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US Naval Academy
Annapolis, Maryland
June 12-13-14 2007
Through Multiple Disciplines, Analytical Power

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Quantifying the Military Effectiveness of Persistent ISR

Presented at 75th MORSS
June 12-14, 2007

Mark A. Rivera
Boeing Phantom Works
Strategic Development & Analysis

Agenda

- Persistent ISR Study Objective

- Persistence Defined

- Modeling & Simulation

- Measures of Effectiveness

- Architecture Design Search

- Summary

- Develop a process for exploration and design of cost effective Persistent Intelligence, Surveillance, & Reconnaissance (P-ISR) architectures
  - How much persistence is enough to provide critically needed utility?
  - What is the cheapest way to get there?

Needed for the Study

- Means to quickly explore and compare a wide variety of P-ISR architecture designs
  - Included air and space assets
- Means to quantify the military effectiveness of those designs
- Means to quantify the cost of those designs

This briefing will focus on the second bullet and partly on the first
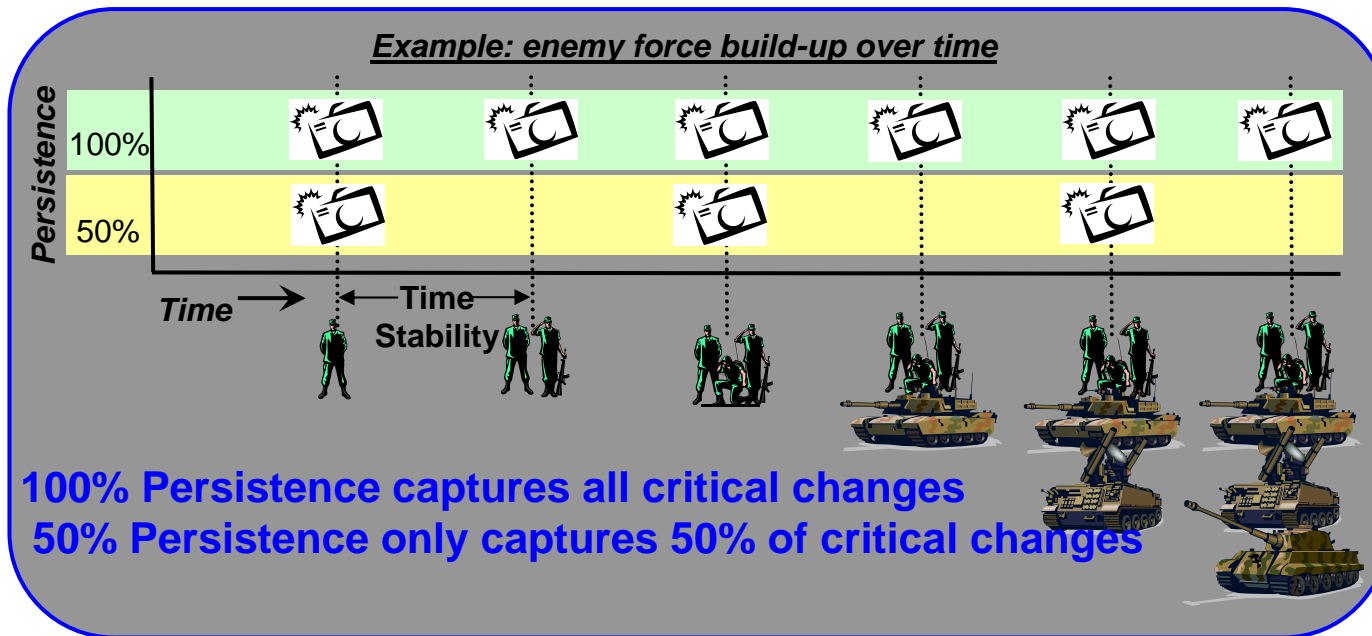
What is meant by "Persistent" ISR?

Definition used in analysis:
Persistence matches the frequency of revisit with the "time stability" of the object that you are looking at—the speed with which things change.

John Stenbit, Former Assistant Secretary of Defense for Networks and Information Integration

Example: enemy force build-up over time

100% Persistence captures all critical changes
50% Persistence only captures 50% of critical changes

Revisit rate required for persistence is scenario specific

How much Persistence is enough?

Approximate Scenario Time Stabilities

Target Type	Time Stability
Construction of Uranium Enrichment Plant	Months
Massing of Forces	Days
Movement of Mobile Missile launchers	Minutes/Hours
Subversive Activity at Infrastructure Sites (Oil pump, Power stations....)	Seconds/Minutes
Human Detection and ID (i.e., Human Bomb)	Seconds
Border Crossings (Humans and Vehicles)	Seconds

*Effectiveness levels off at the time stability of key dynamic observables in the scenario*

Combat Search & Rescue (CSAR) Scenario

Time Stability = 10 mins

MOE: Probability of Rescue

Revisit Cycle (minutes)

0   5   10   15   20   25   30
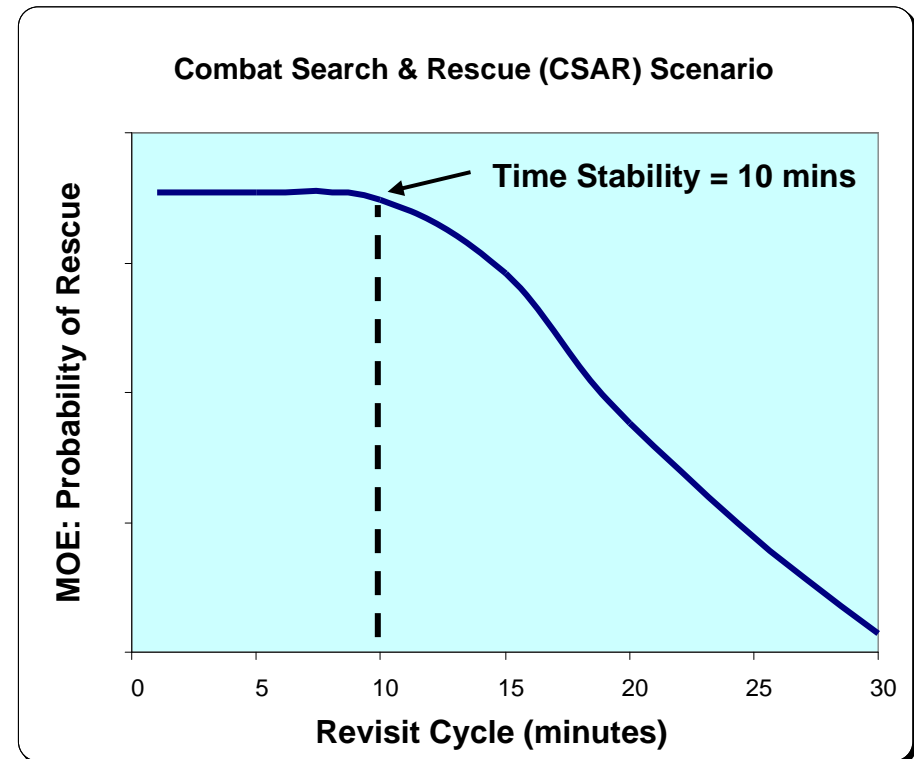
You don't want to buy more persistence than you need

M&S Required to Quantify Value of P-ISR

- Persistence required is scenario specific so you must: Define a specific scenario and mission goals

- Define quantifiable Measures of Effectiveness (MOEs) for achieving those goals

- Define force structures, assets, and capabilities of red and blue forces
  - Blue forces have P-ISR capability

- Model and simulate to determine a force-on-force outcome
  - as a function of P-ISR performance
    - Persistence (Revisit Rate)
    - Data quality (Prob. Of Detection)
    - Data latency (comm/process delays)
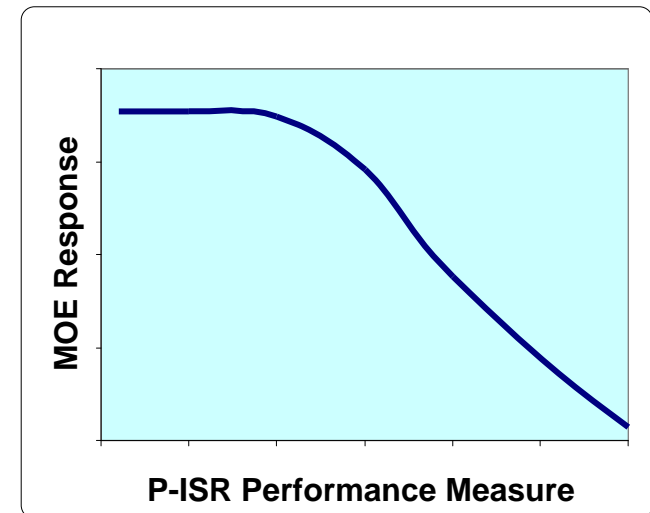
You must have good degree of M&S to capture this response

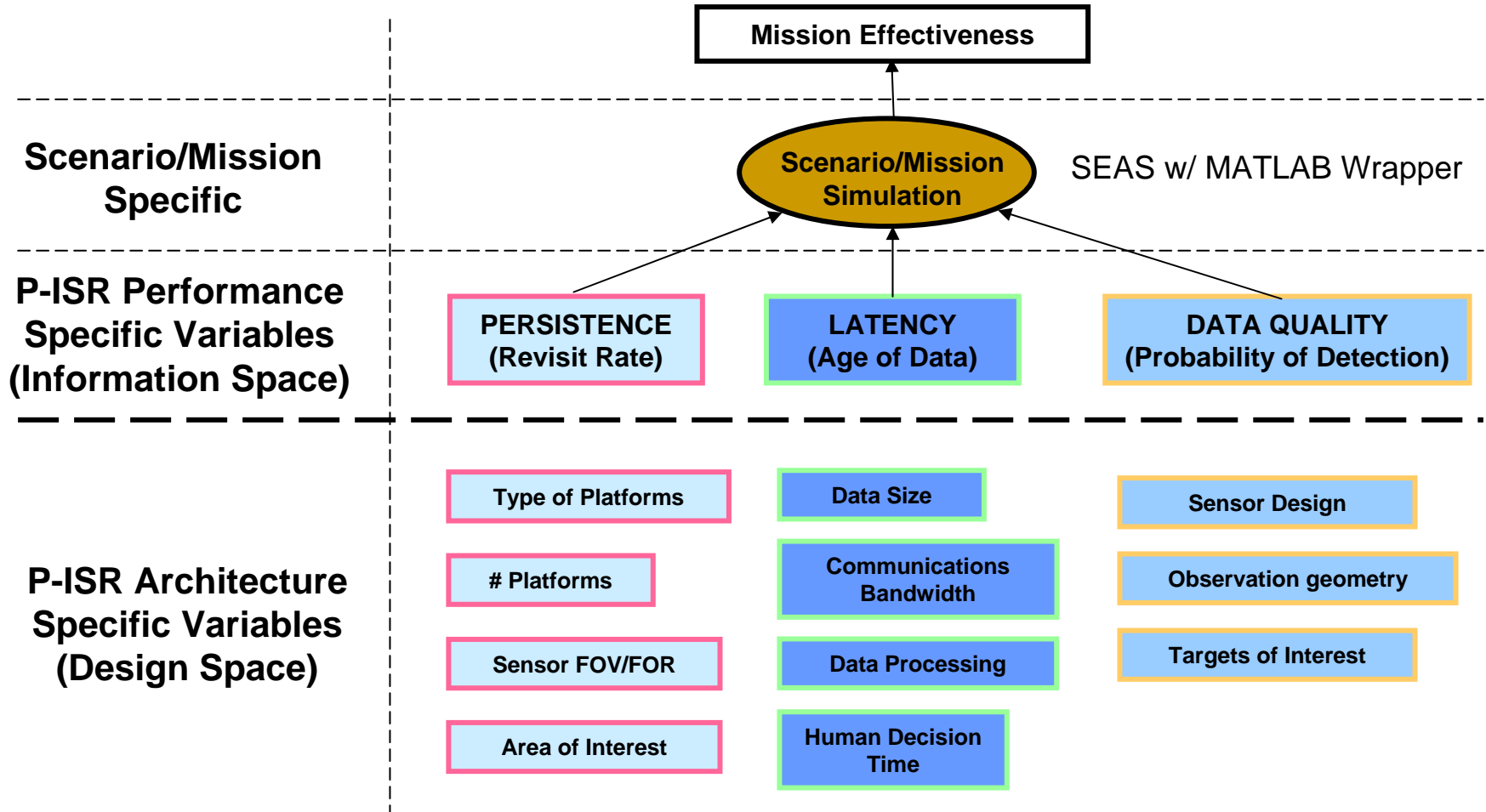# *Systems Effectiveness & Analysis Simulation*

- SEAS is a multi-agent force-on-force reactive simulation
- Blue forces receive P-ISR information in an NCO enabled environment
  – They don't care where or how the information is *originated*, only that they get what they need when they need it
- Blue forces still have some capability even with diminished or absent P-ISR information
  – Indigenous capability determines residual effectiveness
  – Also determines response to decreased/increased ISR
- Red forces have some ability to react and counter
  – Adversary capabilities also determine effectiveness of blue force
  – Both residual and ISR enabled

> *SEAS simulates blue force's improved ability to respond to a capable adversary as a result of acquiring P-ISR information*

Effectiveness and Information

Mission Effectiveness

Scenario/Mission Specific

Scenario/Mission Simulation — SEAS w/ MATLAB Wrapper

P-ISR Performance Specific Variables (Information Space)

- PERSISTENCE (Revisit Rate)
- LATENCY (Age of Data)
- DATA QUALITY (Probability of Detection)

P-ISR Architecture Specific Variables (Design Space)

|		
Type of Platforms	Data Size	Sensor Design
# Platforms	Communications Bandwidth	Observation geometry
Sensor FOV/FOR	Data Processing	Targets of Interest
Area of Interest	Human Decision Time	

Mission effectiveness can be determined by "dialing" architecture performance (information) independently of a specific architecture

- **MOE responses are captured in multi-dimensional look-up tables.**
  - **The result of 1000's of SEAS simulation executions**
- **Variations on level of persistence and accuracy of data can be quickly determined during architecture design searches**
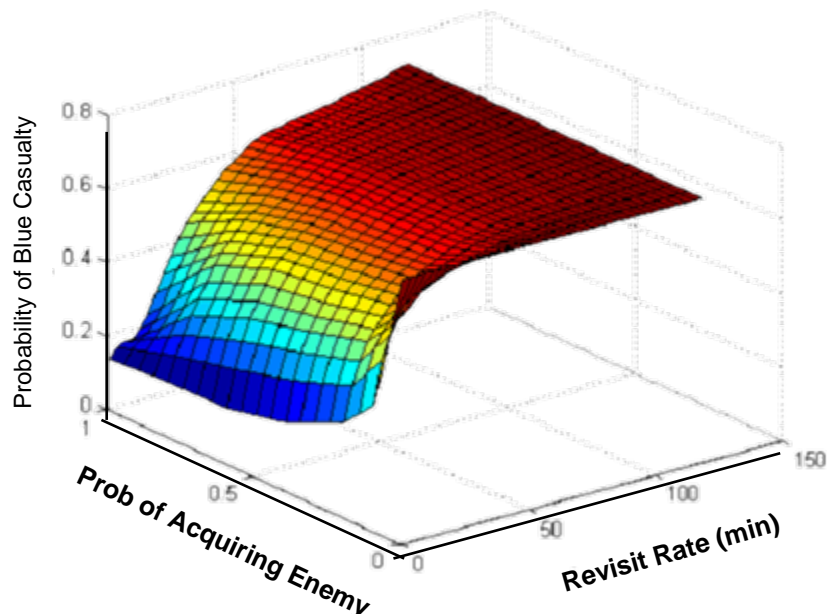
Search & Rescue Scenario

Locate and rescue a handicapped but mobile rescuee in enemy territory

Evade detection by enemy

Avoid combat engagements

MOE response surfaces provide a means for rapidly determining mission effectiveness as a result of any given P-ISR architecture
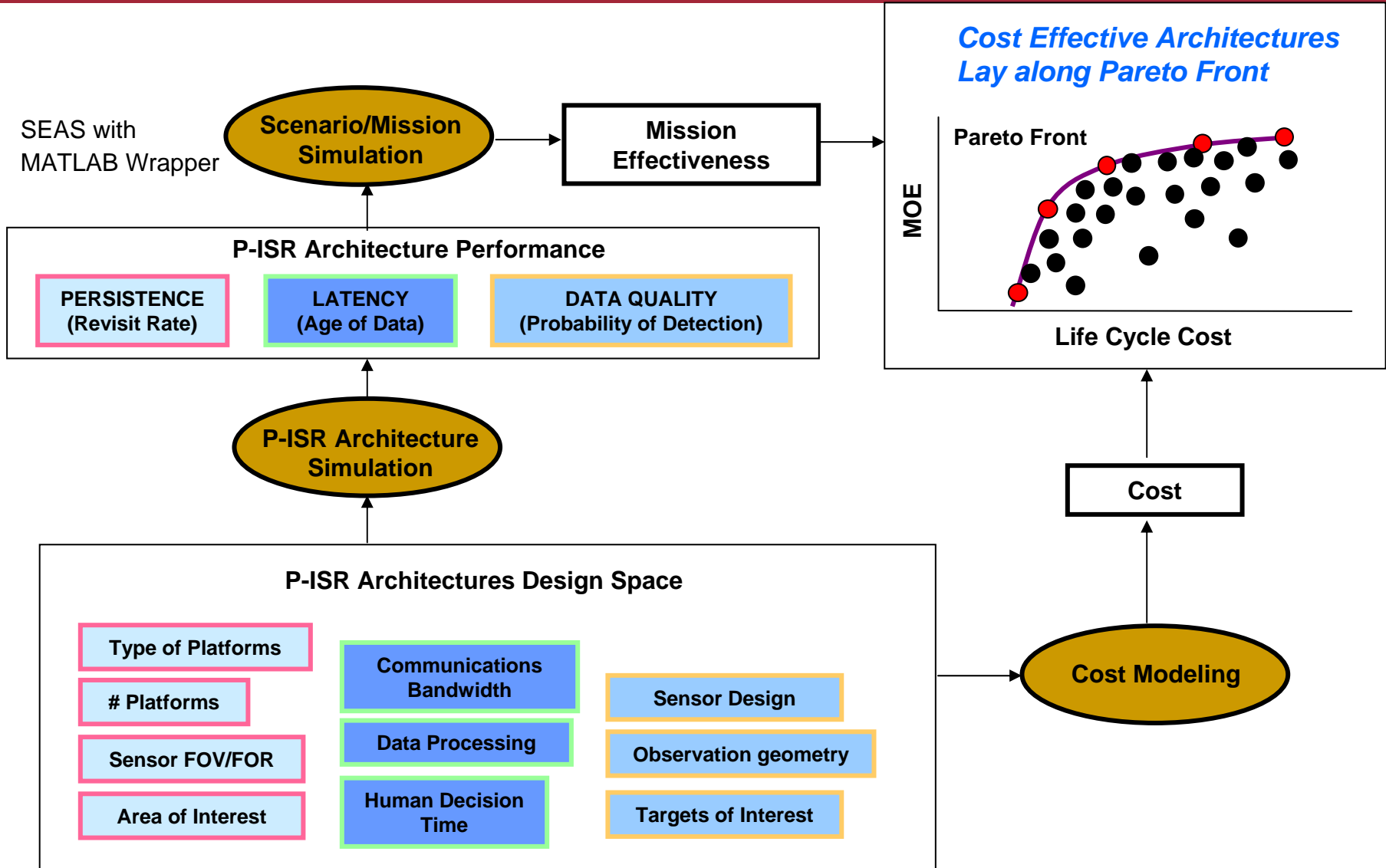
Measures of Effectiveness Types

SEAS / MATLAB Scenarios can Provide These MOEs

- Probability of Mission Success
  - Probability of meeting primary objective(s) i.e. rescue, secure, destroy, etc.
- Mission Duration (Time Improvements)
  - Time to secure an asset or infrastructure under attack
  - Time to neutralize enemy capabilities and assets
- Range of Effectiveness
  - Neutralize enemy from further away (stand-off weapons)
- Cost Effectiveness
  - Required manpower & equipment to achieve a given objective
- Survivability
  - Casualties and Equipment Losses (including those from friendly fire)
  - Duration and probability of survival
- Evasion & Stealth
  - Probability of evading enemy attack assets or danger areas
  - Probability of evading enemy sight
- Lethality
  - Enemy Casualties and Equipment
- Non-combatant Losses
  - Casualties, Assets, Infrastructure, etc.

Architecture Design Search

SEAS with
MATLAB Wrapper

Scenario/Mission Simulation → **Mission Effectiveness**

Cost Effective Architectures Lay along Pareto Front

Pareto Front

MOE

Life Cycle Cost

P-ISR Architecture Performance

PERSISTENCE (Revisit Rate)

LATENCY (Age of Data)

DATA QUALITY (Probability of Detection)

P-ISR Architecture Simulation

Cost

P-ISR Architectures Design Space

Type of Platforms

 # Platforms

Sensor FOV/FOR

Area of Interest

Communications Bandwidth

Data Processing

Human Decision Time

Sensor Design

Observation geometry

Targets of Interest

Cost Modeling

Summary

- Boeing PW has developed a means for quickly exploring cost effective designs of P-ISR architectures

- Revisit rate required for "Persistent" ISR depends highly upon the scenario and mission
  - You don't want more persistence than you need

- Value of P-ISR information depends entirely upon a force's ability to respond to the information
  - The indigenous capabilities of both blue and red forces

- Quantifying increased effectiveness as a result of being provided with P-ISR information requires a high degree of Modeling & Simulation
  - Multi-agent reactive simulation is a must

Backup Charts

Urban Operations Scenarios & MOEs

Embassy Rescue	Search & Rescue	Rescuee Survival	Infrastructure Attack
Probability of Rescue	Probability of Rescue	Probability of Survival	Time to Secure
Mission Duration	Mission Duration	Survival Duration	Probability of Securing
Probability of Blue Casualty	Probability of Blue Casualty	Probability of Red Casualty	Probability of Blue Casualty
Probability of Red Casualty	Probability of Red Casualty		Probability of Red Casualty

MOEs Provided in our study