

# ***Modeling Effects of Counterterrorism Initiatives on Reducing Adversary Threats to Transportation Systems***

**Center for Risk and Economic Analysis  
of Terrorism Events**

**1 April 2011**

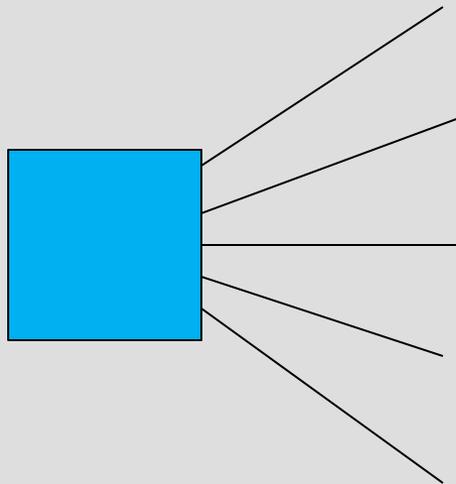
**DHS Science Conference  
Fifth Annual University Network Summit**

**Richard John & Heather Rosoff  
University of Southern California**

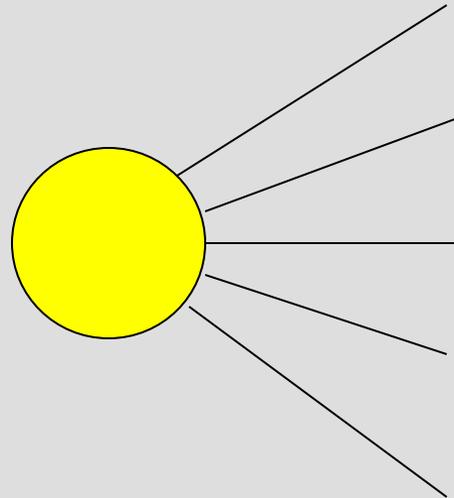


# PRA Framework for Mitigation Decision Modeling

Defender



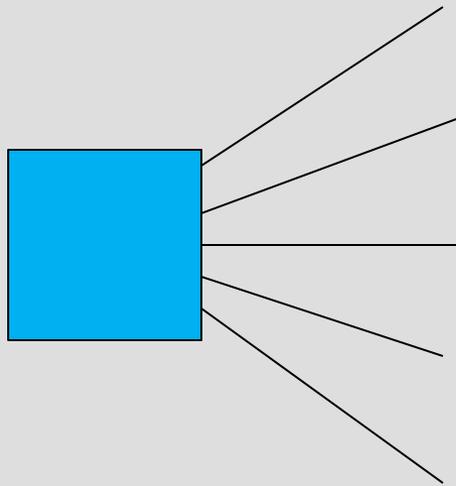
Mitigation  
Options



Outcomes

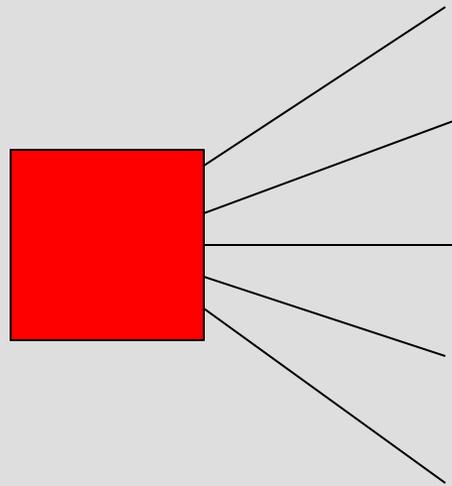
# Framework for Adaptive Adversary Modeling

Defender

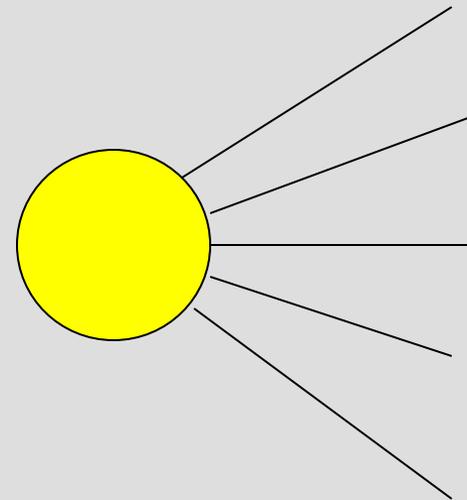


Counter-measures

Adversary



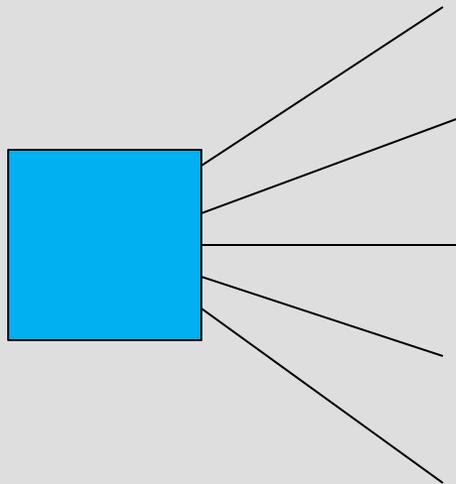
Attack Modes  
& Targets



Attack  
Outcomes

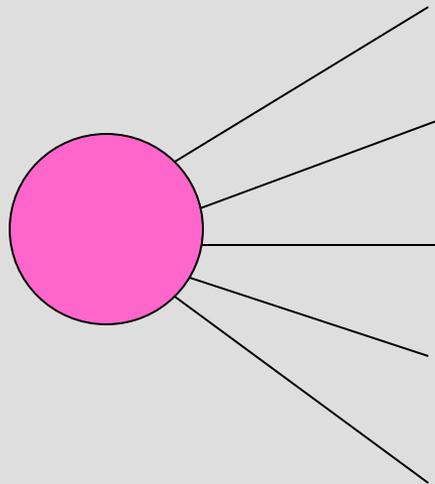
# Adversary Value Focus Framework for Adaptive Adversary Modeling

Defender

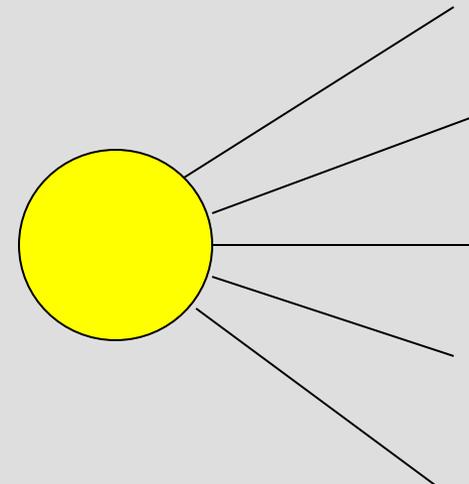


Counter-measures

Adversary

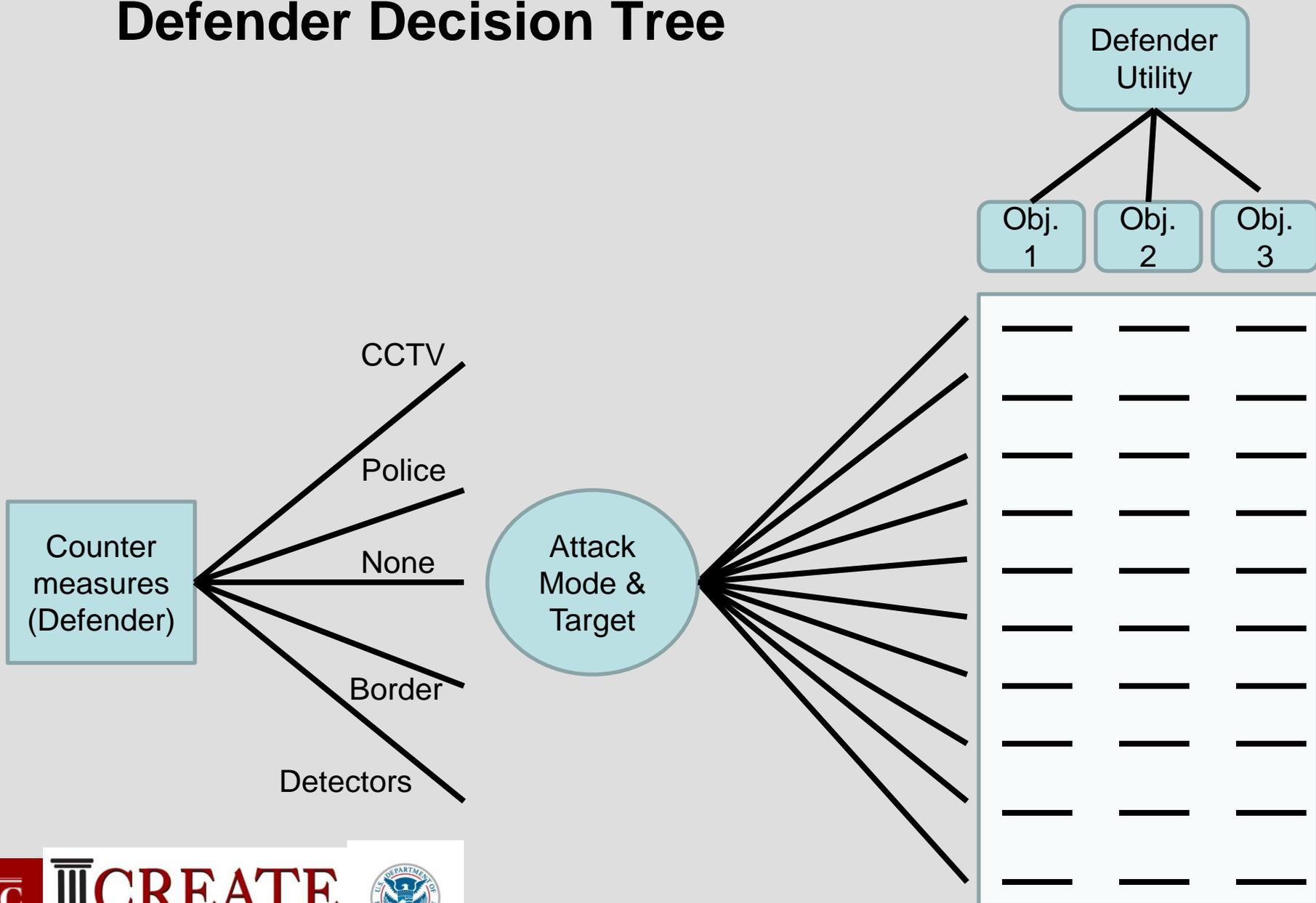


Attack Modes  
& Targets

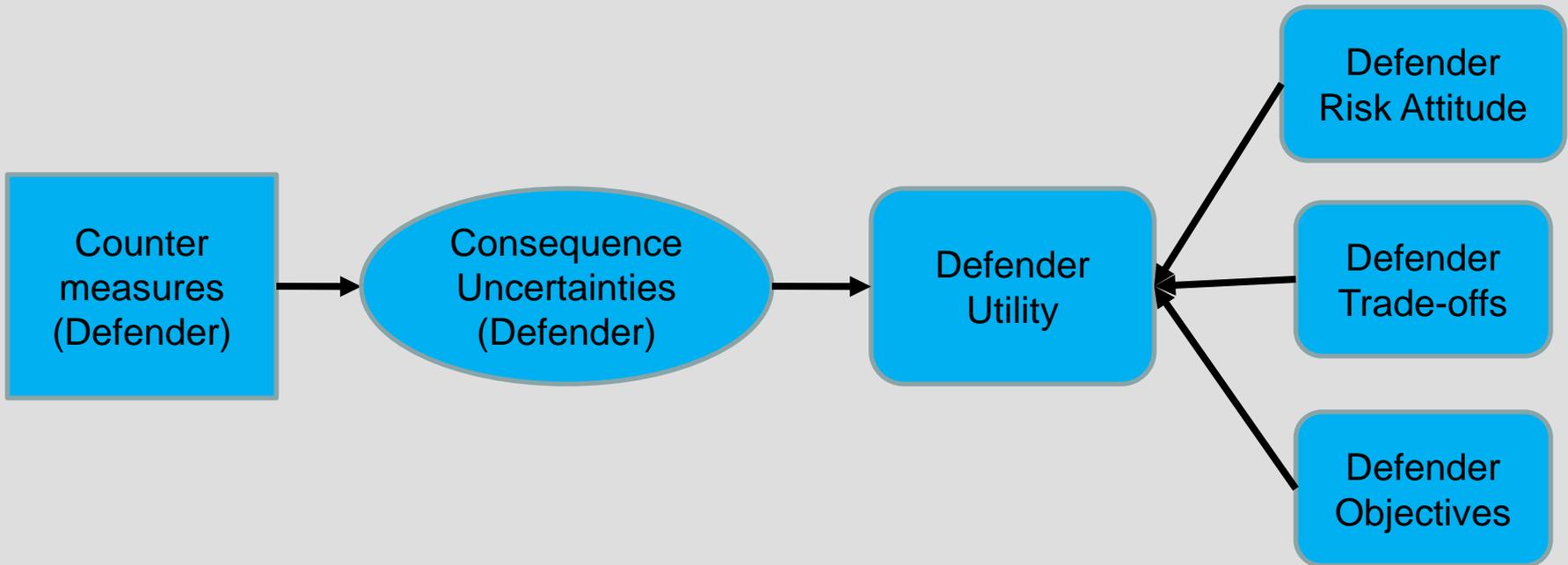


Attack Outcomes

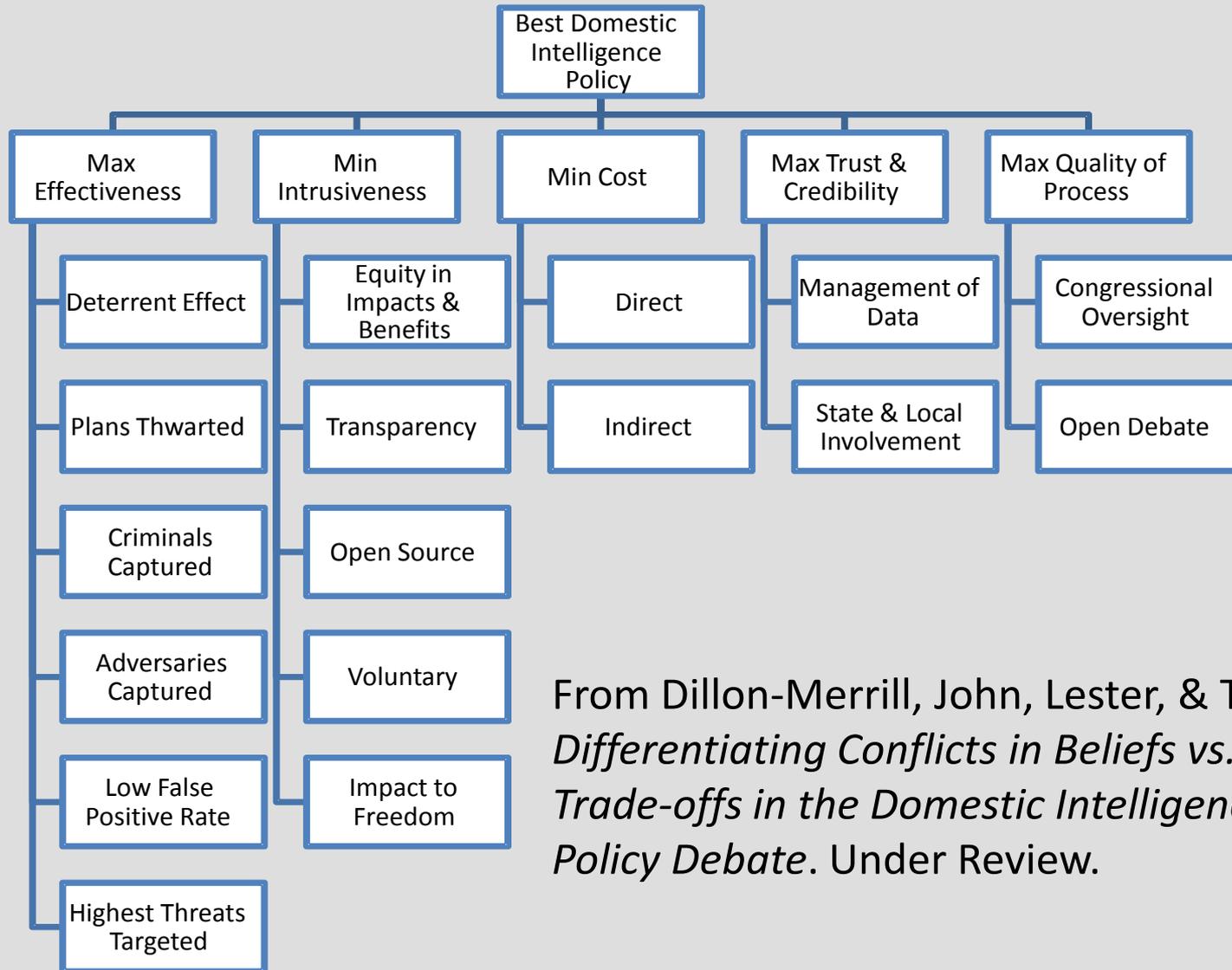
# Defender Decision Tree



# Decision Analysis

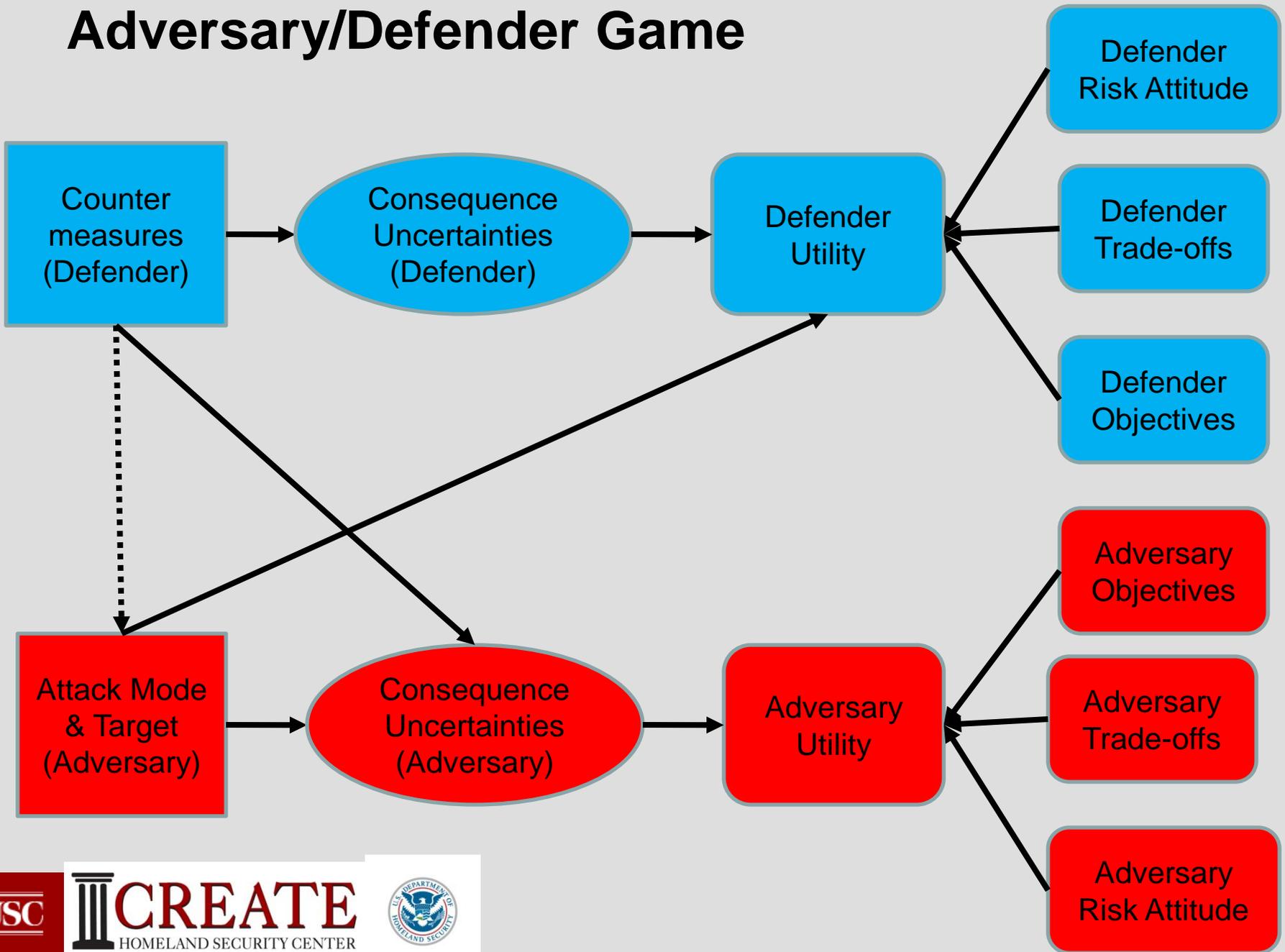


# Domestic Intelligence Countermeasures Objectives Hierarchy

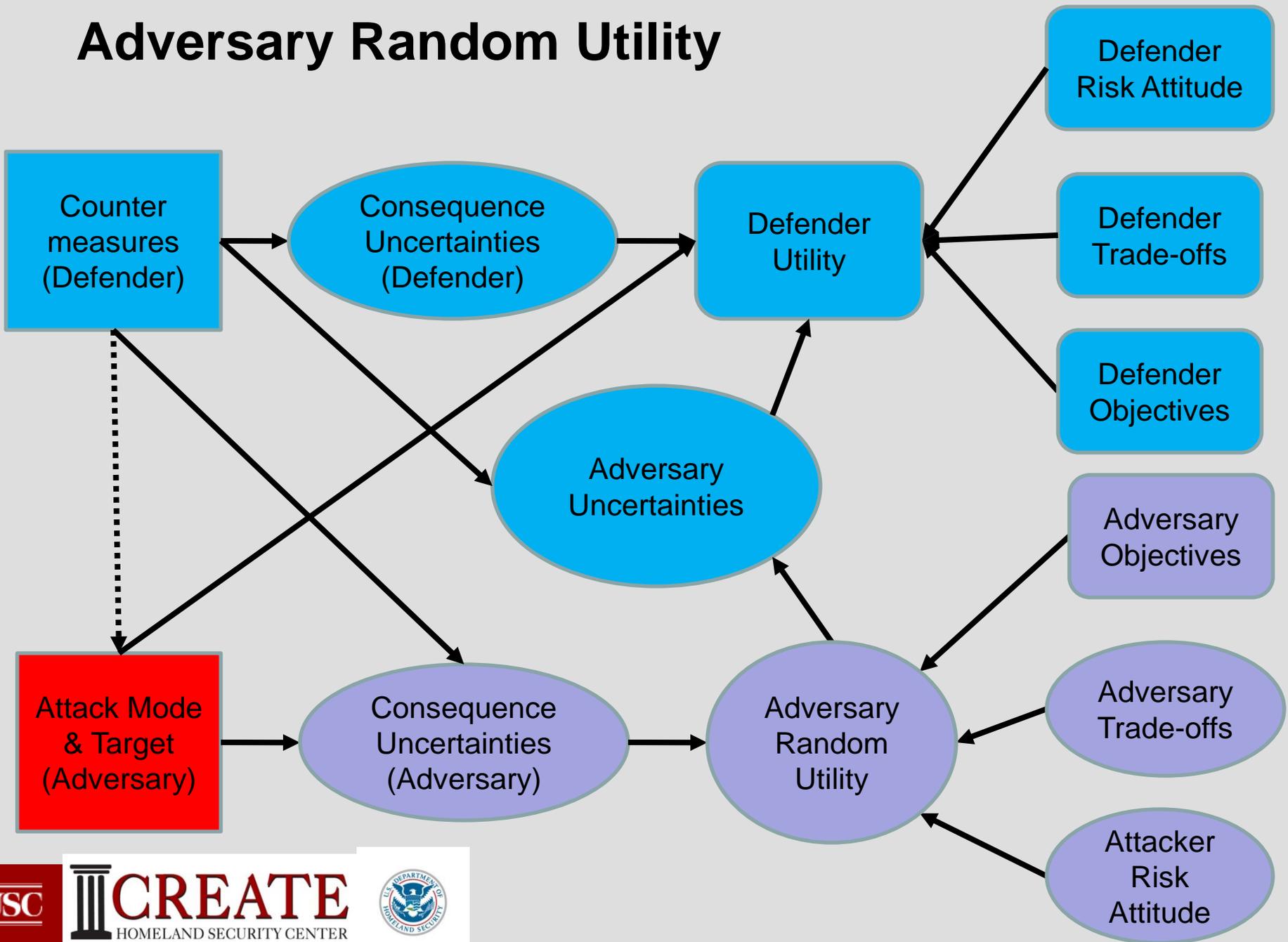


From Dillon-Merrill, John, Lester, & Tinsley. *Differentiating Conflicts in Beliefs vs. Value Trade-offs in the Domestic Intelligence Policy Debate*. Under Review.

# Adversary/Defender Game



# Adversary Random Utility



# Adversary Leader - General Approach

- Studying beliefs and motivations of adversary leaders
  - Beliefs: What do adversary leaders believe about the likely outcomes of specific attacks?
  - Motivations: What are the values and objectives of adversary leaders?
- Interviewing Adversary Values Experts (AVEs)
  - Intelligence experts
  - People who understand and/or empathize with adversary leaders
- Using published writings by and about adversary leaders to infer beliefs and motivations

# Defender Countermeasures

## (1) CCTV

Widespread use of camera surveillance of public activities near targets of concern

## (2) Police

Greatly enhanced police presence near targets of concern, with power to search indiscriminately

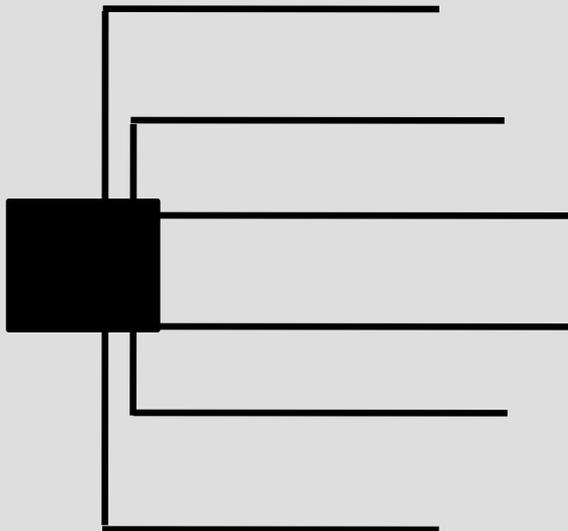
## (3) Border Security

Greatly enhanced border security, including both technological and human barriers

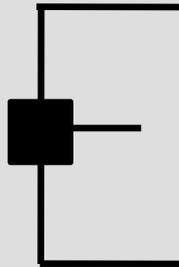
## (4) Detectors

Widespread installation and monitoring of detectors (biological, chemical, radiological and explosive) in urban areas of concern

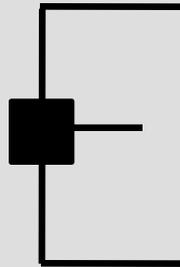
# Attack Mode



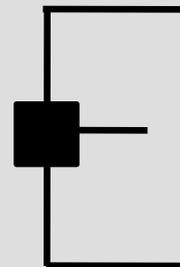
Attack Frequency



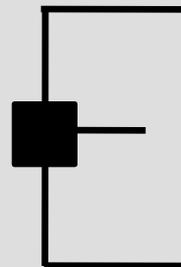
Attack Timing



Attack Target



Attack Size

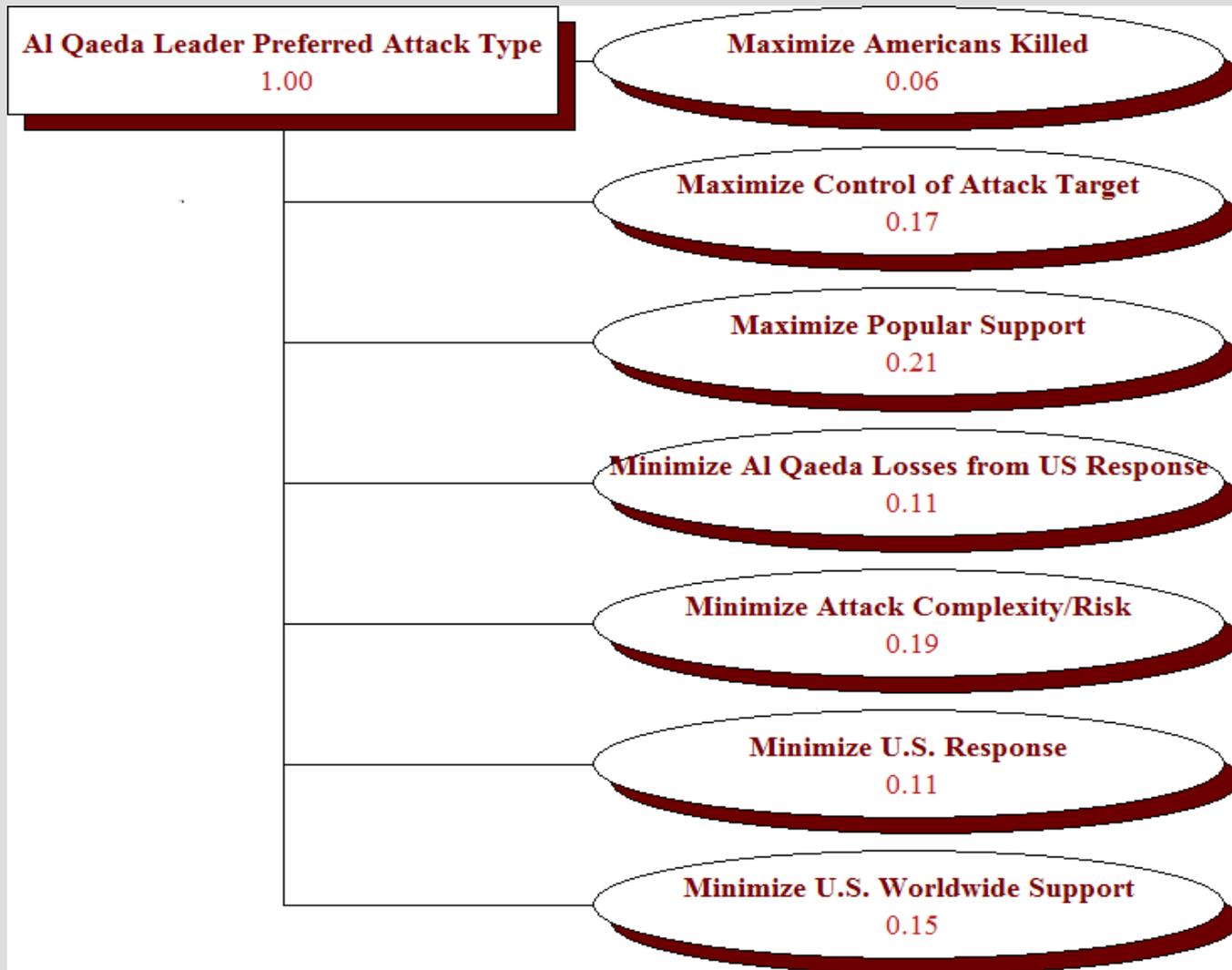


# Transportation System Attacks

## Modes and Targets

- Dirty bomb attack on a major US seaport
- Sarin gas attack on a subway system in a large US city
- Pneumonic plague release in US train stations
- Anthrax release in large US oil refineries
- IED attacks on gas stations in US cities
- No attack

# Adversary Objectives Hierarchy

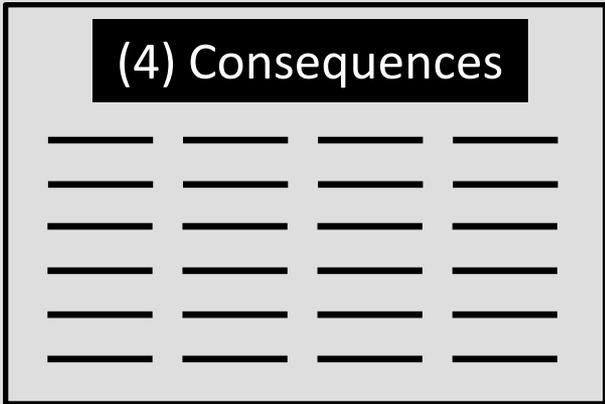
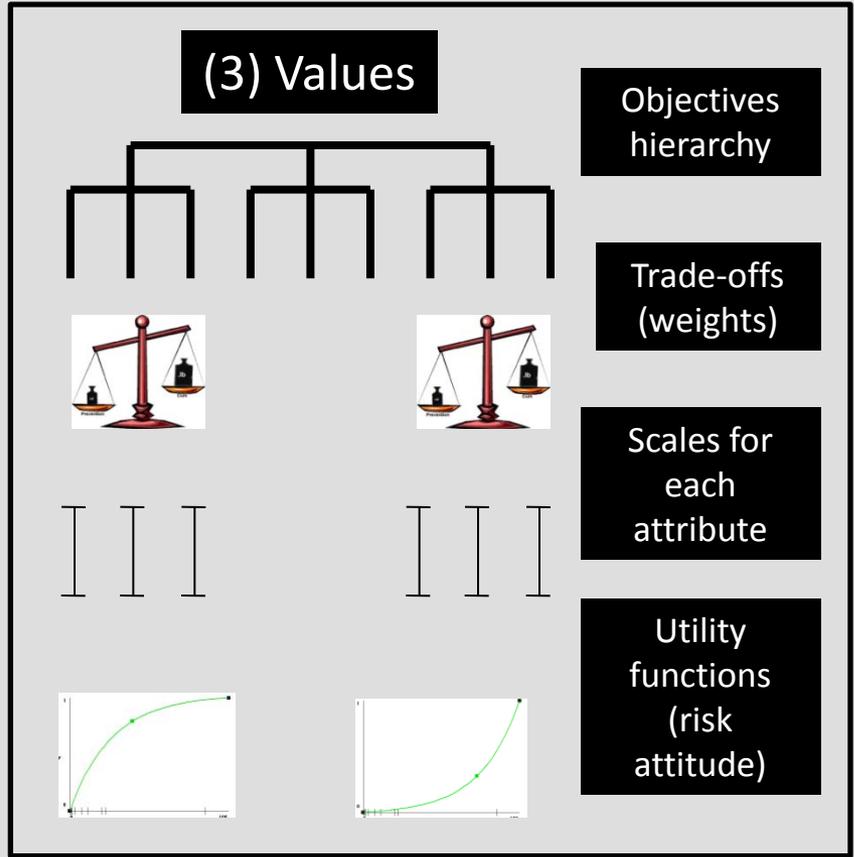
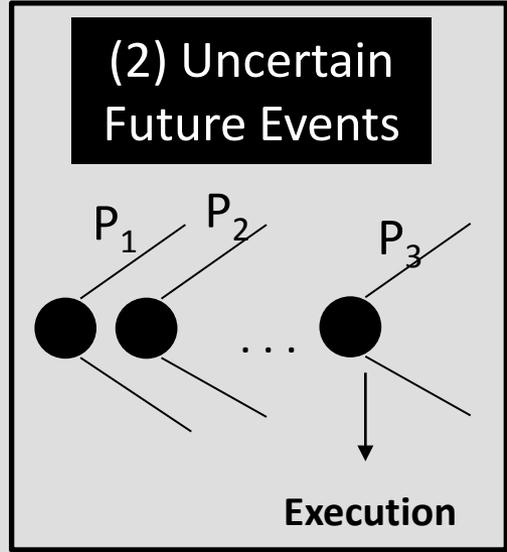
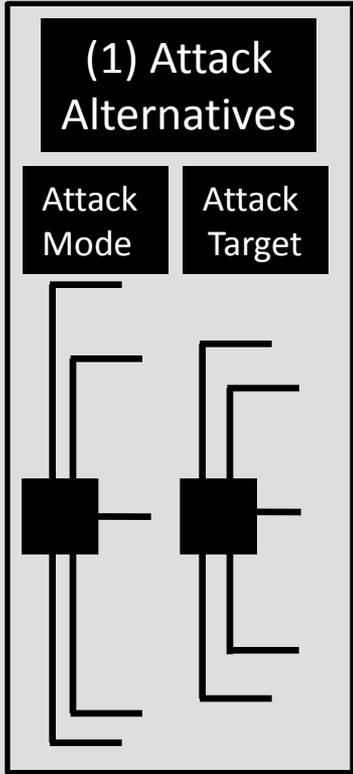


# Elicitation Methodology

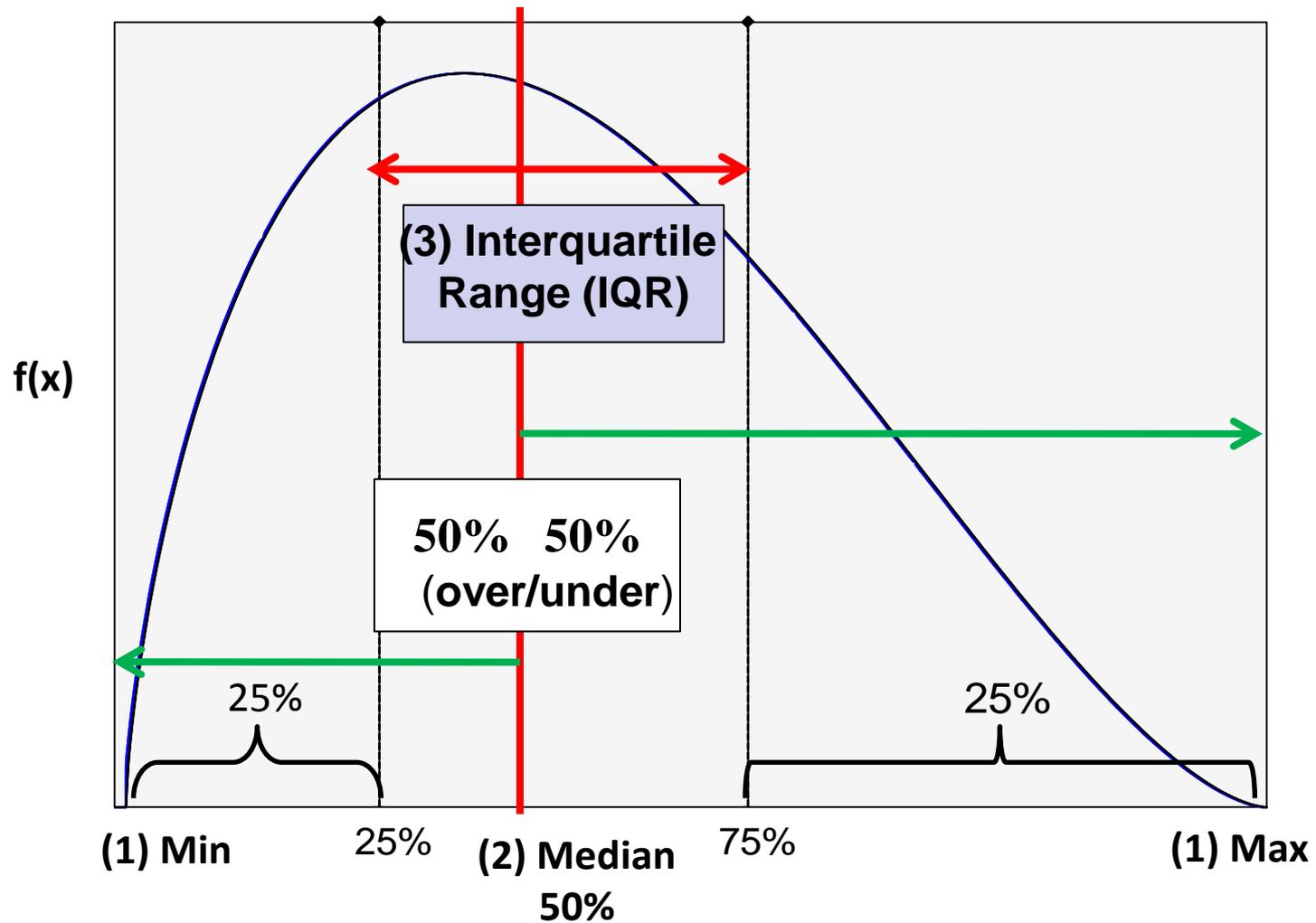
- Conducted assessments of:
  - Score matrix (7 attributes X 6 attack scenarios)
  - Single attribute utility functions (7 attributes)
  - Scaling parameters (weights) for additive model (7 attributes)
- Beta distribution assumption, with min and max defined by scale endpoints (anchors)
- Elicited inter-quartile range (25<sup>th</sup> & 75<sup>th</sup> %-tiles) for Betas
- Total judgments required:  $\# \text{ attrib} * (\# \text{ alternatives} + 2) * 2$ 
  - $7 * (6+2) * 2 = 112$
  - Consistency checks using median estimates
- Assessed shifts in Adversary attribute estimates given select countermeasure implementation (4 countermeasures)

# Adversary Attributes & Scales

Objective (Attribute)	Scale Type	Scale	Worst	Best
1. Maximize Popular Support	Estimated Percentage	% of ummah support for adversary organization (Assumes status quo is 10%) 0% (no ummah support) - 100% (full ummah support)	0	100
2. Minimize U.S Response/Reaction	Constructed Scale	Magnitude of the U.S. response 0 (no response) - 100 (Invade a country friendly to Al Qaeda)	100	0
3. Minimize Blowback	Estimated Percentage	% of Al Qaeda destroyed by US response 0 (Al Qaeda fully intact) - 100 (Al Qaeda wiped out)	100	0
4. Minimize U.S. support worldwide	Estimated Count	Number of G20 countries involved militarily (0 – 20)	20	0
5. Maximize Americans/other westerners killed	Estimated Count	American Fatalities (0-1 million)	0	1,000,000
6. Minimize Complexity (and associated Risk) of Mission	Constructed Scale	Level of Risk/Complexity Associated with Attack (0 not complex/no risk of failure - 100 very complex/high risk of failure)	100	0
7. Maximize ability to control the target, i.e., Power target	Constructed Scale	Control over consequences (e.g. max symbolic value, min death of children, etc) (0 No Control -100 Complete Control)	0	100



# Elicited Uncertainty Distributions



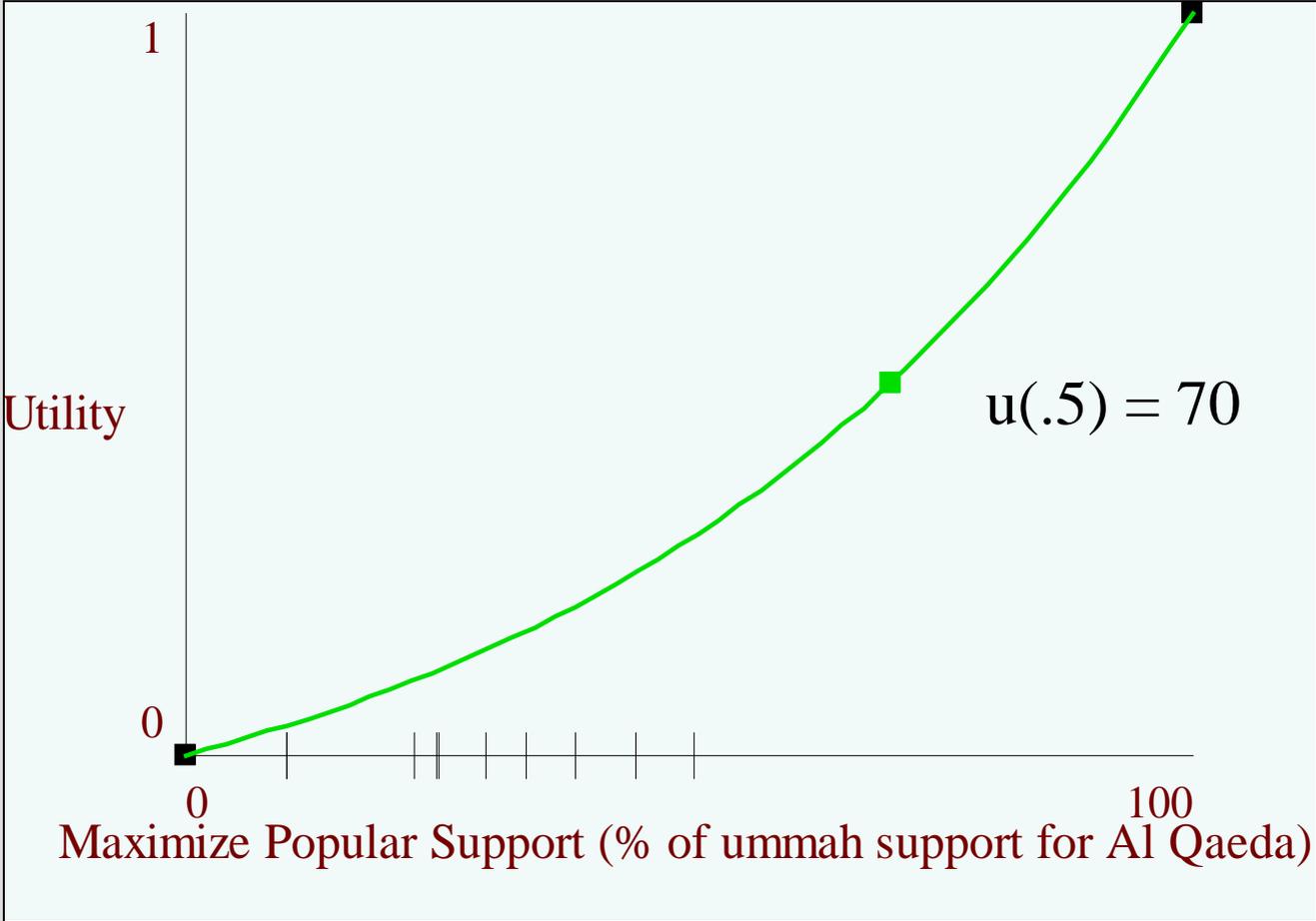
# Adversary Certainty Equivalents for Single Attribute Utility Functions

## SUF Formulas for Values Expert NEW PREF. SET

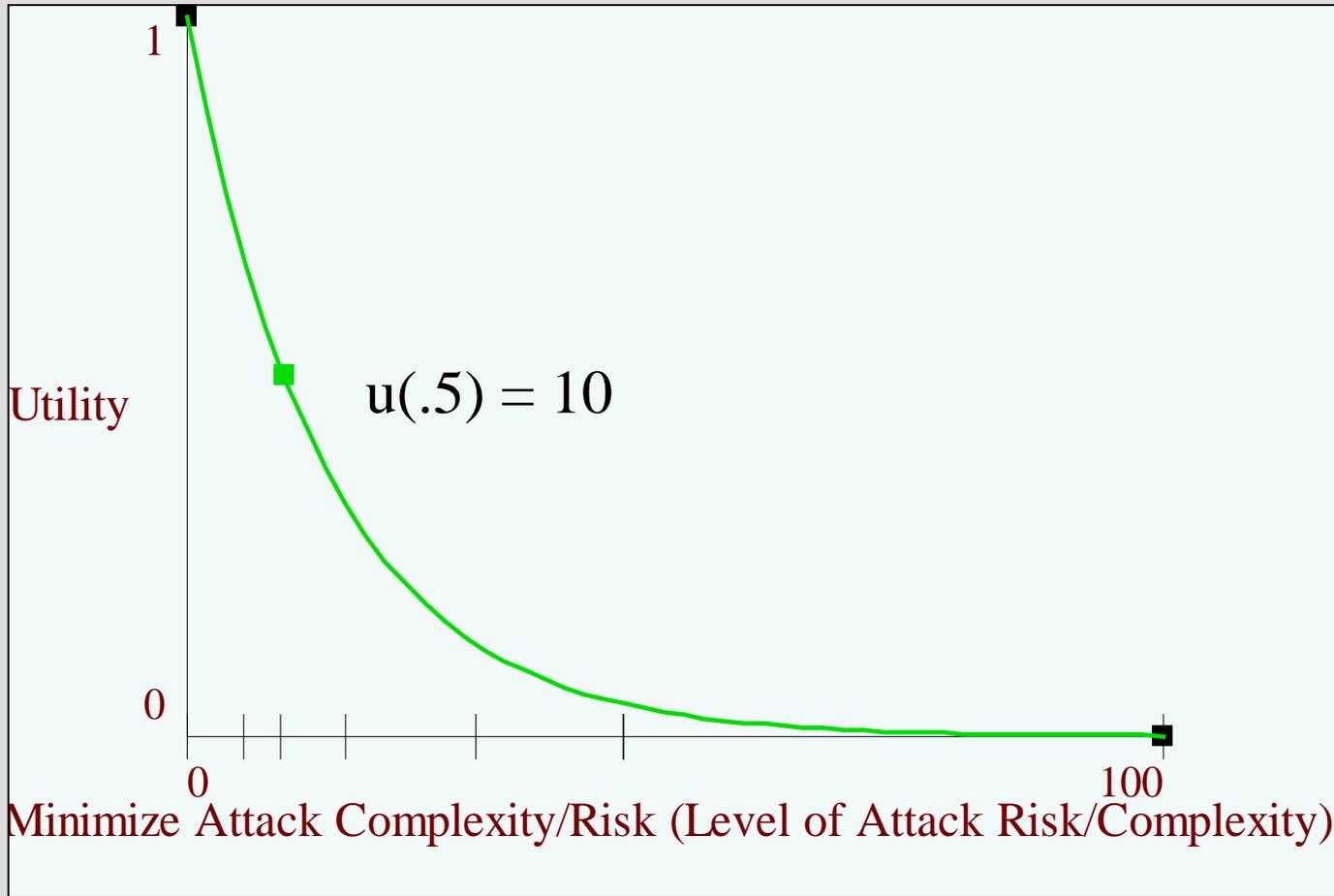
Range		Midpoint		SUF Parameters		
Minimum	Maximum	Level	Utility	a	b	c
Maximize Americans Killed						
0	1e+006	5000	0.5	1	-1	3.518e-005
Maximize Control of Attack Target						
0	100	90	0.5	-0.0009872	0.0009872	-0.06922
Maximize Popular Support						
0	100	70	0.5	-0.1978	0.1978	-0.01801
Minimize Al Qaeda Losses from US Response						
0	100	80	0.5	1.039	-0.03905	-0.03281
Minimize Attack Complexity/Risk						
0	100	10	0.5	-0.0009872	1.001	0.06922
Minimize U.S. Response						
0	100	40	0.5	-0.7841	1.784	0.008222
Minimize U.S. Worldwide Support						
0	20	16	0.5	1.039	-0.03905	-0.1641

SUF Parameters: if  $c = 0$ ,  $U(x) = a + bx$ , if  $c \neq 0$ ,  $U(x) = a + b(\text{EXP}(-cx))$

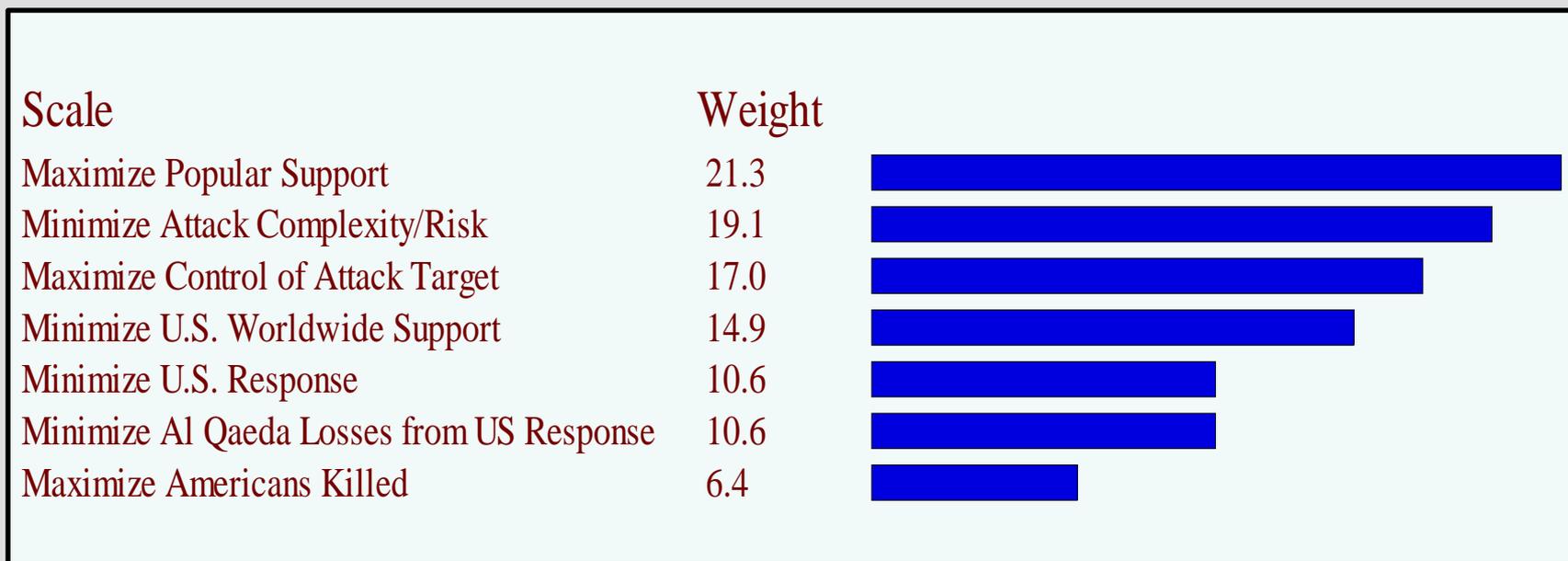
# Adversary Utility for Popular Support



# Adversary Utility for Risk & Complexity



# Median Adversary Swing Weights



# Adversary Implied Trade-Offs (at Median)

## Tradeoffs computed against Maximize Popular Support

	A	B
Maximize Popular Support (% of uma support for Al Qaeda)	84.0	100
Maximize Americans Killed (Number killed)	993277	0
Maximize Popular Support (% of uma support for Al Qaeda)	38.8	100
Maximize Control of Attack Target (% Control of Attack Consequences)	100	0
Maximize Popular Support (% of uma support for Al Qaeda)	70	100
Minimize Al Qaeda Losses from US Response (% of Al Qaeda destroyed by US response)	0	100
Maximize Popular Support (% of uma support for Al Qaeda)	22.6	100
Minimize Attack Complexity/Risk (Level of Attack Risk/Complexity)	0	100
Maximize Popular Support (% of uma support for Al Qaeda)	70	100
Minimize U.S. Response (Magnitude of the U.S. response)	0	100
Maximize Popular Support (% of uma support for Al Qaeda)	51.2	100
Minimize U.S. Worldwide Support (No. G20 countries supporting US response militarily)	0	20

# Multi-Attribute Utility Model (MAUM)

$$U(X_j) = \sum_{i=1}^N k_i u_i (x_{ij})$$

When:

$X_j$  = attack strategies

$k_i$  = attribute  $i$  scaling parameter (weight)

$u_i$  = exponential single attribute utility for attribute  $i$

$x_{ij}$  = consequence measures for attack strategy  $j$  on attribute  $i$

$N$  = number of attributes

# Random Multi-Attribute Utility Model (RMAUM)

$$U(X_j) = \sum_{i=1}^N k_i u_i (x_{ij})$$

When:

$X_j$  = attack strategy  $j$

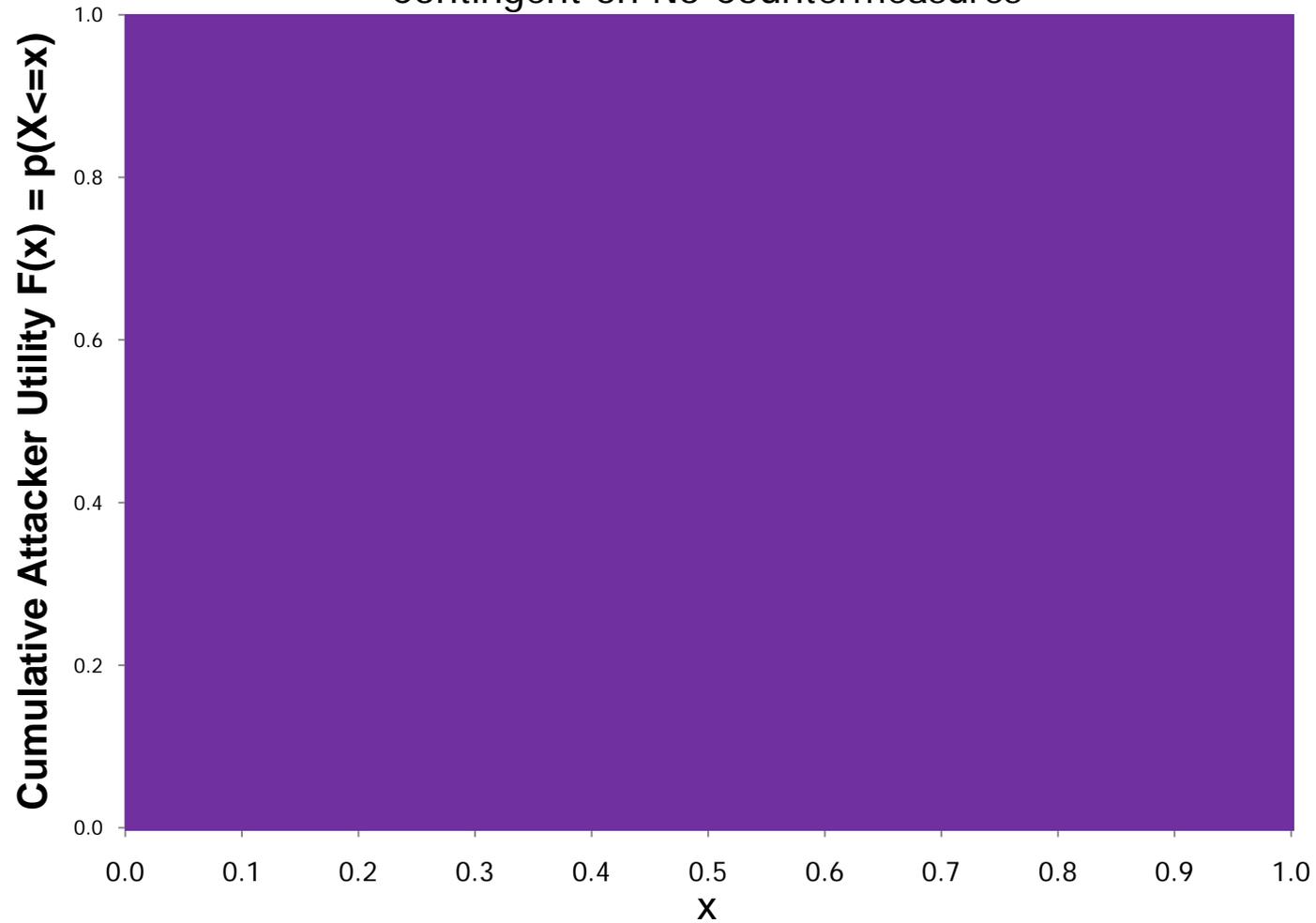
$k_i$  = *random* attribute  $i$  scaling parameter

$u_i$  = *random* exponential single attribute utility for attribute  $i$

$x_{ij}$  = *random* consequence measures for attack strategy  $j$  on attribute  $i$

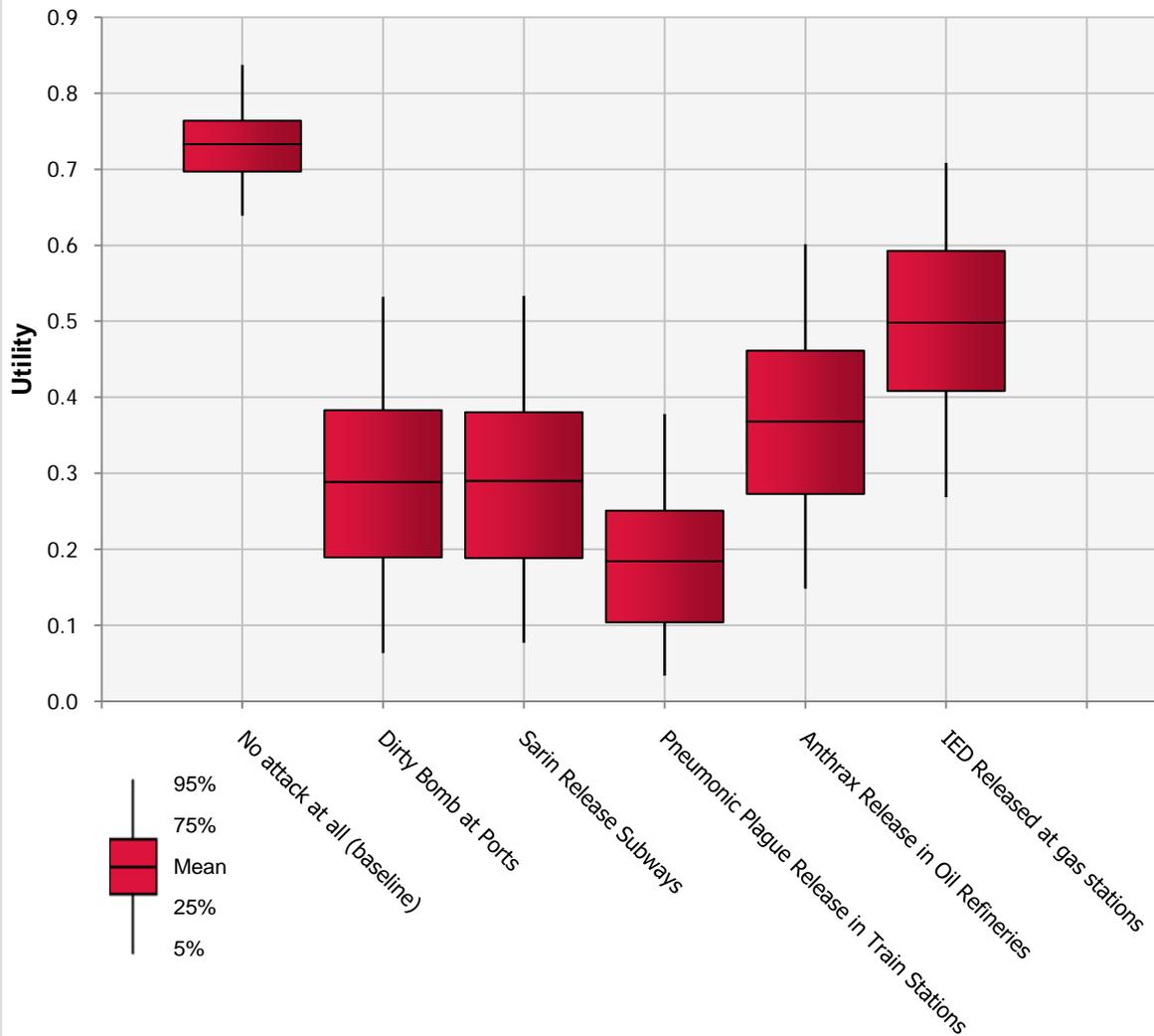
$N$  = number of attributes

# Cumulative Attacker Random Utility Distributions Contingent on No Countermeasures



- No attack at all (baseline)
- Sarin Release Subways
- Anthrax Release in Oil Refineries
- Dirty Bomb at Ports
- Pneumonic Plague Release in Train Stations
- IED Released at gas stations

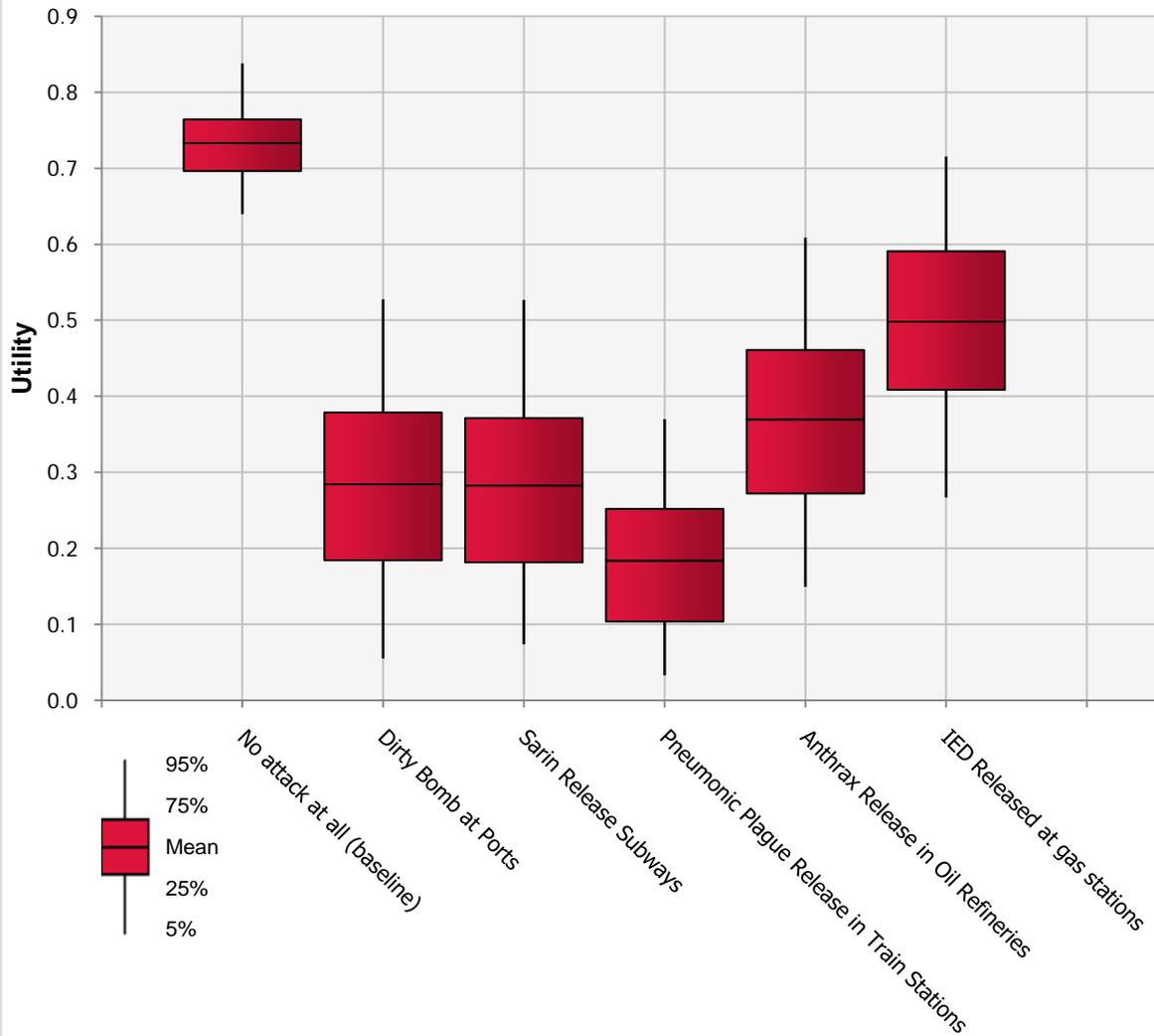
# Adversary Utility distributions, contingent on NO Countermeasures



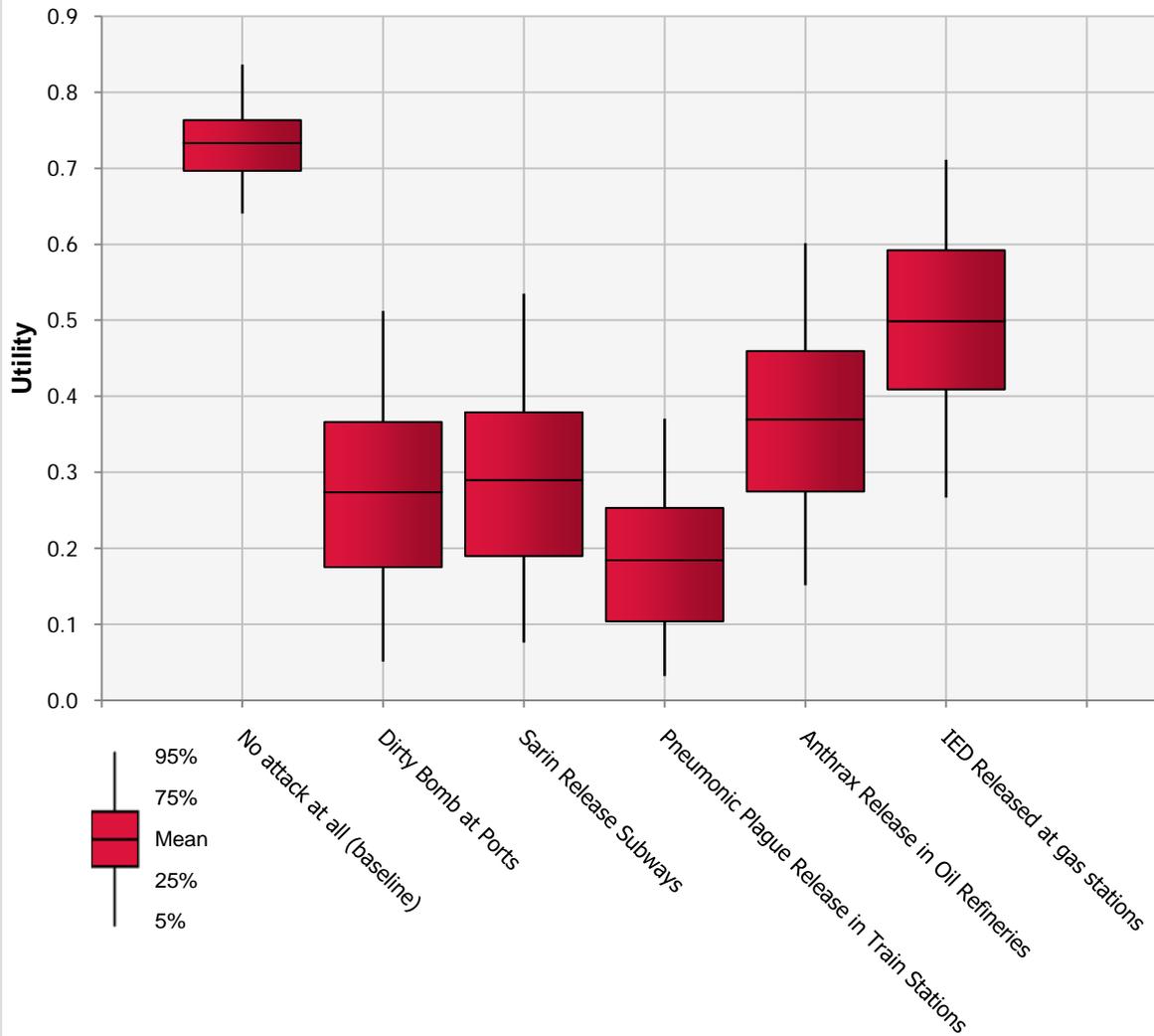
# Median Adversary Utilities

- The RMAUM was estimated using a simulation model implemented within Excel and @Risk.
- Results presented here are based on 5000 iterations and Latin-Hypercube sampling.
- Best possible attack = 1.0 and worst possible attack = 0.0.
- 0.73, No attack
- 0.48, IED attacks on gas stations in US cities
- 0.36, Anthrax release in large US oil refineries
- 0.28, Dirty bomb attack on a major US seaport
- 0.28, Sarin gas attack on subway system in a large US city
- 0.17, Pneumonic plague release in US train stations

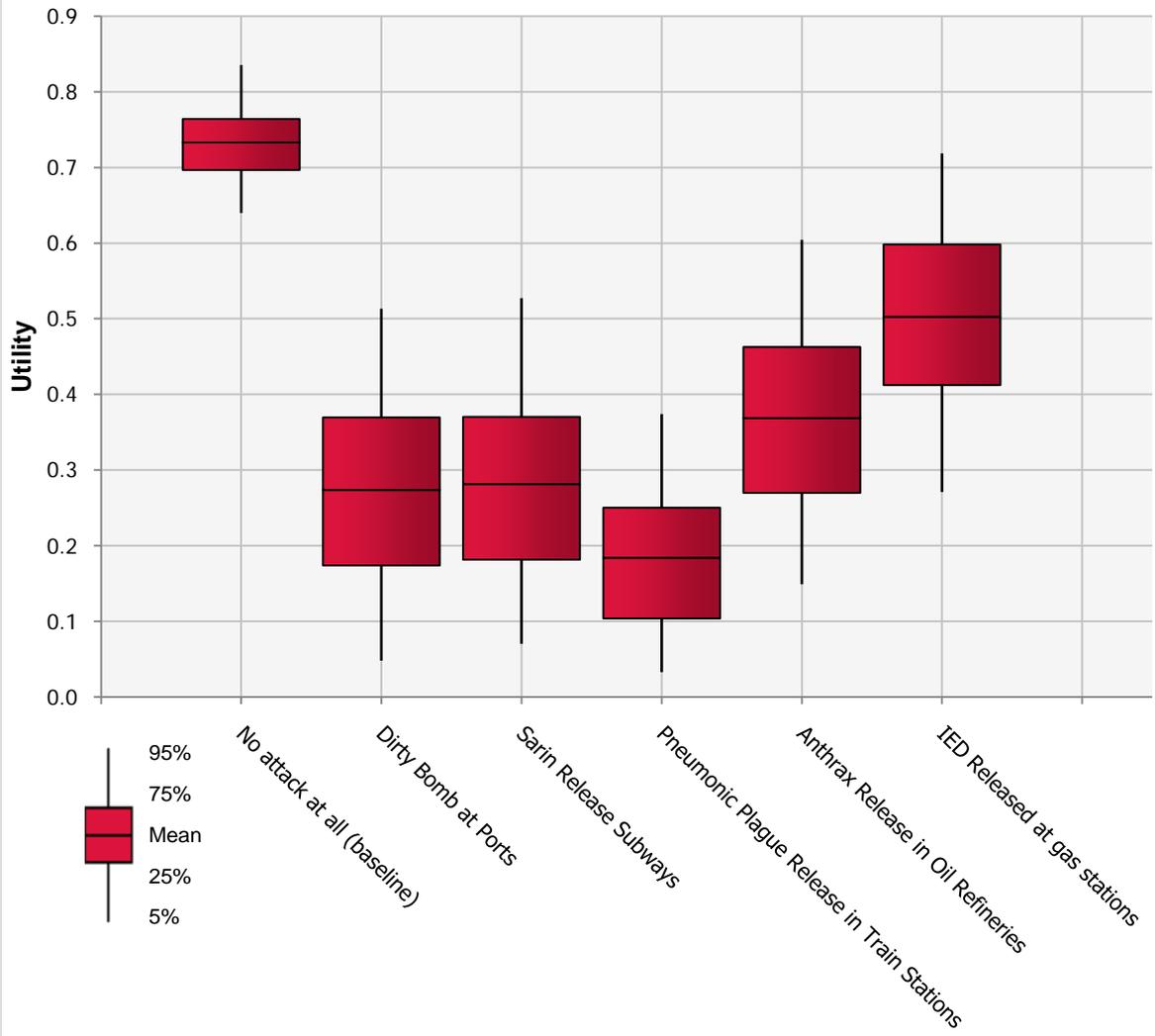
# Adversary Utility Distributions Contingent on CCTV Countermeasure



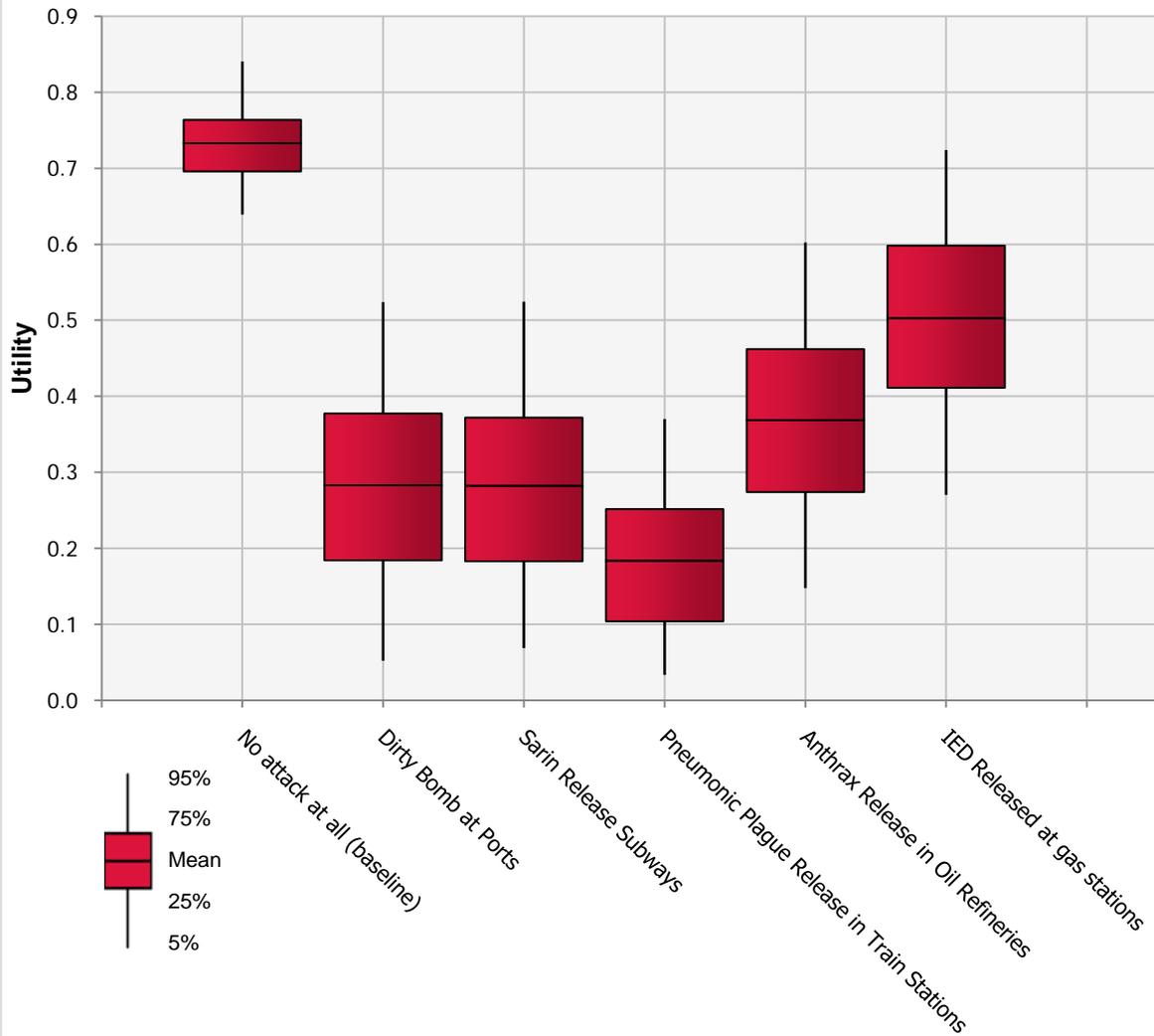
# Adversary Utility Distributions Contingent on Border Security Countermeasures



# Adversary Utility Distributions Contingent on Detector Countermeasures



# Adversary Utility Distributions Contingent on Police Countermeasure



# Choice Axiom

Given  $k$  Possible discrete Attacks  $A_1, A_2, \dots, A_k$

$P$  (Adversary selects  $A_J$ ),  $1 \leq J \leq k$

$= P (A_J \gg A_i)$ , for all  $1 \leq i \leq k$  &  $i \neq J$

$= P (u(A_J) > \max u(A_i))$ , for all  $1 \leq i \leq k$  &  $i \neq J$

# Attack Probabilities

- Estimated probability of each attack conditional on no additional anti-terror countermeasures:
- 0.985, No Attack
- 0.013, IED attacks on gas stations in US cities
- $< .001$ , Anthrax release in large US oil refineries
- $< .001$ , Dirty bomb attack on a major US seaport
- $< .001$ , Sarin gas attack on a subway system in a large US city
- 0.000, Pneumonic plague release in US train stations

# Contingent Attack Probabilities

- Assuming one of the five attacks will be selected by the Al Qaeda leader, i.e., Eliminate No Attack
- Estimated probability of each attack conditional on no additional anti-terror countermeasures:
  - 0.811, IED attacks on gas stations in US cities
  - 0.100, Anthrax release in large US oil refineries
  - 0.082, Dirty bomb attack on a major US seaport
  - 0.007, Sarin gas attack on a subway system in a large US city
  - 0.000, Pneumonic plague release in US train stations

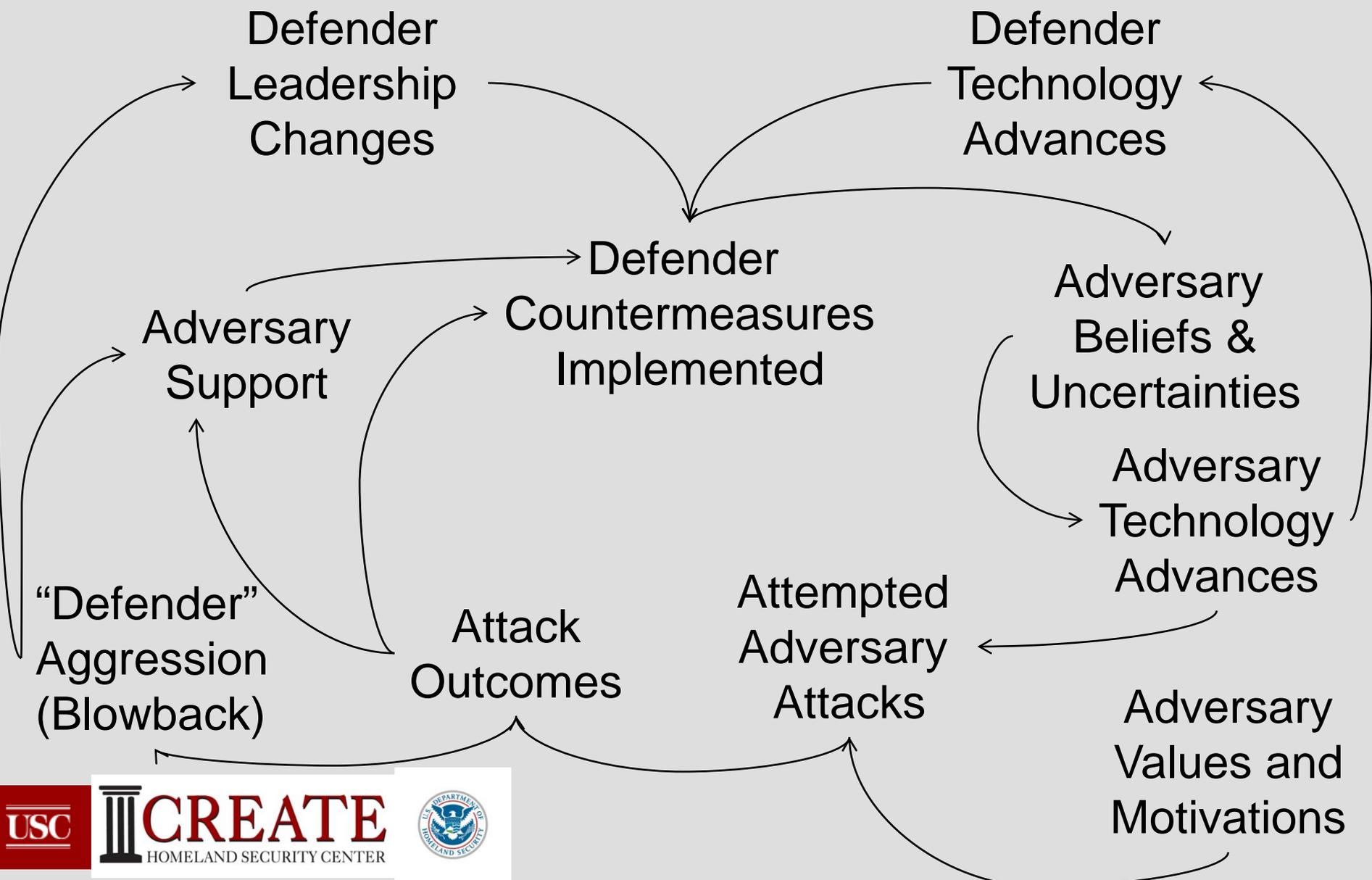
# Conditional Adversary Preferences for each Defender Countermeasure

- Countermeasures have slight effect of increasing the likelihood of No Attack.
- All transportation attack strategies have negligible conditional probability for each countermeasure.

# Challenges and Difficulties

- Adversary leaders not unified
  - Different adversary stakeholder groups, separated geographically
  - Values and beliefs of adversary groups may conflict with one another
- Adversary leadership may change
  - Leadership evolves; some are killed or captured
  - Beliefs and motivations may change over time
- Adversary beliefs may change
  - Success probabilities and consequence expectations may change due to counterterrorism efforts
- Attack alternatives may change
  - Alternative set is growing due to adversary advances
- Adversary values and objectives may change

# Dynamics of Adaptive Adversary Modeling



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