An Adaptable Architecture for the Airborne Electronic Attack (AEA) System of Systems (SoS)

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Intro

- This briefing was developed during funded research for the U. S. Air Force Aeronautical Systems Center for the AEA Capability Planning Manager (ASC/XRS)
- This briefing is unclassified in its entirety

Purpose Statement

- **Discuss the methodology to build an *adaptable System of Systems* architecture that can be used to compare performance of alternative solutions.**

- **Definitions**
  - **Adaptable – capable of becoming suitable to a particular situation or use**
  - **System of Systems – a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities**

Outline

- AEA SoS Description
- Focus of Effort
- Methodology
- Architecture Challenges
- Solutions
- System Analyses

Airborne Electronic Attack System of Systems (AEA SoS) Description

- Limited number of AEA assets support multiple air and ground elements against multiple threats
- Requires informed AEA decisions across the theater in real-time
- Requires coordination between a variety of assets (SoS) to improve:
  - AEA tasking awareness
  - Flexibility and confidence to make changes
  - Overall AEA Efficiency
- Goal – to improve AEA support through interoperability & coordination
  - Information sharing
  - Management of assets

Focus of Effort

- Develop a means to verify that the SoS provides significant improvements to combat effectiveness
- Develop a means to quantify those improvements
- Determine which ‘attributes’ make a statistically significant difference

Methodology

- **Build an adaptable architecture to model the AEA SoS**
- **Using the architecture as a baseline, perform Systems Analyses to determine and measure the improvements to combat effectiveness**
  - **Screening model – to identify the key 'attributes'**
  - **High Fidelity model – to determine effectiveness**

Architecture Challenges

- Need an *adaptable* architecture that represents various:
  - Configurations
  - Situations
  - Attributes

Architecture Challenge – Various Configurations

- **AEA SoS Architecture must be adaptable to many different configurations**

- **AEA SoS consists of many different players/roles**
  - **AEA Platforms *(Jammers)***
  - **Intelligence, Surveillance, and Reconnaissance (ISR) Platforms**
  - **Protected Element *(Bombers, Ground troops, etc)***
  - **Command Element *(Air Operations Center, Air Control aircraft, etc)***
  - **AEA Battle Management *(Operational-level, Tactical-level)***

- **Each role can be thought of as its own *Family of Systems***

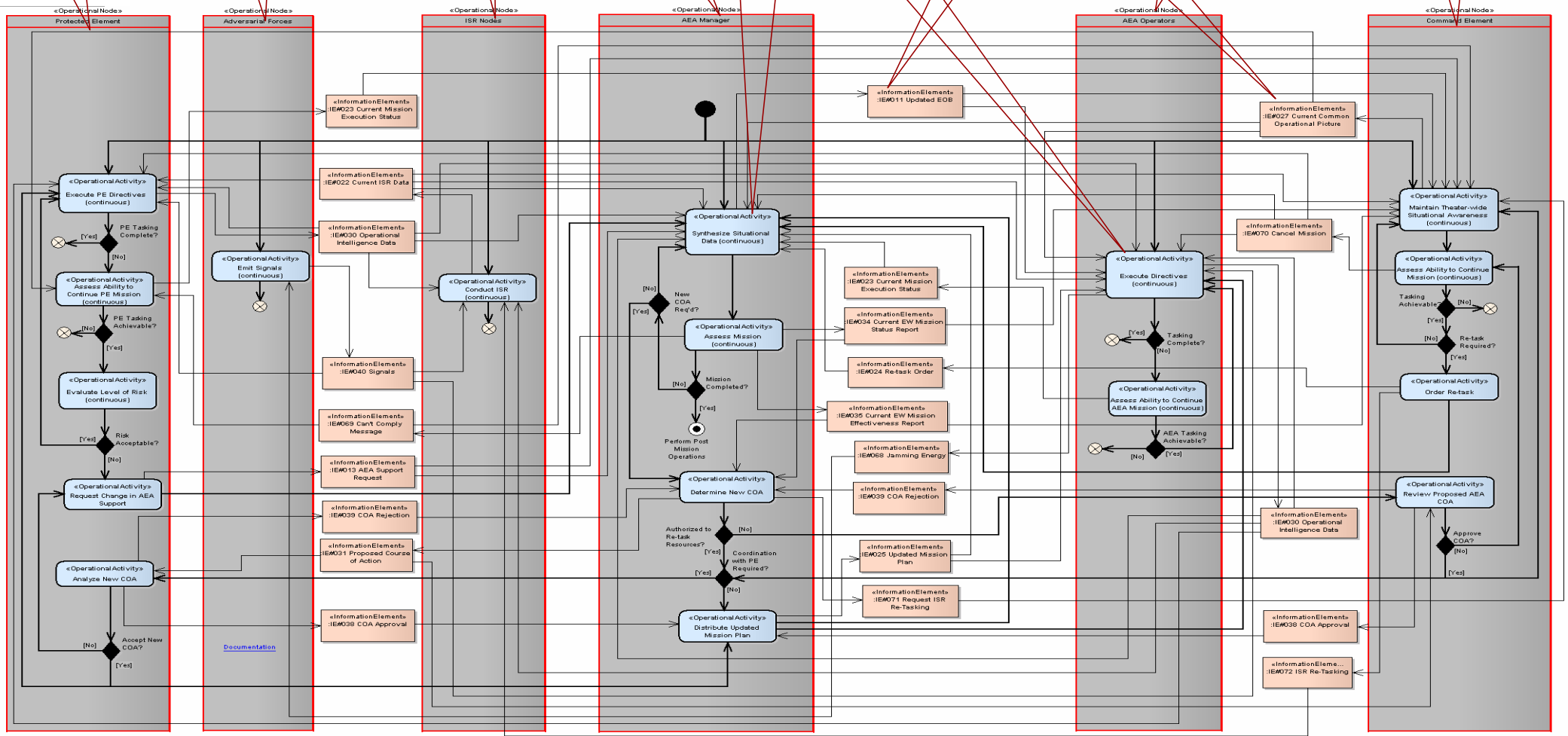
- **Definition**
  - **Family of Systems – a set of systems that provide similar capabilities through different approaches**

Solution – Generic Activity Modeling

- Activity diagrams - used to model activities and exchanges within the AEA SoS
  - *Abstract* Operational Node classes – defined to account for variable configurations
  - *Abstract* High Level Activities – defined for each operational node
  - *Abstract* Information Element classes – defined to represent the information exchanges between operational node activities
- Result – an all-encompassing "one size fits all" operational model
- Definitions
  - Generic – very comprehensive, relating to or descriptive of an entire group or class
  - Abstract – thought of or stated without reference to a specific instance; generalized

Protected Element | Adversarial Forces | ISR Nodes | AEA Manager | Operational Activities | Information Exchanges | AEA Operators | Command Element

Notional Activity Model – Execute AEA Mission



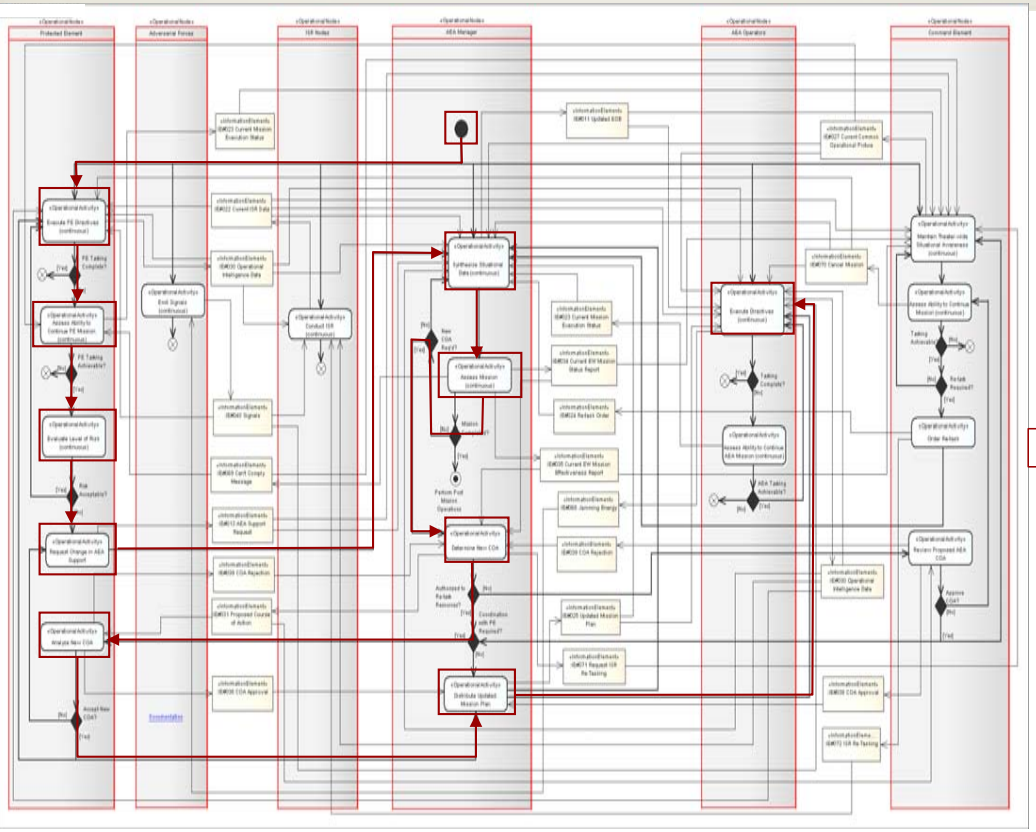
Architecture Challenge – Various Situations

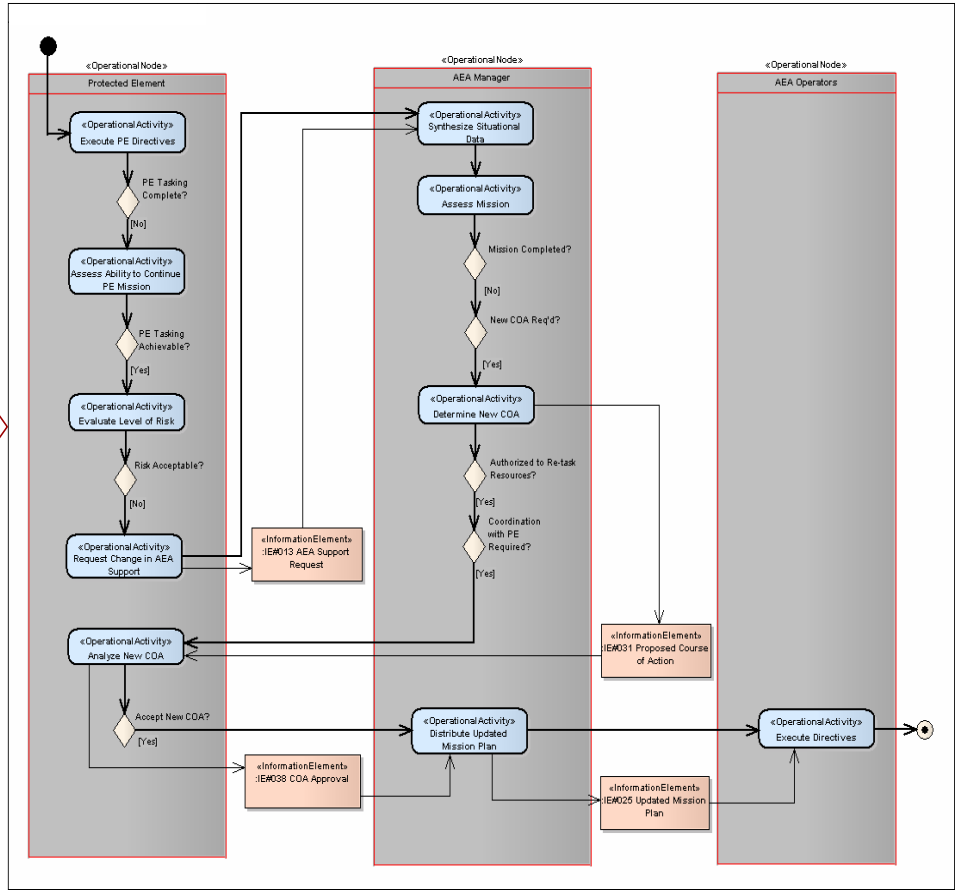
- AEA SoS Architecture must be adaptable to the many different 'situations' that may occur during a mission
  - New Jamming Request from the Protected Element
  - AEA Platform Malfunction
  - Change in Mission Priorities
  - Command Element Cancels Mission
  - React to a Pop-up SAM

Solution – Notional Modeling of Specific Situations

- Activity diagrams – used to model specific ‘situations’
- Derived from notional Execute AEA Mission Activity Diagram
- Each Situation represents a single thread through the architecture

Solution – Notional Modeling of Specific Situations





Architecture Challenge – Various Attributes

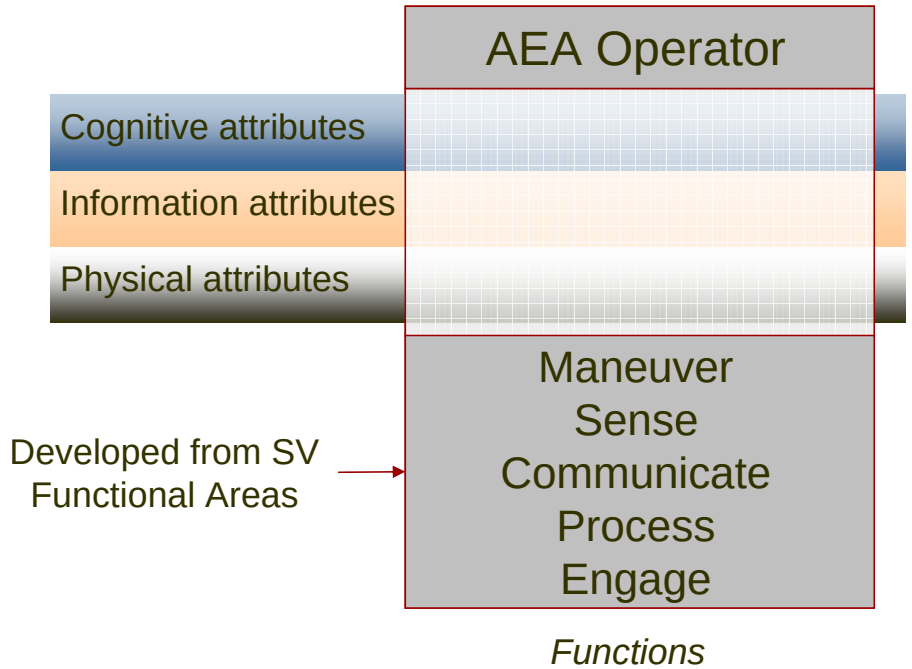
- The AEA SoS Architecture must be adaptable to take into account a number of various ‘attributes’ that can change from one mission to the next.

- Some examples out over 40 identified attributes:
  - AEA – PE Support Relationship
  - Communications Quality
  - Jammer Effectiveness

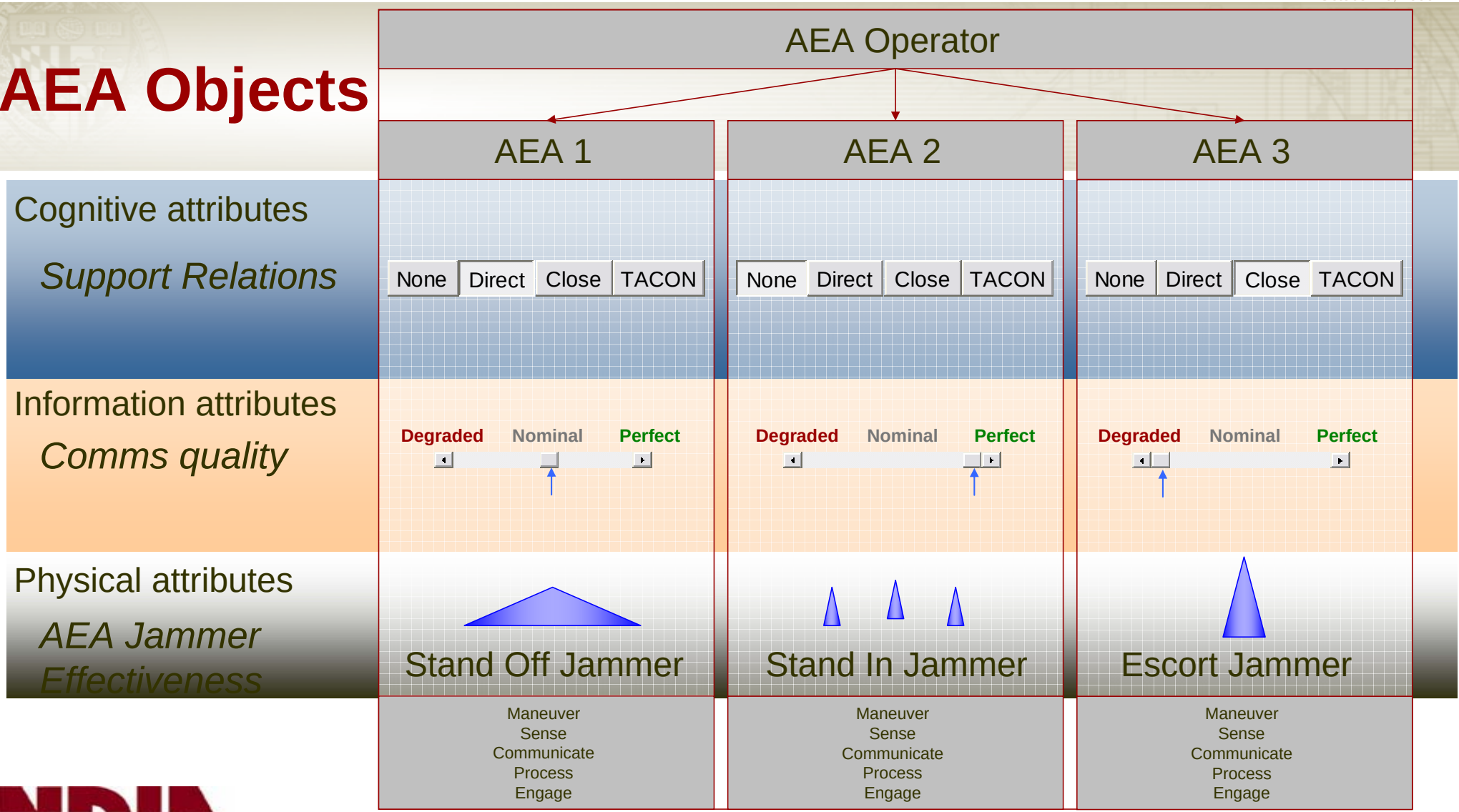
Using the adaptable architecture

Method:

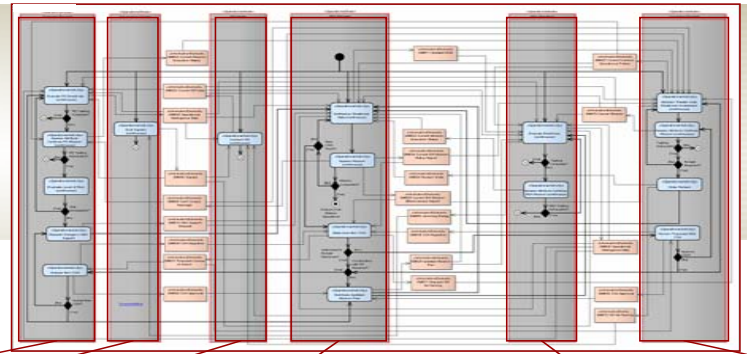
1. **For each swimlane, show settings for appropriate attributes**
2. **Inside each swimlane, show standardized operations functions**
3. **Build multiple configurations (attributes & functions)**
4. **Model attribute and function interactions *using the architecture foundation***
5. **Simulate to compare performance from different configurations**



AEA Objects



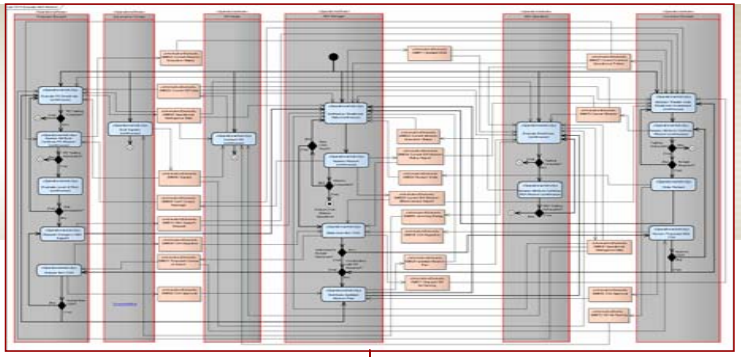
2. Single Configuration (example)



Swim lanes (Roles)

Protected Entity	Adversary	ISR	AEA BM		AEA Operator			Command Element	
Objects									
Bomber	Radar	Air Recon	Oper	Tac	AEA 1	AEA 2	AEA 3	Air Control	CAOC
Attributes									
					SOJ	SIJ	Escort		
Functions									
M, S, C, P, E	M, S, C, P, E	M, S, C, P	C, P	M, S, C, P	M, S, C, P, E	M, S, P, E	M, S, C, P, E	M, S, C, P	C, P

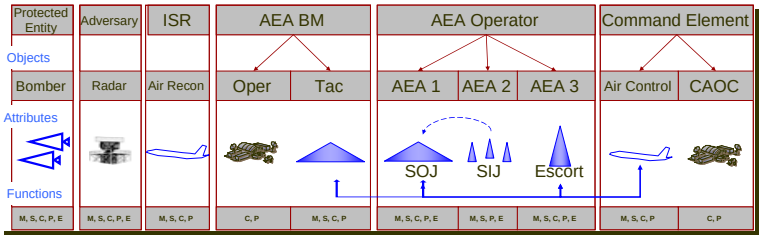
3. Multiple configurations



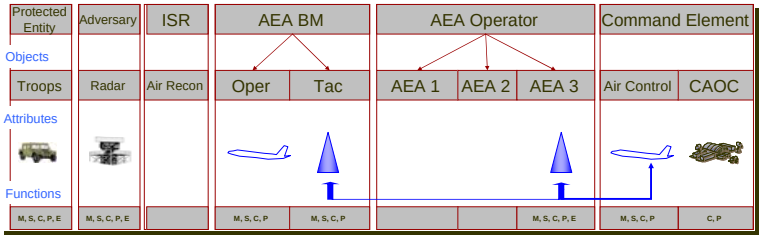
- Each configuration accounts for all swim lanes & functions

- Each configuration has different:
  - Attributes
    - Cognitive / authorities
    - Information / communications
    - Physical / platform types
  - Functions
    - Attribute impacts on performance

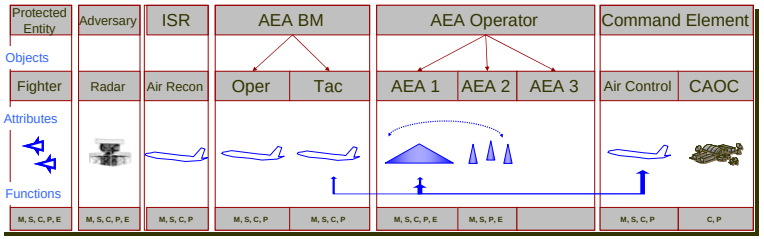
Configuration A



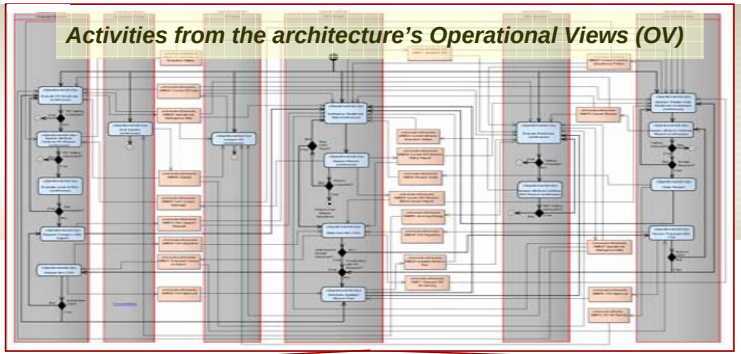
Configuration B



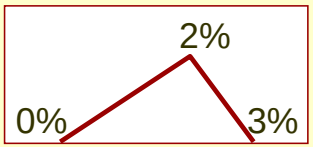
Configuration C



4. Attributes impact on functions



Nominal values shown. Simulations calculations generated from Triangle distributions (Lowest, Nominal, Highest)



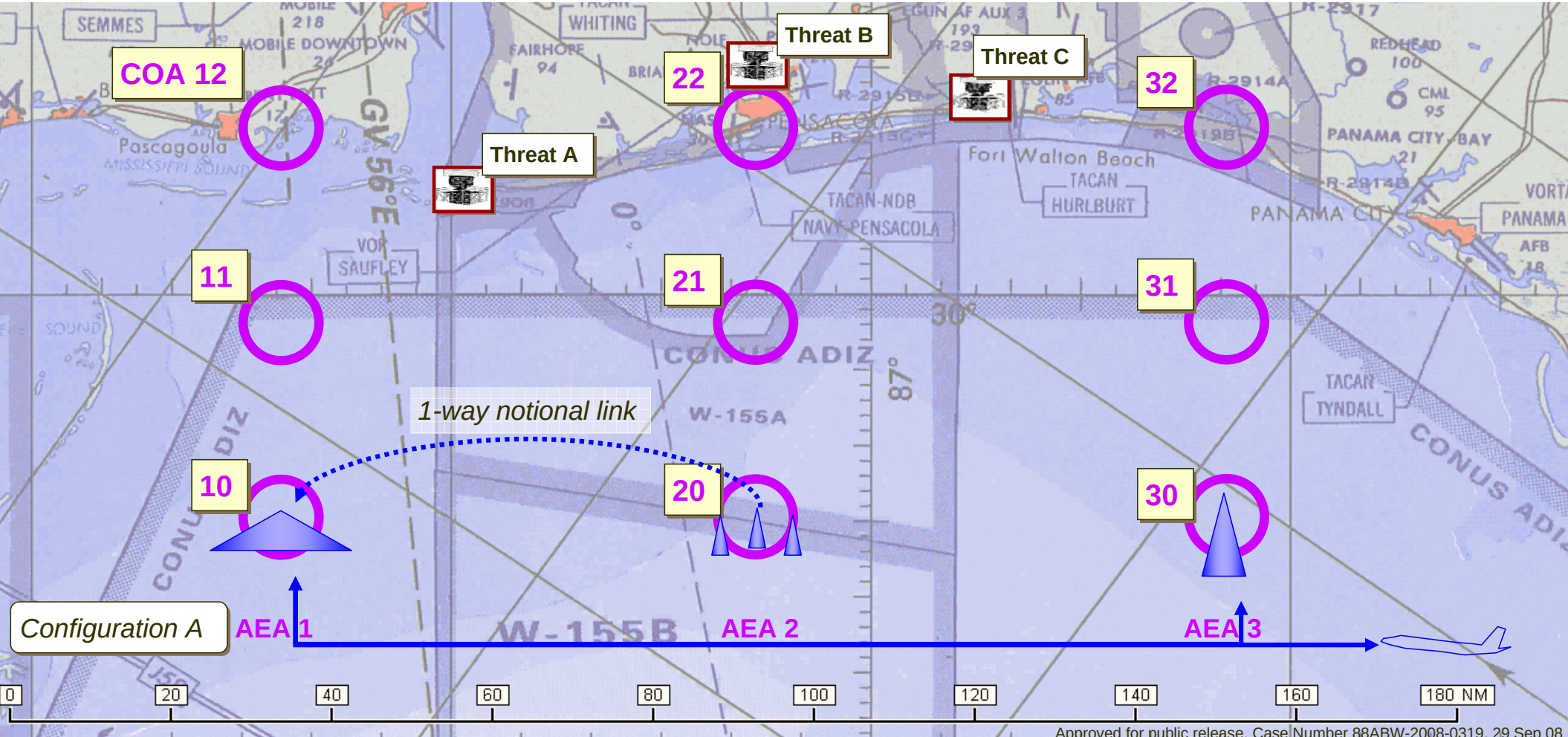
Attributes from configuration factors

	Maneuver	Sense	Communicate		Process		Engage
Cognitive *AEA-PE Support Relationship*	Spatial relationships	Sensor interpretation	Message interpretation		▪ None ▪ Direct ▪ Close ▪ TACON	**Speed** Nominal +2% +5% +5%	Weapon control
Informational *Comms Quality*	Velocity and acceleration data	Sensor data/reports	▪ Degraded ▪ Nominal ▪ Perfect	**Speed** 90 sec 43 sec 0	Algorithms		Weapon data
Physical *Effectiveness*	Platform characteristics	Sensor characteristics	Radio/Data Link characteristics		Computer characteristics		▪ Effectiveness ▪ Effectiveness Error ▪ Jammer Location

Functions from the architecture's System Views (SV)

NOTIONAL Data

Simulation Courses of Action (COA)

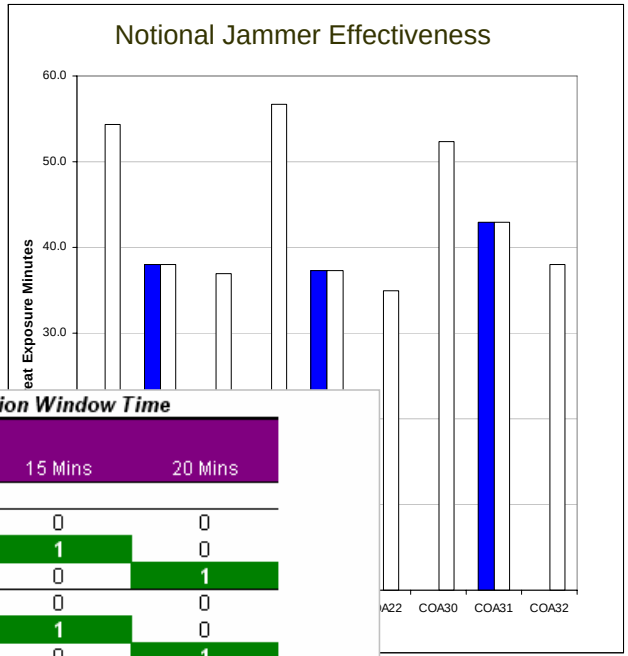


5. Simulate to compare performance from different configurations

- **Course Of Action (COA) Scorer model**
  - **Jammer location**
  - **Expected Jammer Effectiveness**
  - **Time to implement**
- **Monte Carlo Simulation**
  - **Attributes' effect on Battle Manager's Decision Window**

Do longer decision windows make a difference in AEA combat?

For these configurations, faster decisions increased jammer effectiveness by 45% and 53%



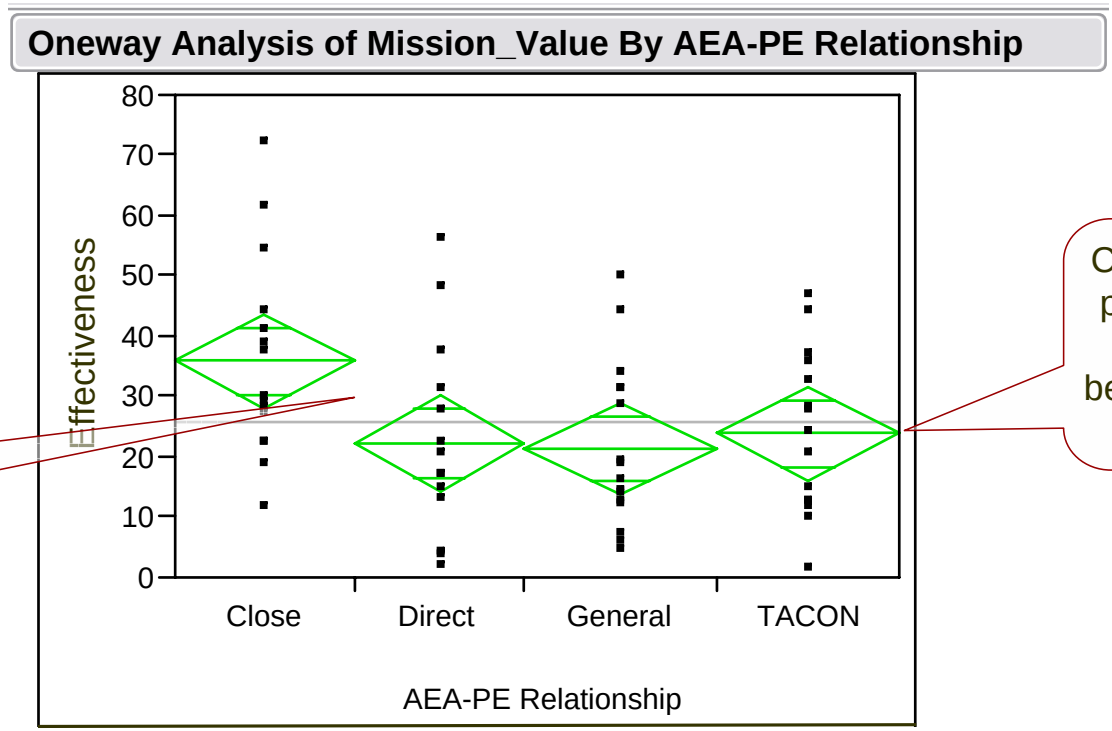
Decision Window Time

Scenario Summary	10 Mins	15 Mins	20 Mins
Changing Cells:			
COA10	1	0	0
COA11	0	1	0
COA12	0	0	1
COA20	1	0	0
COA21	0	1	0
CAO22	0	0	1
COA30	1	0	0
COA31	0	1	0
COA32	0	0	1
Result Cells:			
Jammer effectiveness	163.3	118.3	110.0

Less is better

5. Simulate to compare performance from different configurations

Sample data plots using JMP ANOVA



Statistical different performance between these configuration factors

Can't see any performance differences between these factors

NOTIONAL Data

Adaptable Architecture Summary

- Adaptable Architecture provides a neutral arena to compare performance from multiple alternatives
- AA employs a capability-based approach vs platform-based approach to SoS solutions
- AA enables a comprehensive analysis across different force configurations and dynamic situations

Questions?