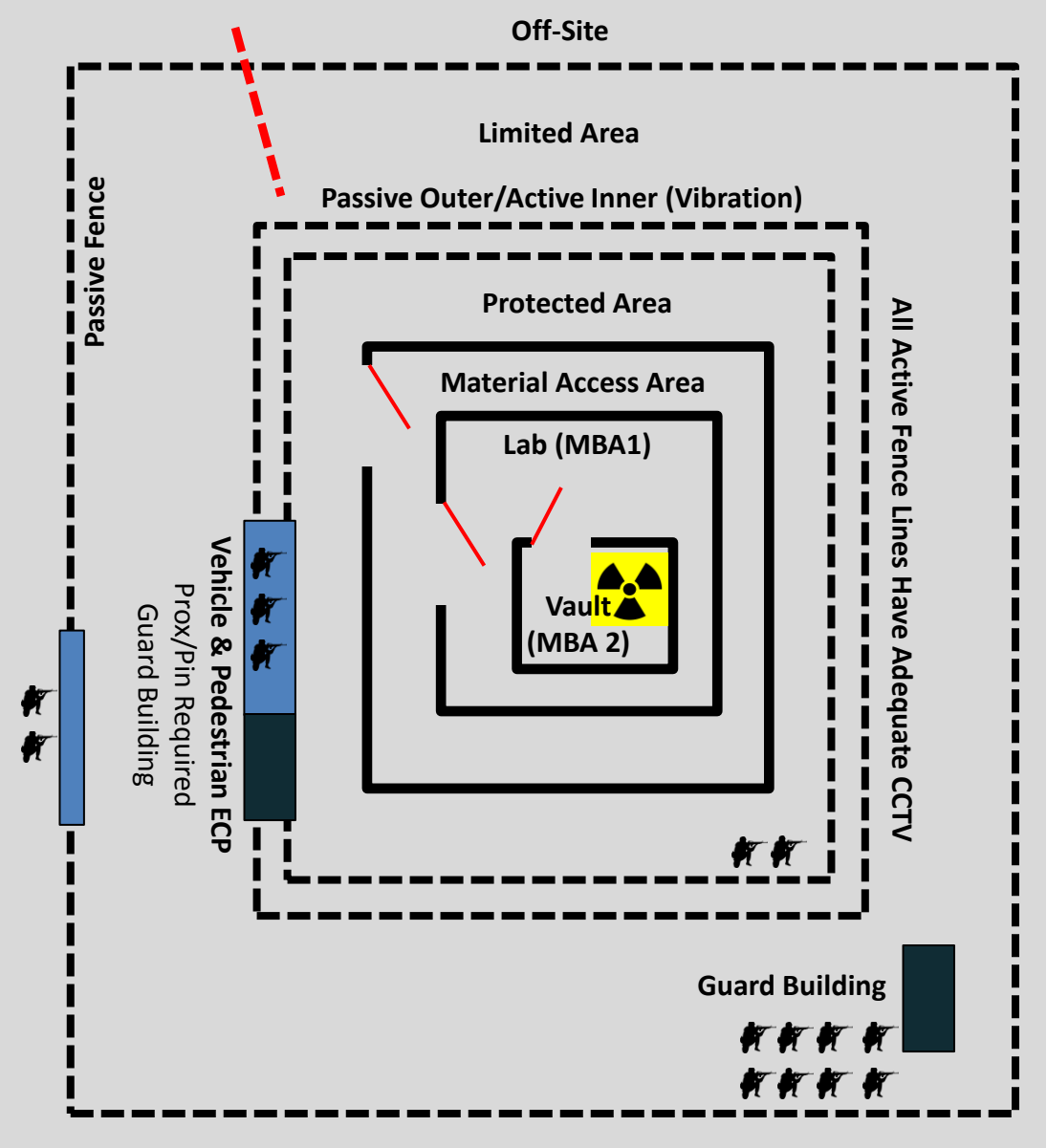
#		P_D
1	Off-Site	
	Gate, Fence, Building	
2	Limited Area	
	Gate, Fence, Building	
3	Protected Area	
	Door, Walls, Roof	
4	Material Access Area	
	Door, Walls, Roof	
5	MBA	
	Door, Walls, Roof	
6	Vault	
	Container	
7	Target	



Path Analysis Example

Adversary Sequence Diagram





Path Analysis Example

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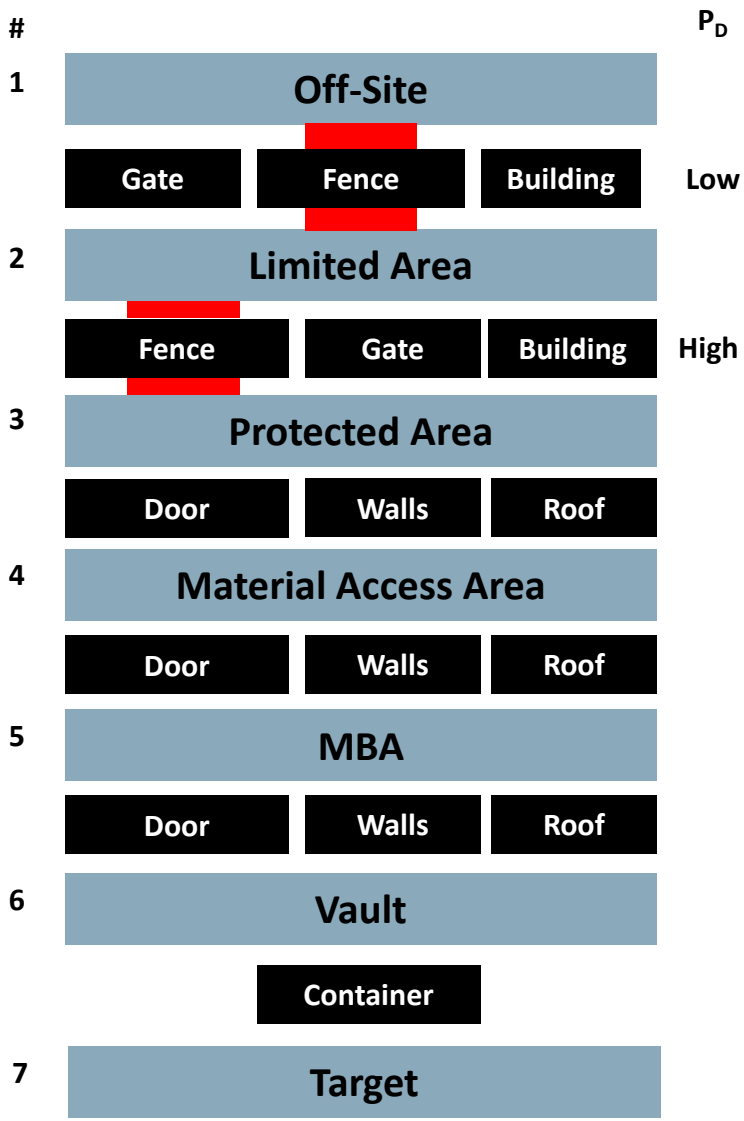

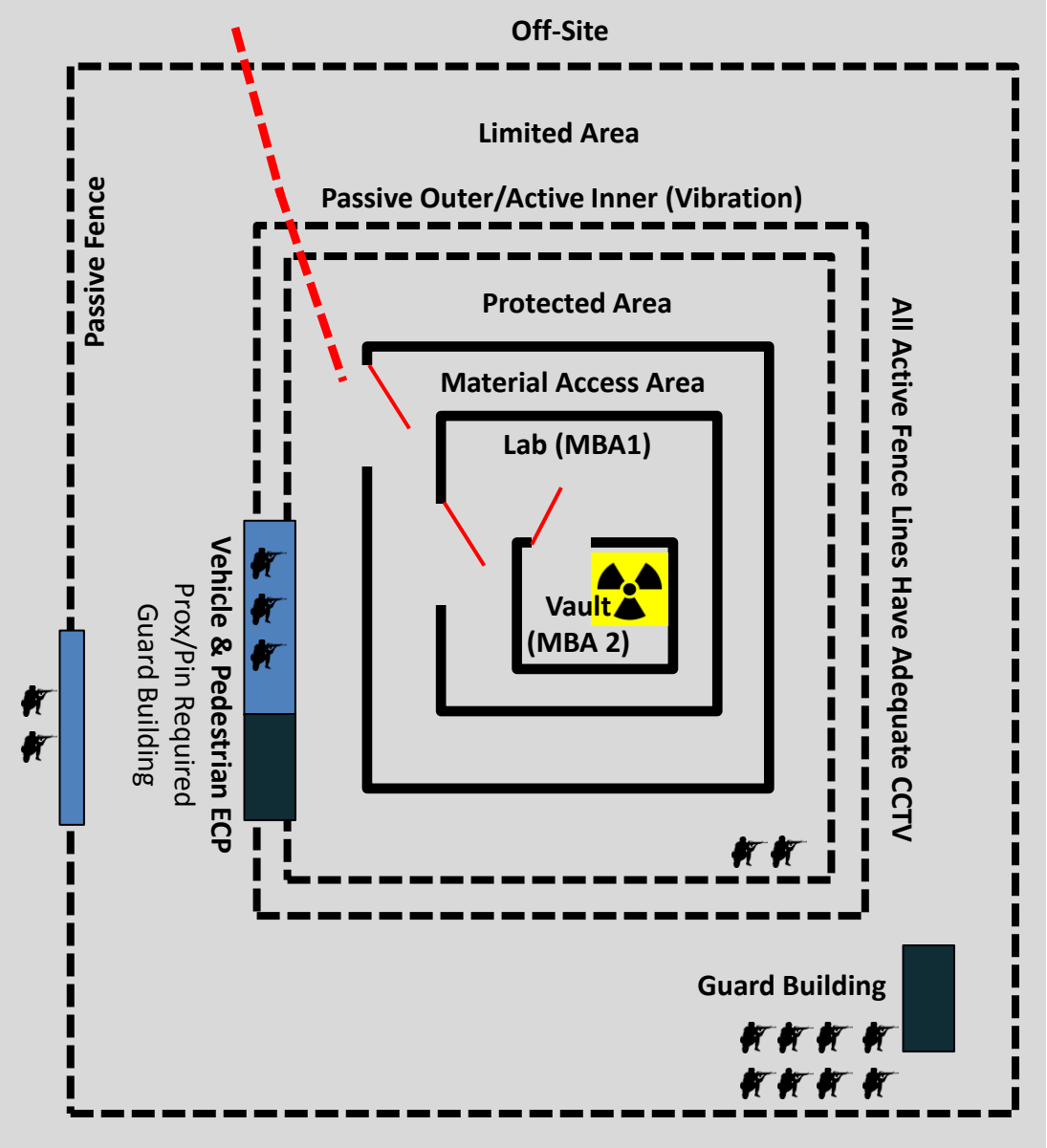

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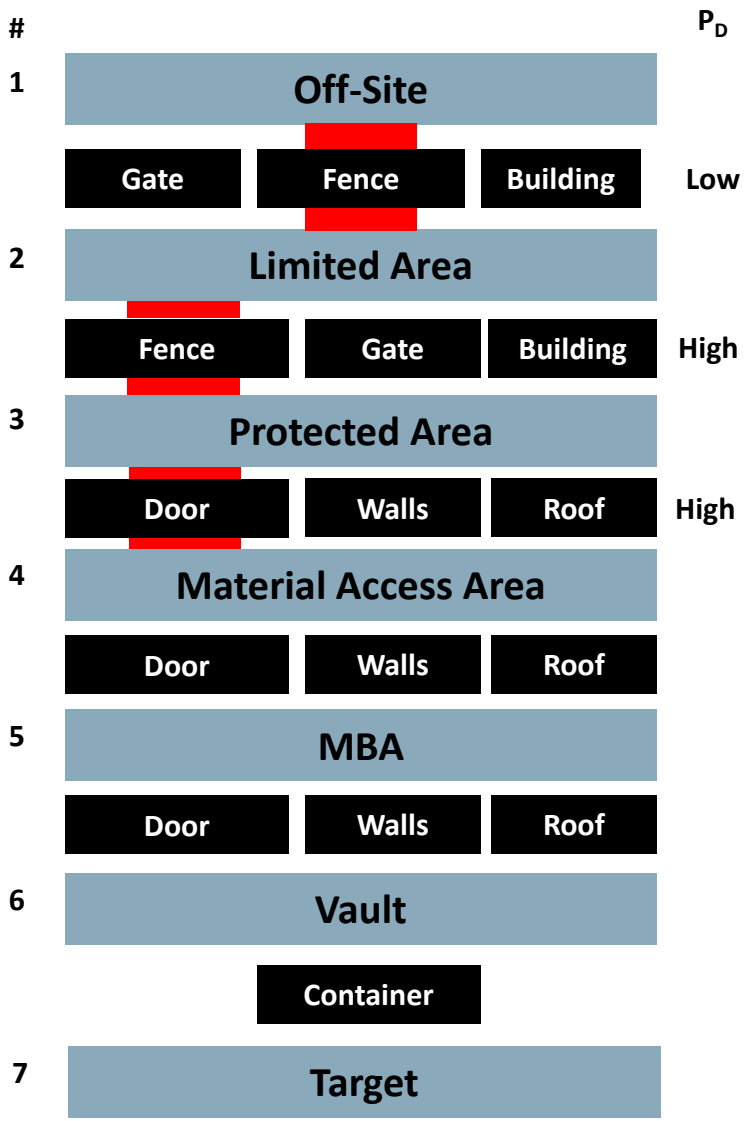

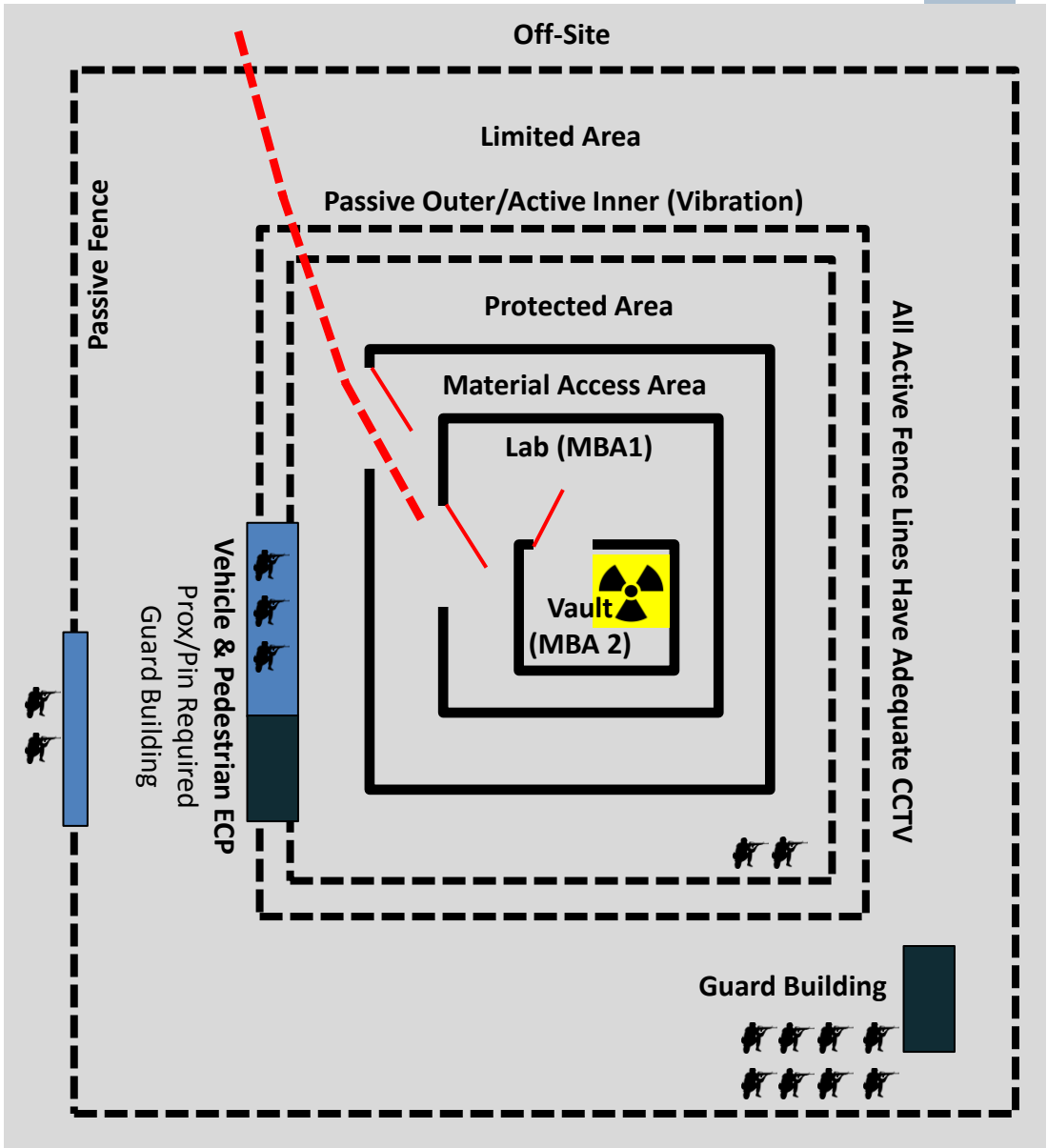

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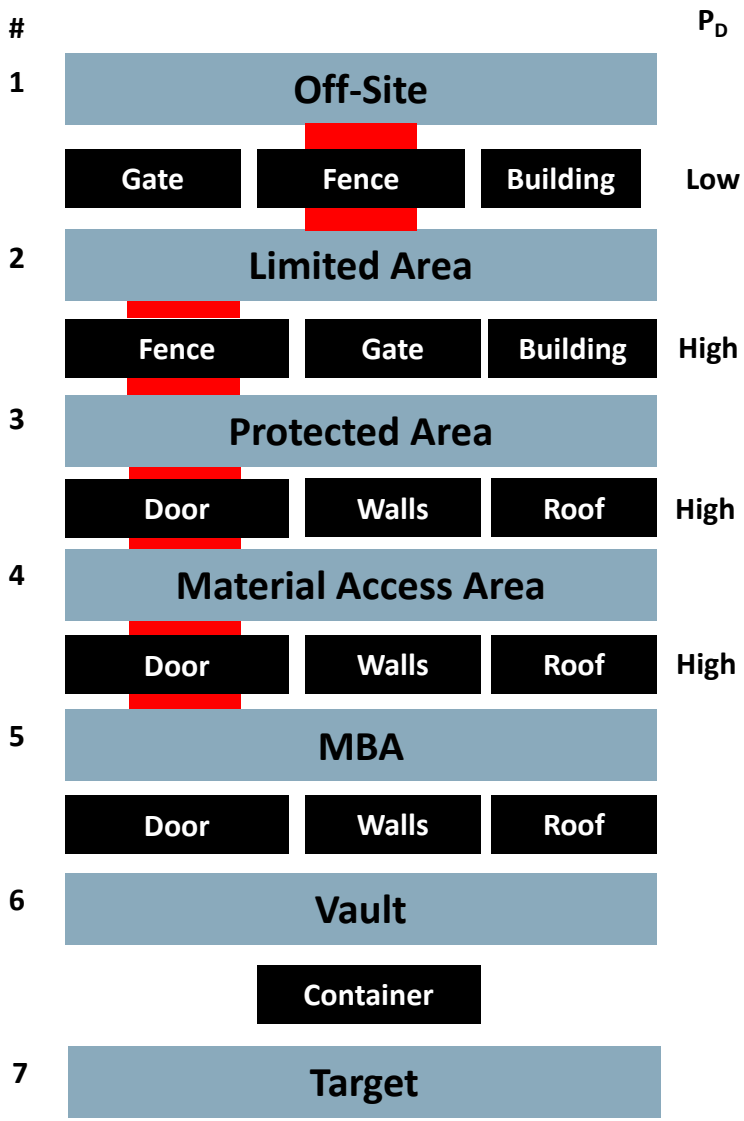

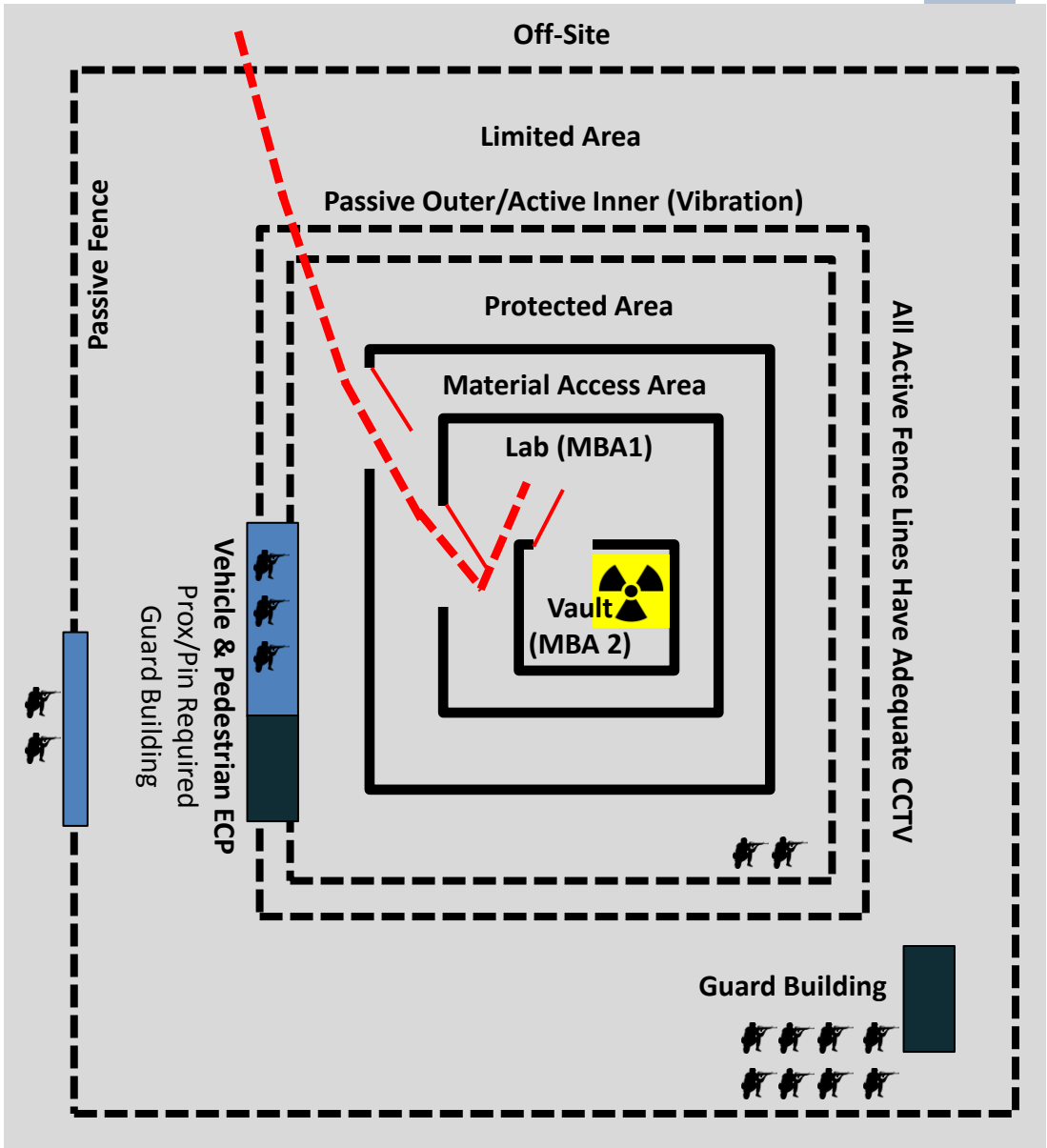

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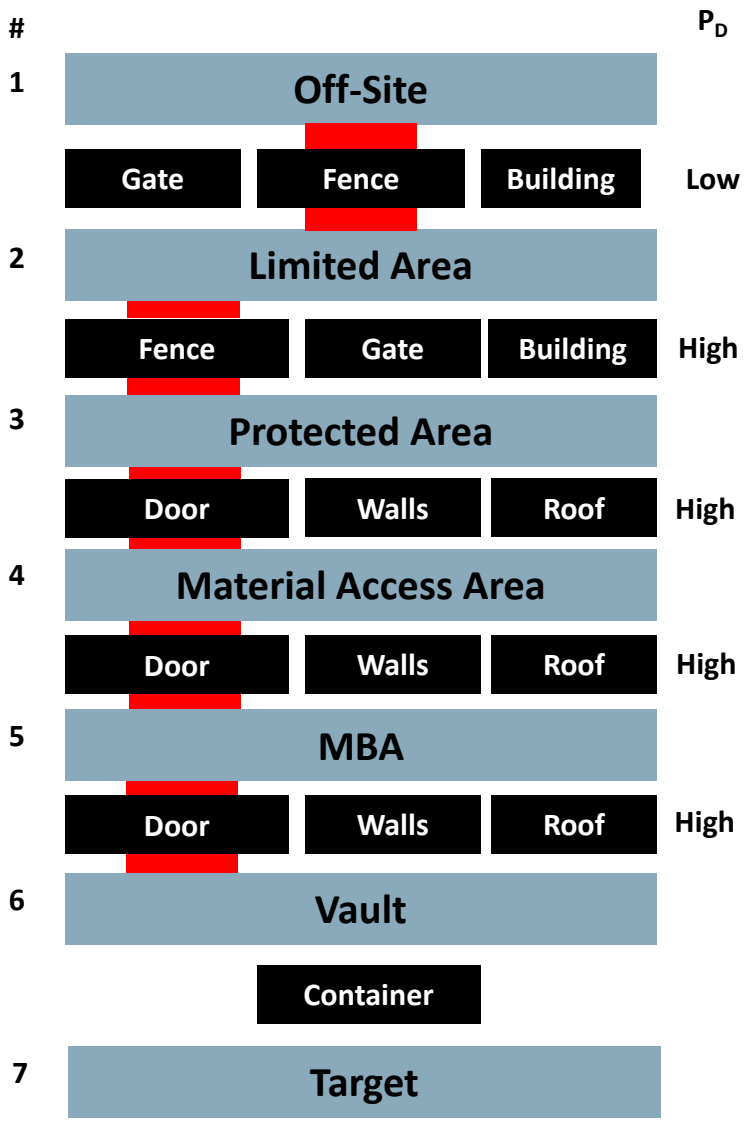

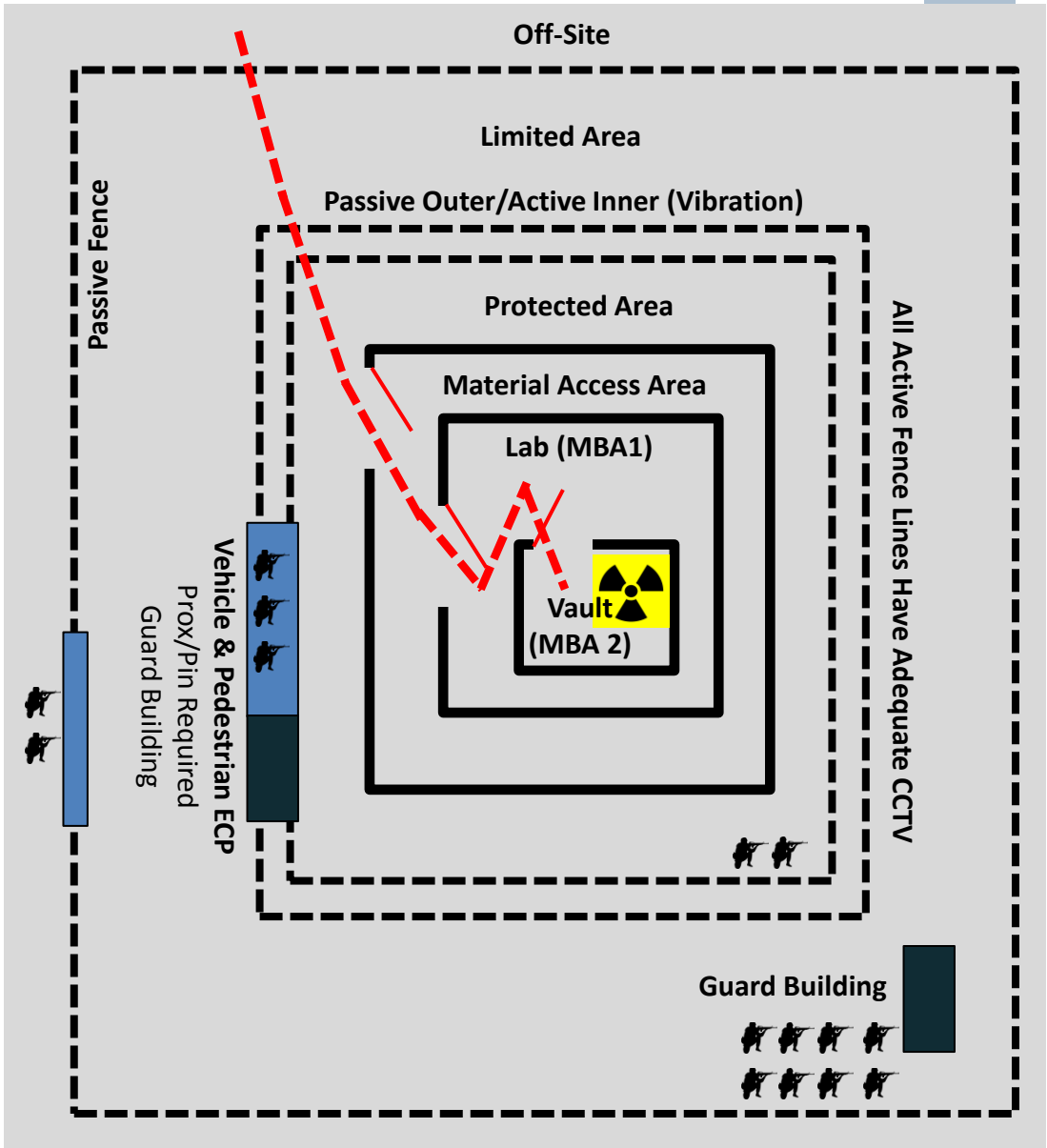

Path Analysis Example

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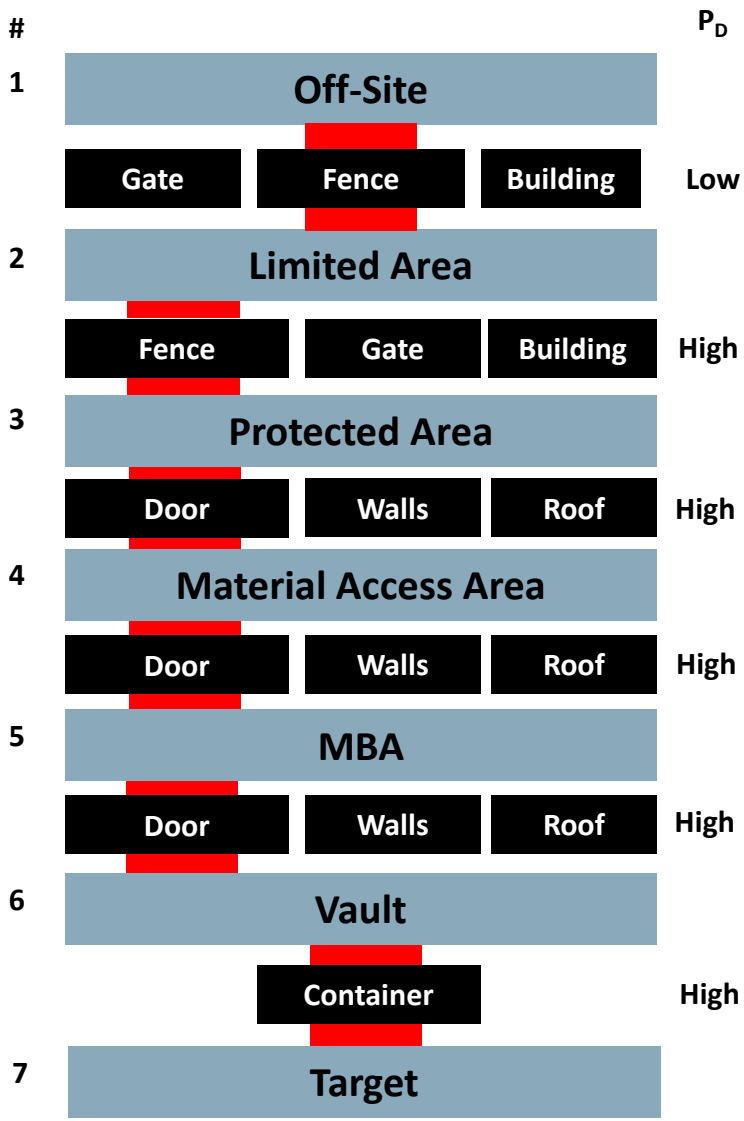

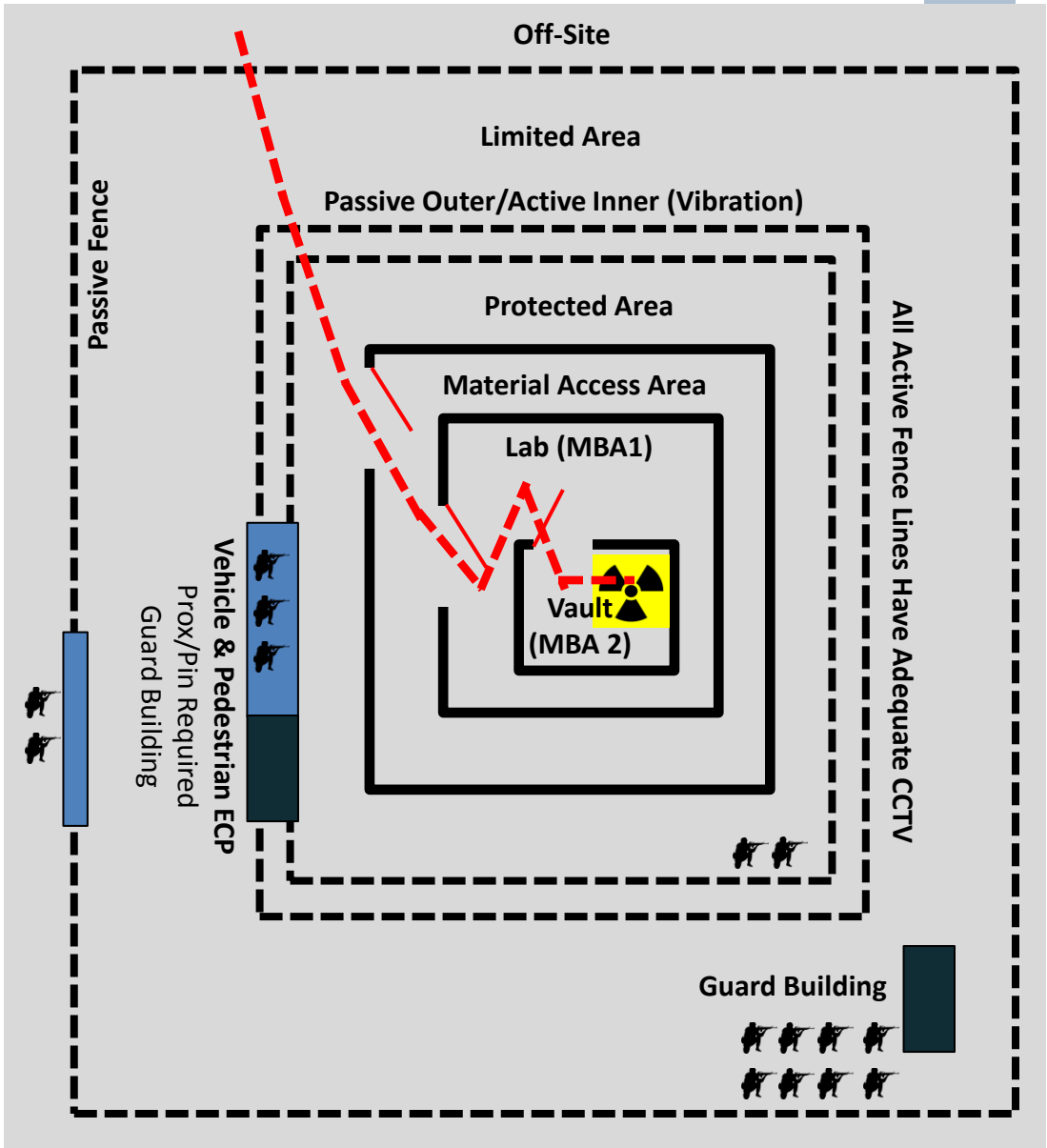

Path Analysis Example

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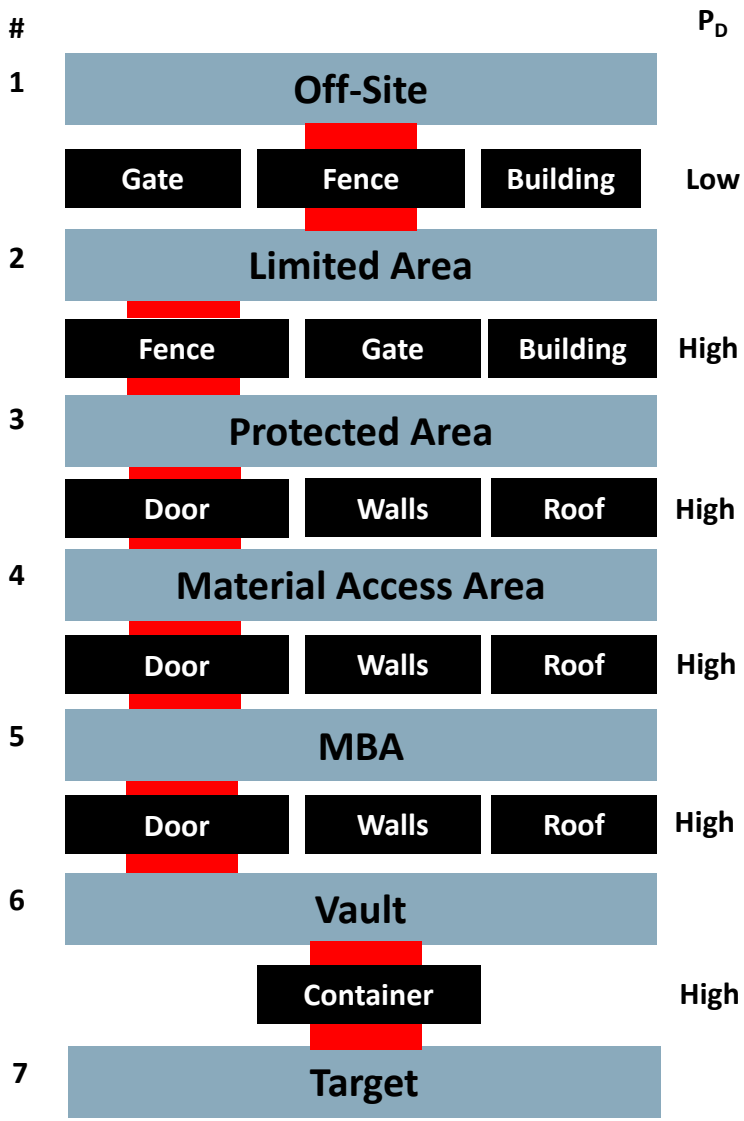
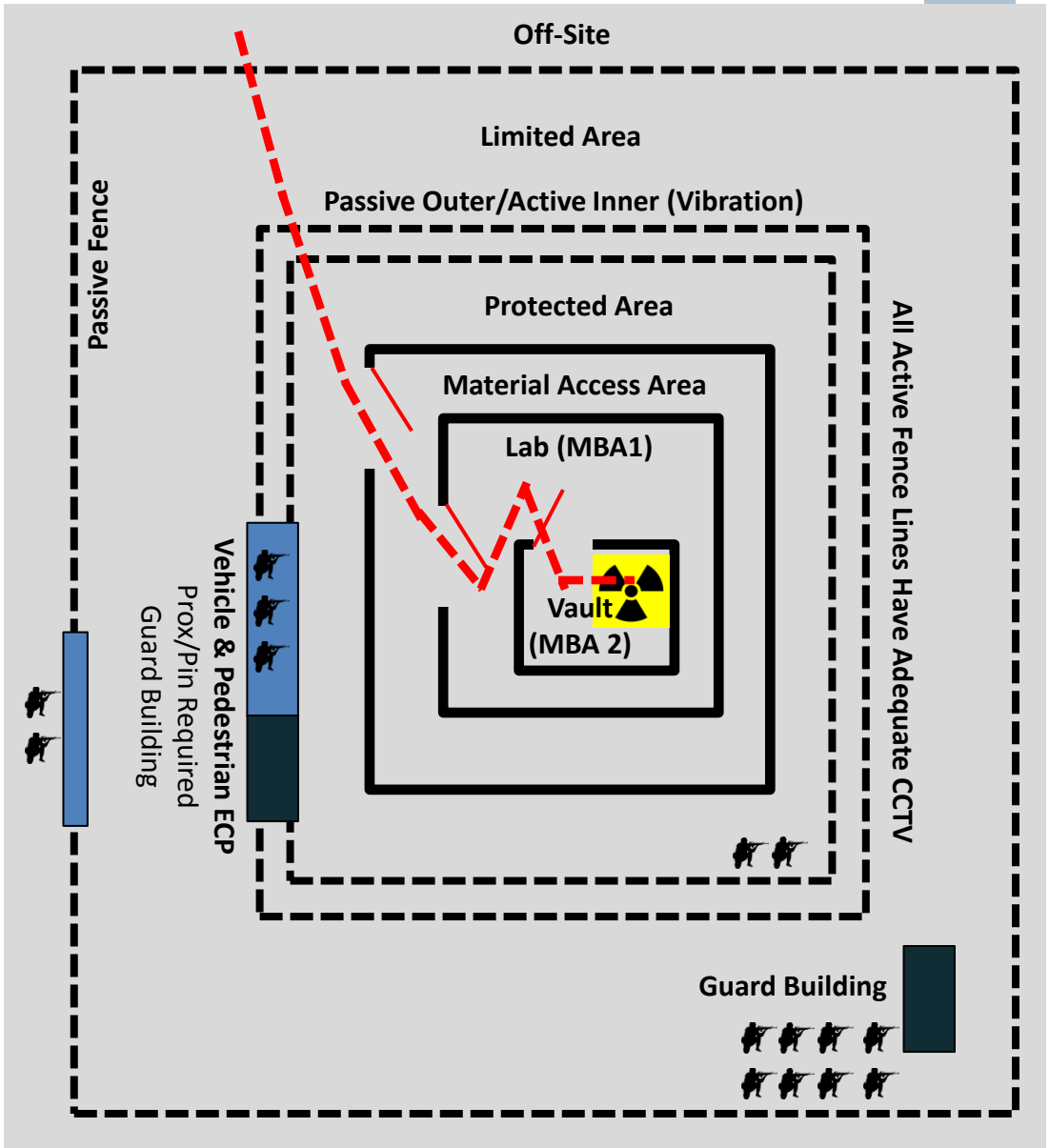


How do you get out?



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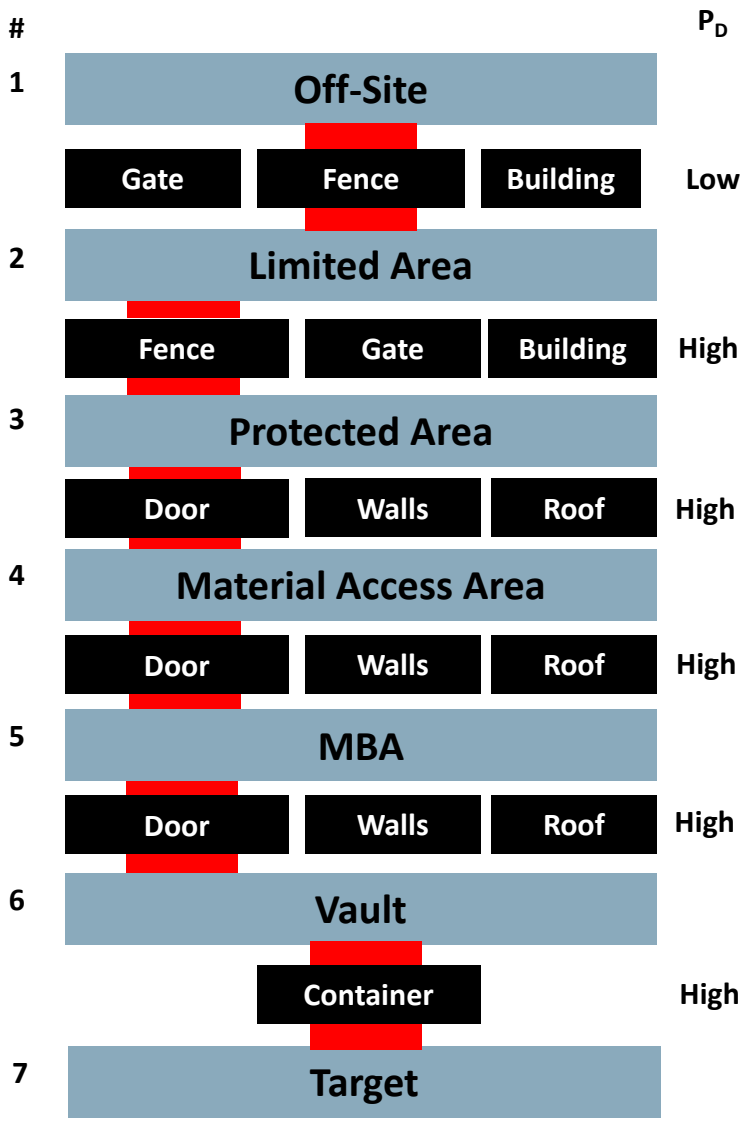

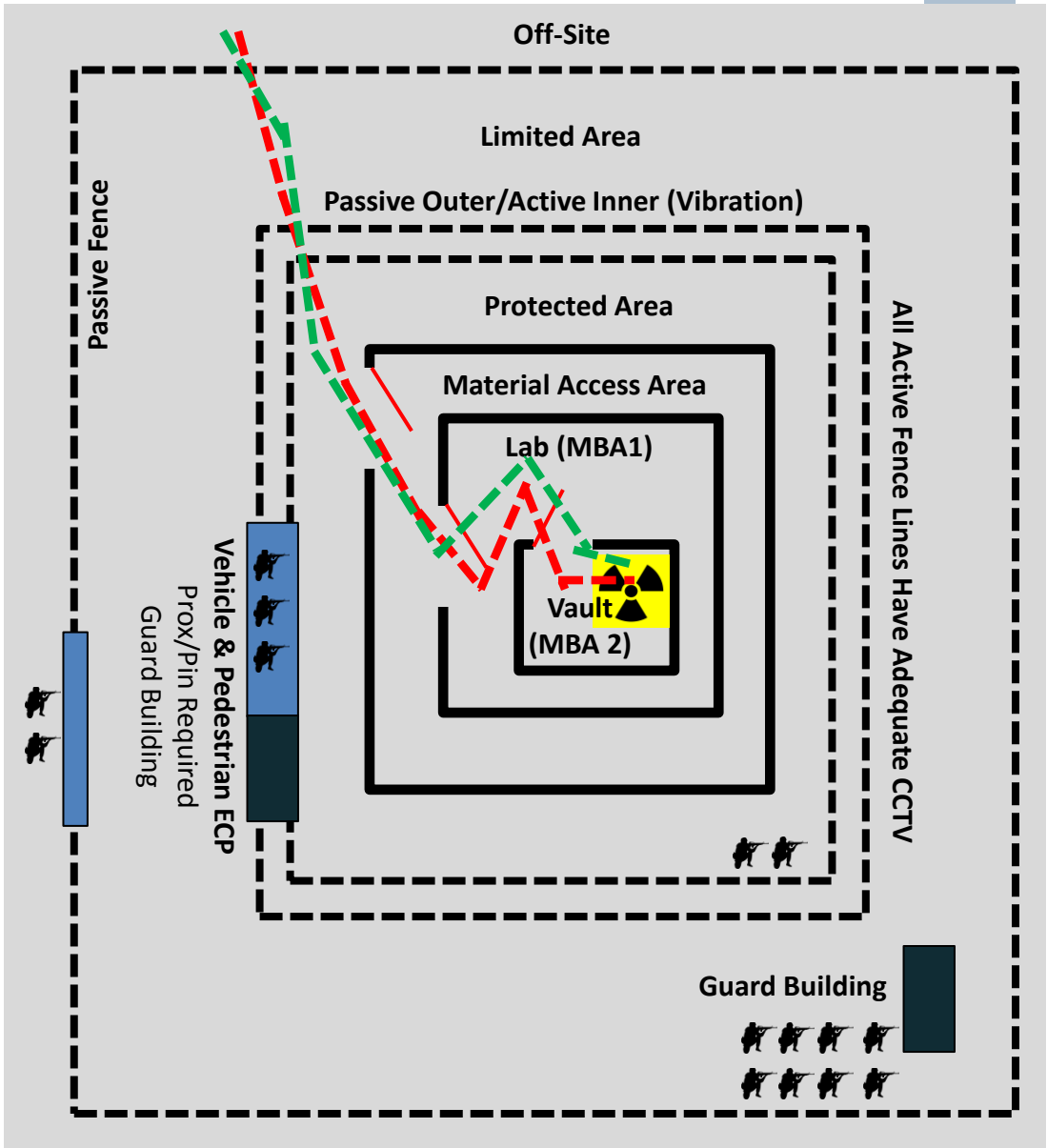

Path Analysis Example

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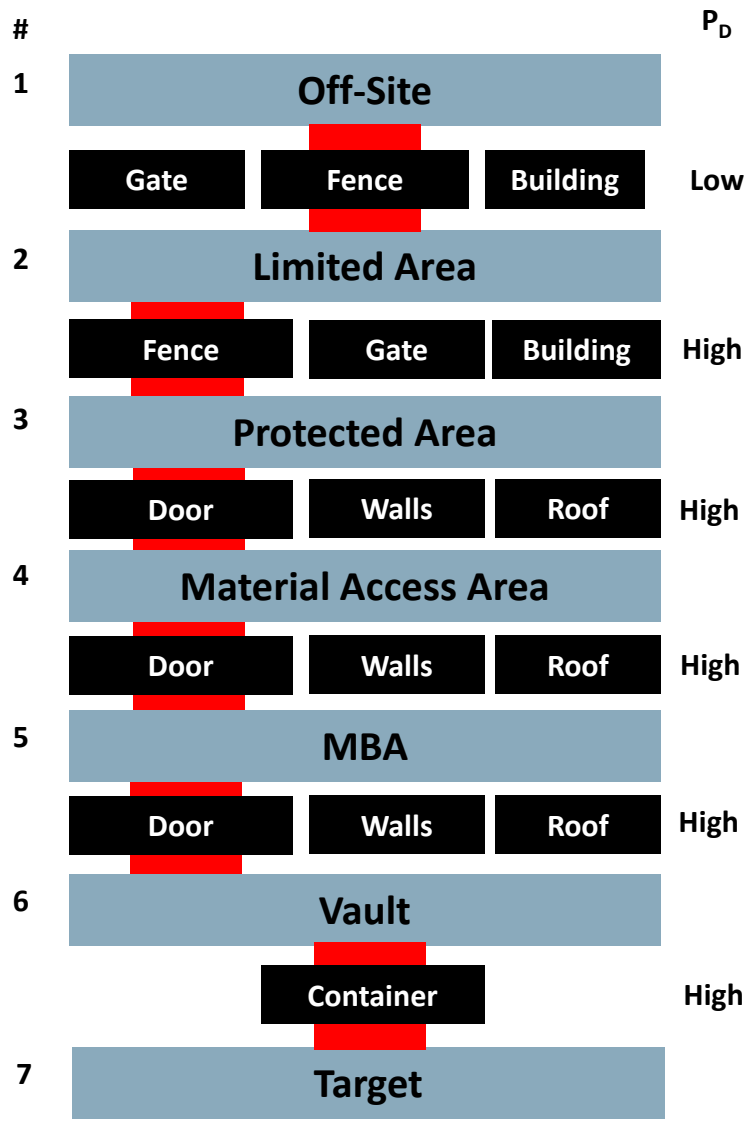
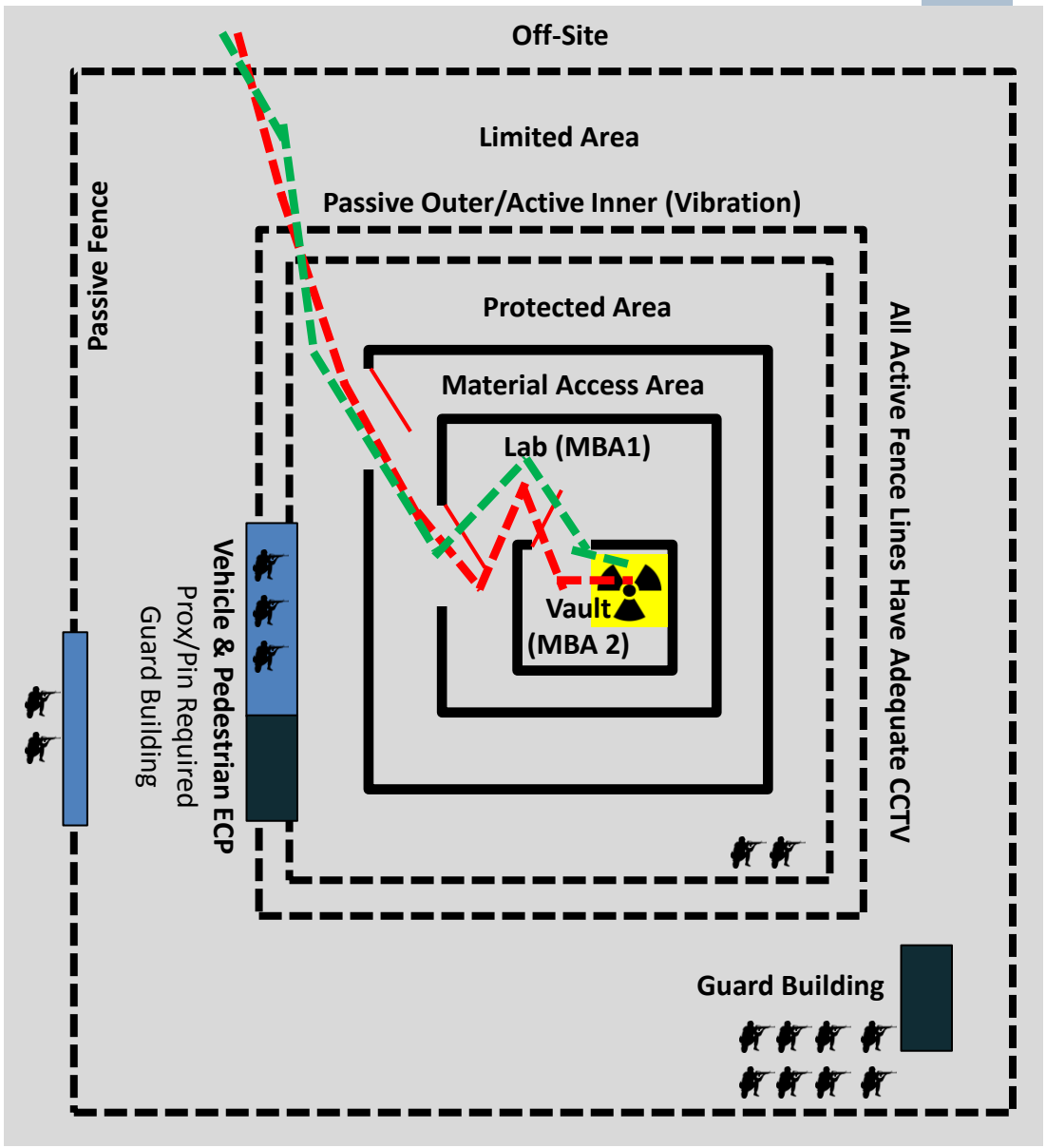


When Does Interruption Occur?



Path Analysis Example

Adversary Sequence Diagram

#		P_D	Adversary Step Time	Cumulative Time
1	Off-Site		0	
	Gate, Fence, Building	Low	30	30
2	Limited Area		45	75
	Fence, Gate, Building	High	60	135
3	Protected Area		30	165
	Door, Walls, Roof	High	15	180
4	Material Access Area		10	190
	Door, Walls, Roof	High	15	205
5	MBA		10	215
	Door, Walls, Roof	High	15	230
6	Vault		5	235
	Container	High	15	250
7	Target	Task Time	90	340

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?

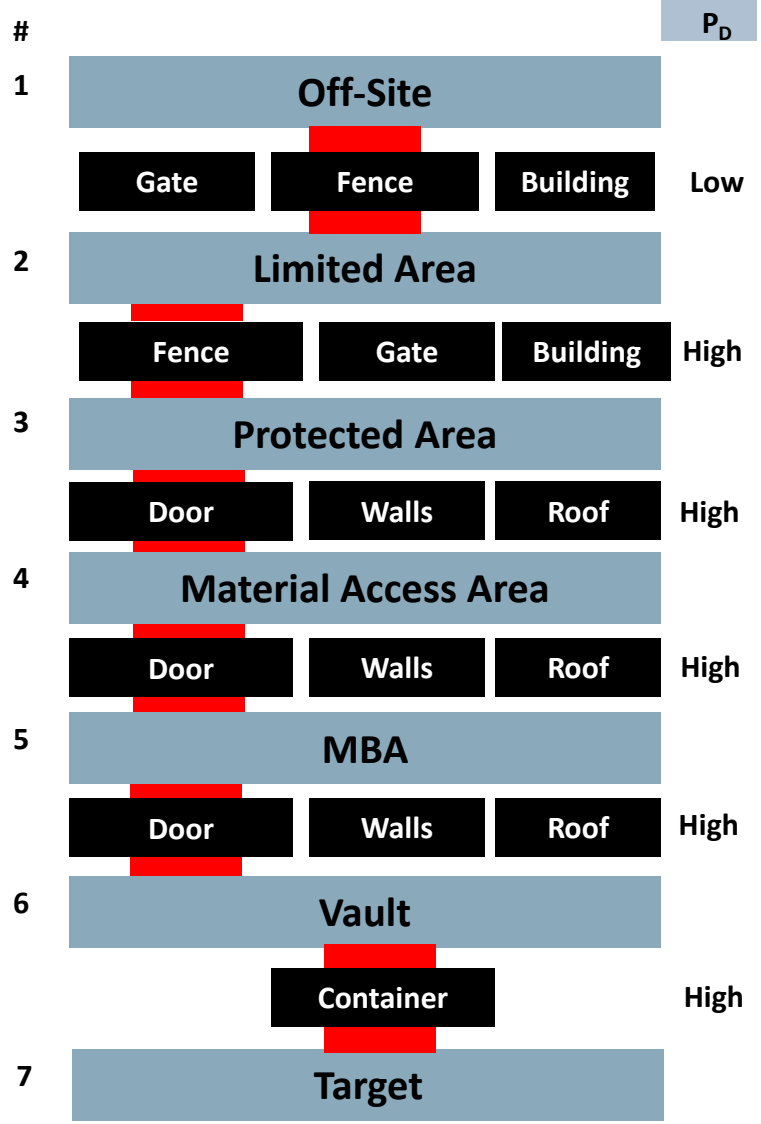
Path Analysis Example

Location	Response	Response Details
Site ECP	2 Guards @ _ seconds	Assessment Time = Muster Time = Transit to Specific Location =
Protected Area ECP	3 Guards @ _ seconds	Assessment Time = Muster Time = Transit to Specific Location =
Patrol Squad	2 Guards @ _ seconds	Transit to Specific Location =
Guard Building	8 Guards @ _ seconds	Assessment Time = Muster time = Transit to Specific Location =

Total Adversary Task Time = 440

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

Adversary Sequence Diagram



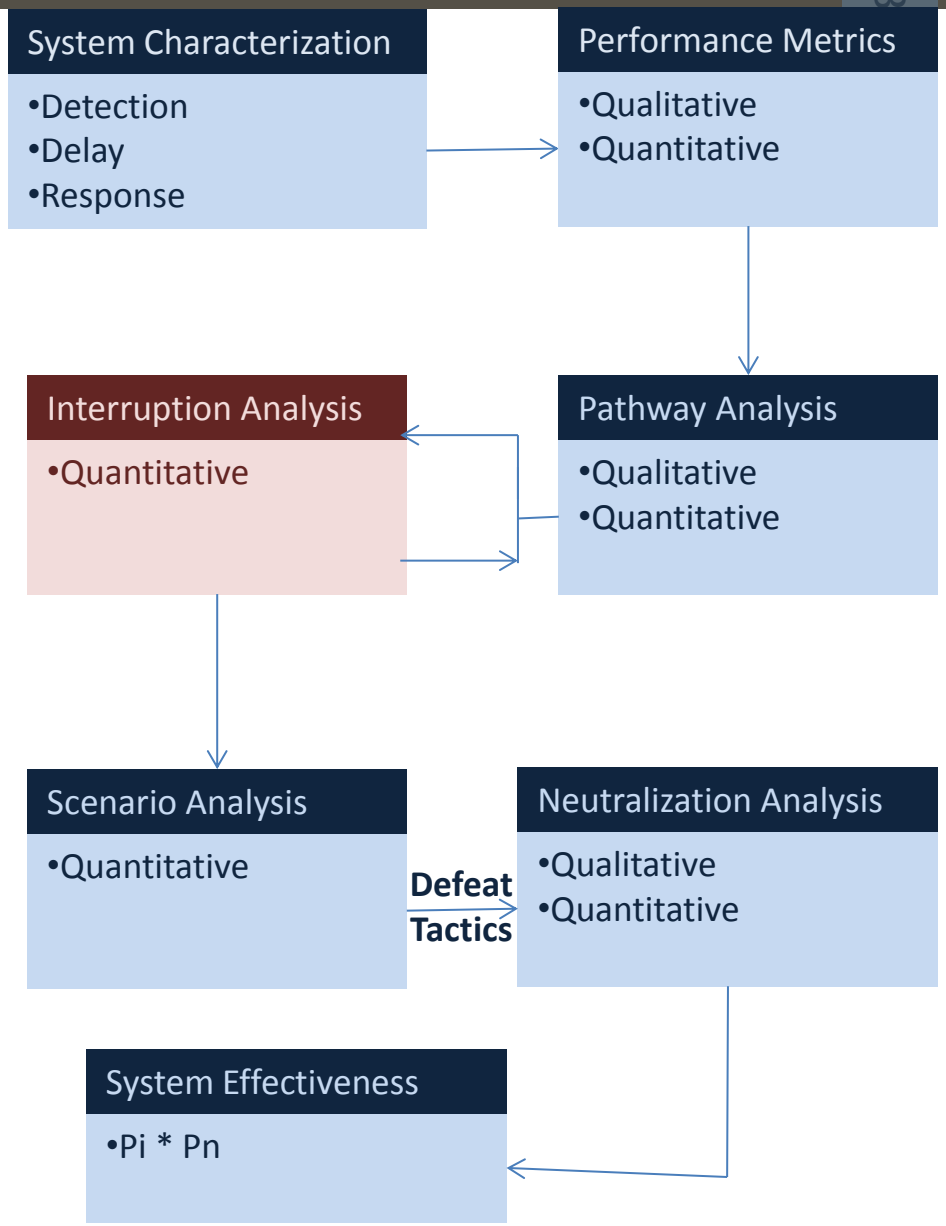
Path Analysis Example

Step	Step Time	Cuml Time	Response Time	Description	P_D	P_A	P_I	P_N	Step Score
1	30	30	-	Cut Passive Fence leading to Limited Area	VL	VL	VL		
2	13	43	-	Transit to Protected Area Fence	VL	VL	VL		
3	30	73	-	Cut Passive Fence to Protected Area	VL	VL	VL		
4	3	76	-	Transit to Active Fence in Protected Area	VL	VL	VL		
5	30	106	30	Cut Active Fence leading to Protected Area	M	VH	VL		
6	6	112	36	Transit to Door on MAA Building	VL	VL	VL		
7	5	117	41	Breach Unarmored Door	VH	VH	VL		
8	4	121	45	Transit to MBA Door #1	VL	VL	VL		
9	30	151	75	Breach hardened MBA Door	VH	VH	VL		
10	4	155	79	Transit to hardened Vault Door	VL	VL	VL		
11	30	185	109	Breach hardened vault door	VH	VH	VL		
12	4	189	113	Transit to Vault	VL	VL	VL		
13	21	210	134	Prepare containers for Transport	VL	VL	VL		
14	34	244	168	Escape	VH	VH	H		
				Step Score = Probability of Effectiveness					

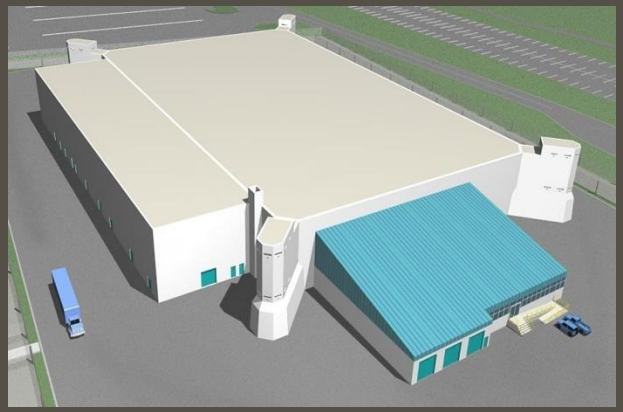
Path Analysis Example

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



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