Effects of Functional Allocations and Associated Communications on C2ISR Mission Effectiveness

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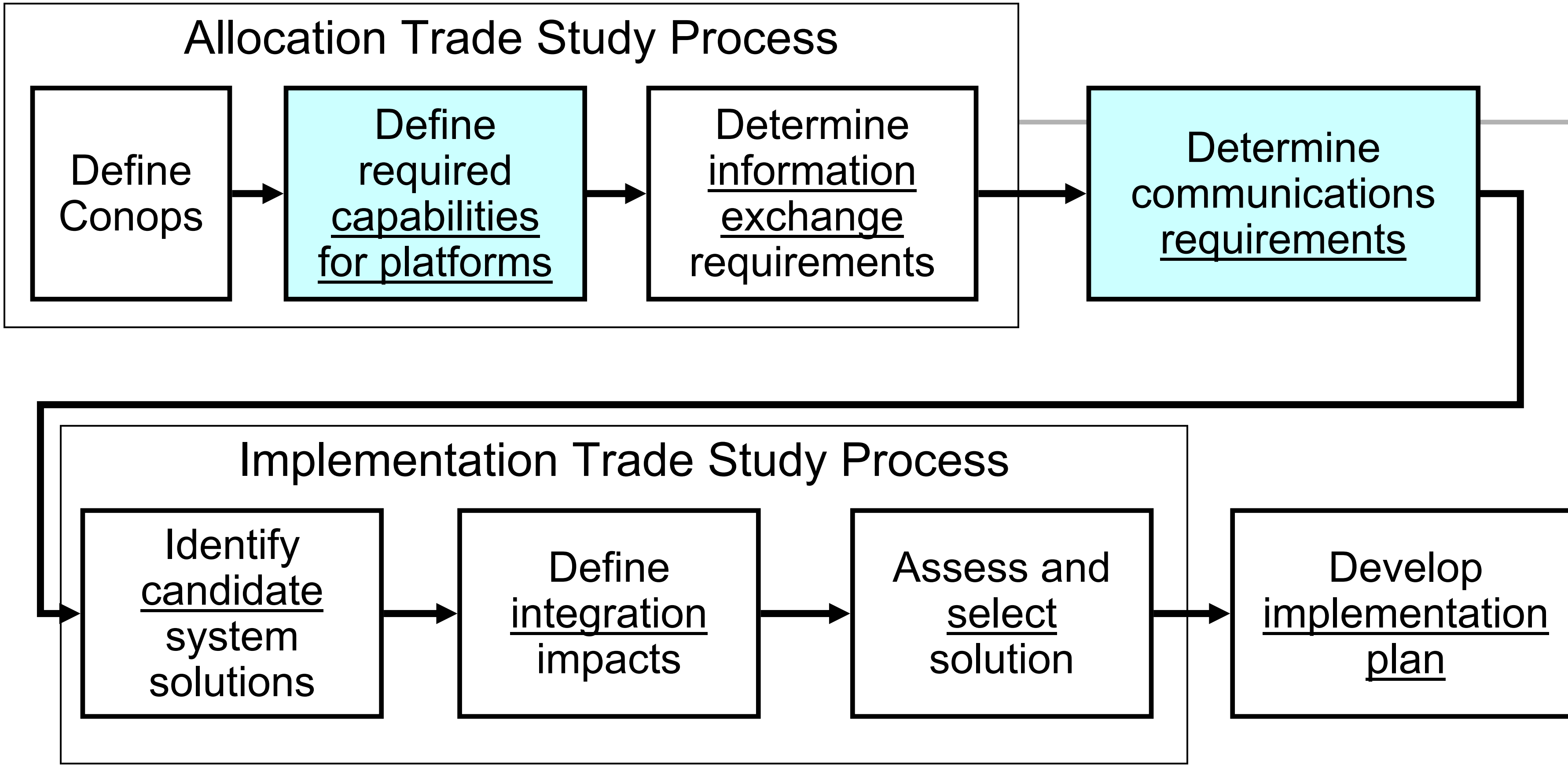
Outline

- The Promise of NCO
- Analysis & Modeling Approach
- Force Measures of Effectiveness
- Architecture and Functional Allocation
- Communications Consistent with Architecture

The Promise of NCO

- An NCO environment with adequate, assured communications provides the potential for architectural flexibility in allocating functionality to platforms
  - If all force elements have sufficient connectivity such that communications is not an issue, what is an optimum architecture for a given mission?
    - What are the Measures of Effectiveness for deciding among competing architectures?
  - What are the communication requirements which enable the achieved force effectiveness?

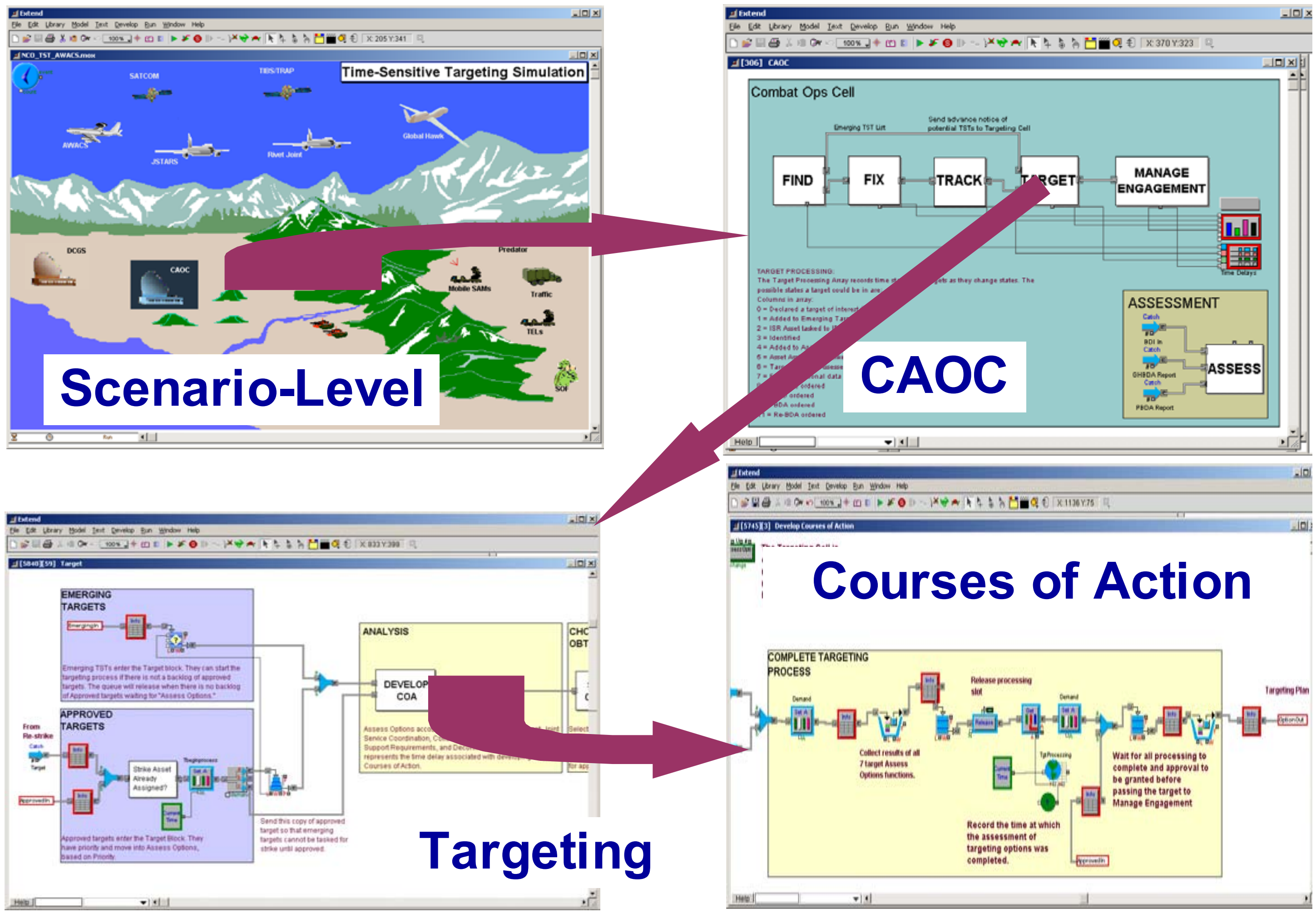
Analysis Process



- Analysis of communications requirements links force-level architecture development with communications implementation
- Force-level architectures which are optimum assuming communications with zero latency, 100% reliability, and infinite bandwidth, may not be optimum when communications implementation is considered

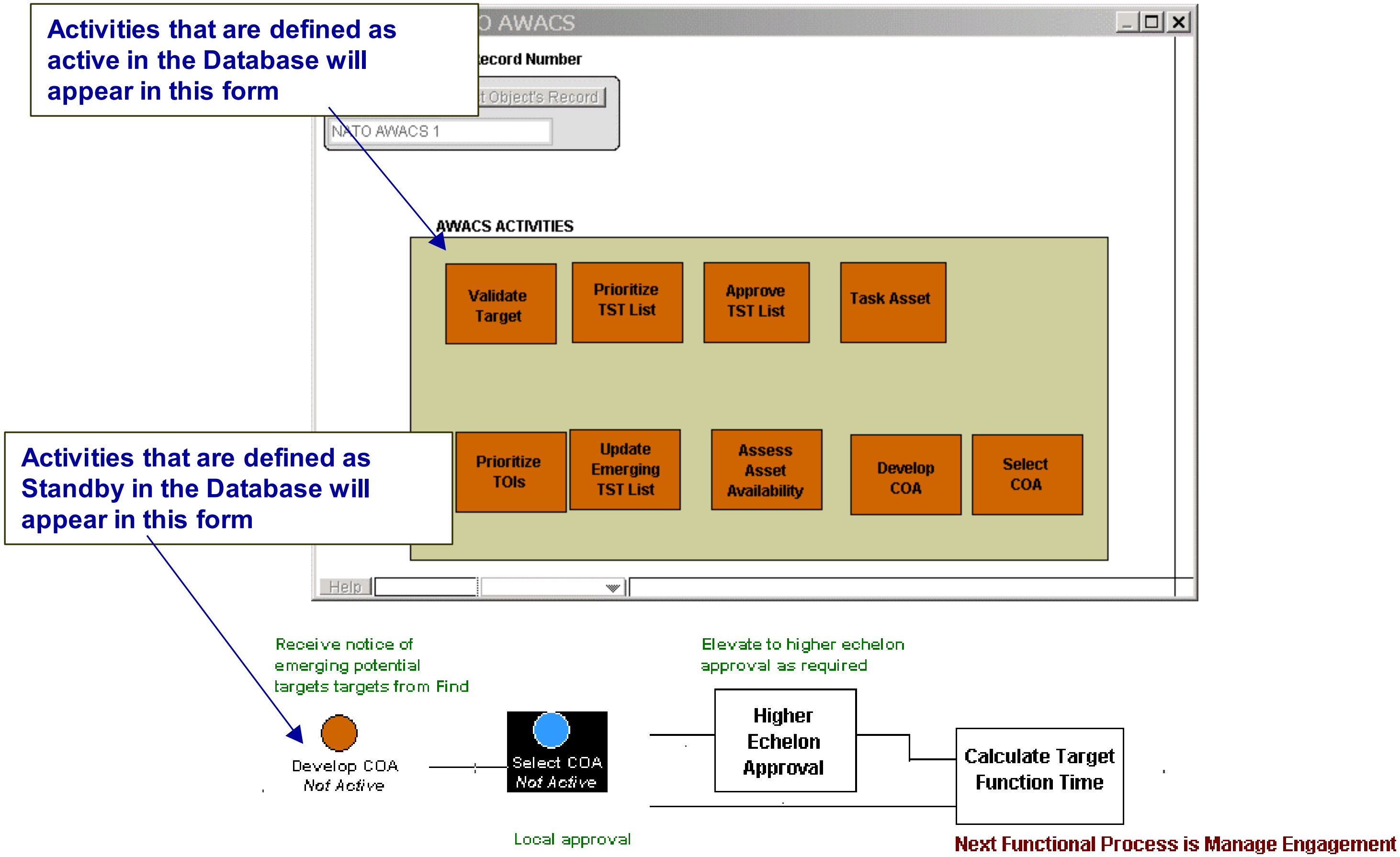
Modeling Approach – 1 of 2

- Extend™ Tool
  - Discrete-event simulation
  - Functional decomposition of operational tasks



Modeling Approach – 2 of 2

- "Truth" of the modeled architecture is captured in the database which drives the simulation
- Relocatable Functions enable quick architecture changes without "rewiring" the models

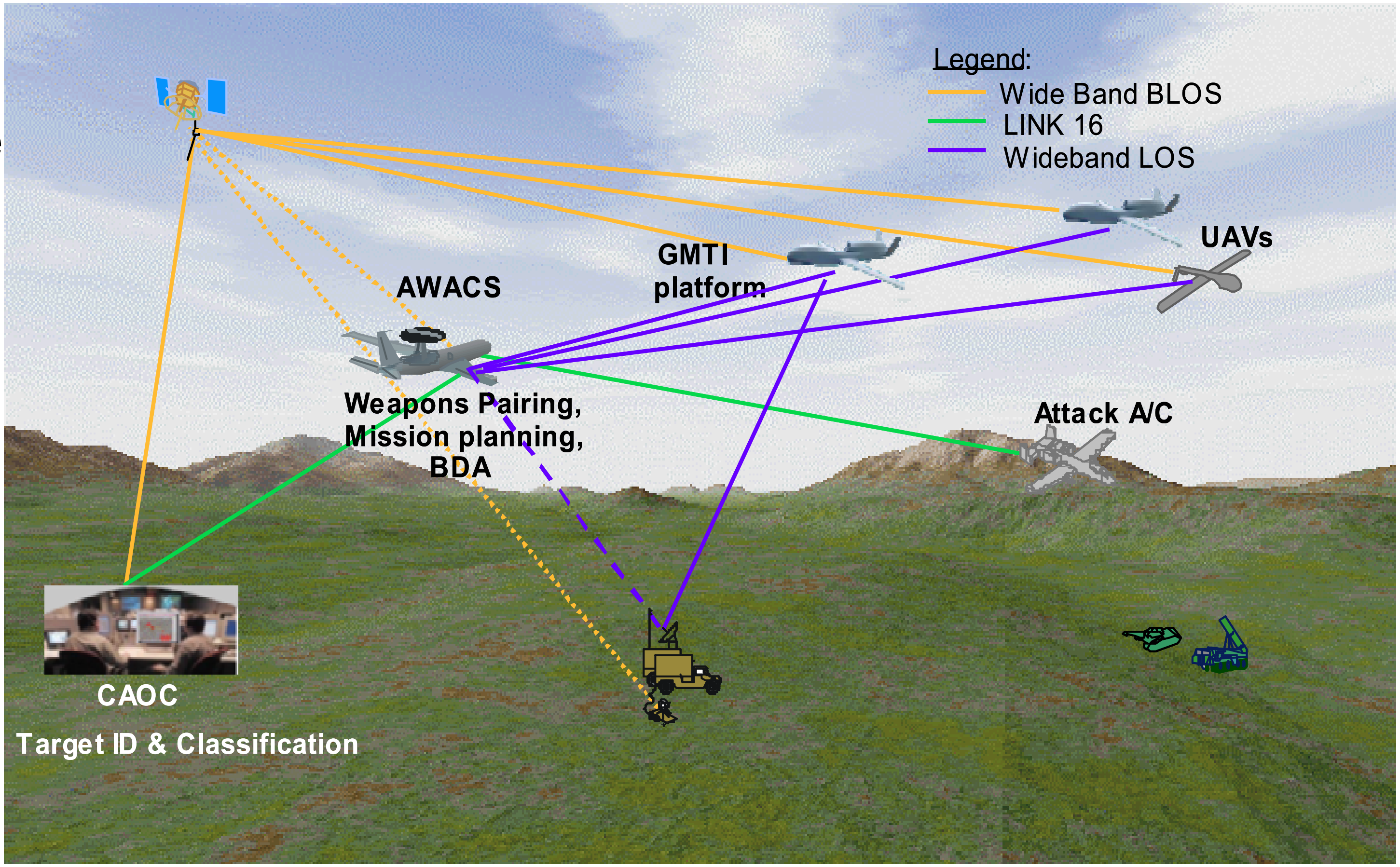


Example Force-Level MOEs

- Time
  - Time-to-detect (ISR)
  - Time-to-kill (Shooter)
  - ➢ Detect-to-Engage (C2)
- Quantity of personnel and platforms required to accomplish the mission at a given P_s
- Associated System Measures of Performance (MOP) include communication latency: how long to get messages between nodes

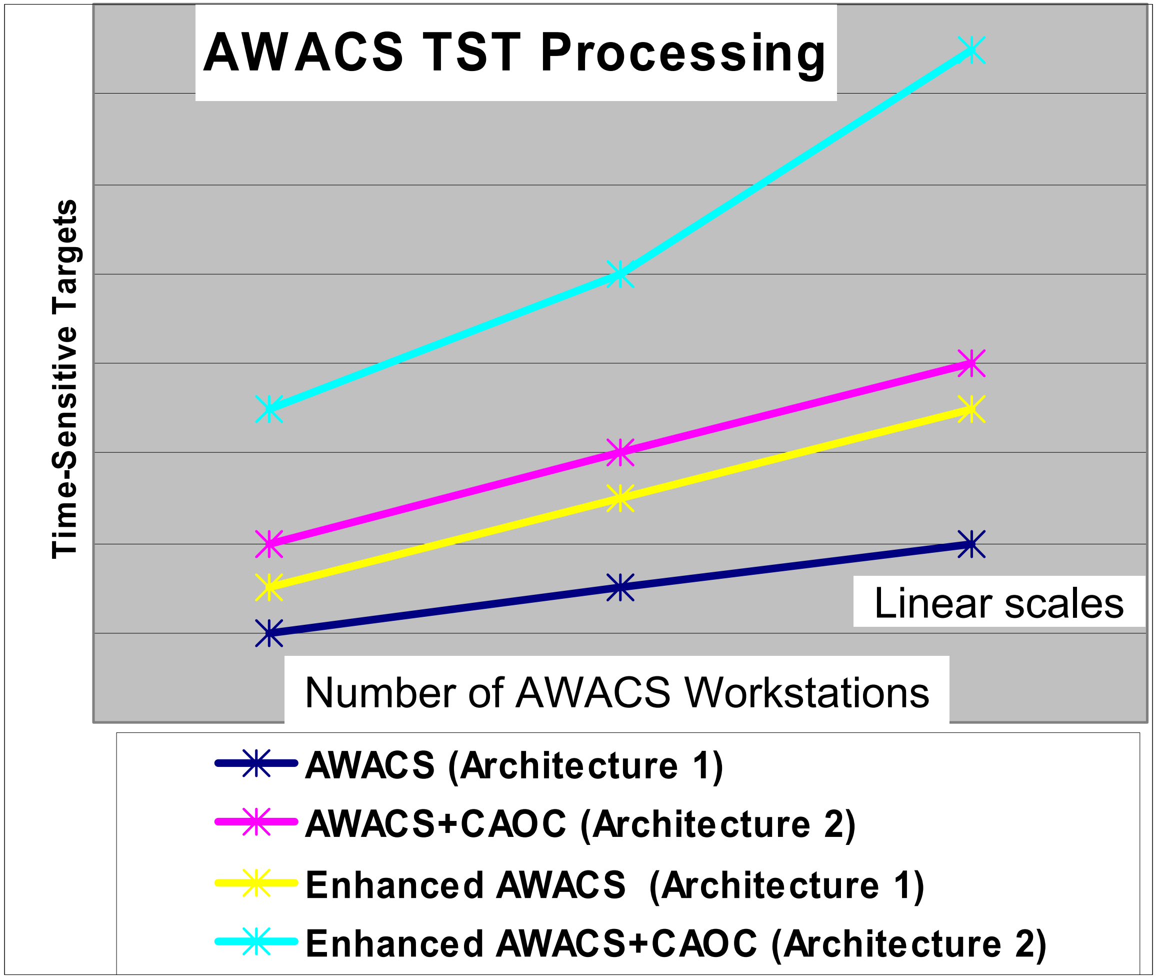
1. Function Reallocation Scenario – Airborne Battle Management of Time-Sensitive Targets

- Two architectures
  - Relocatable functions moved between AWACS and CAOC



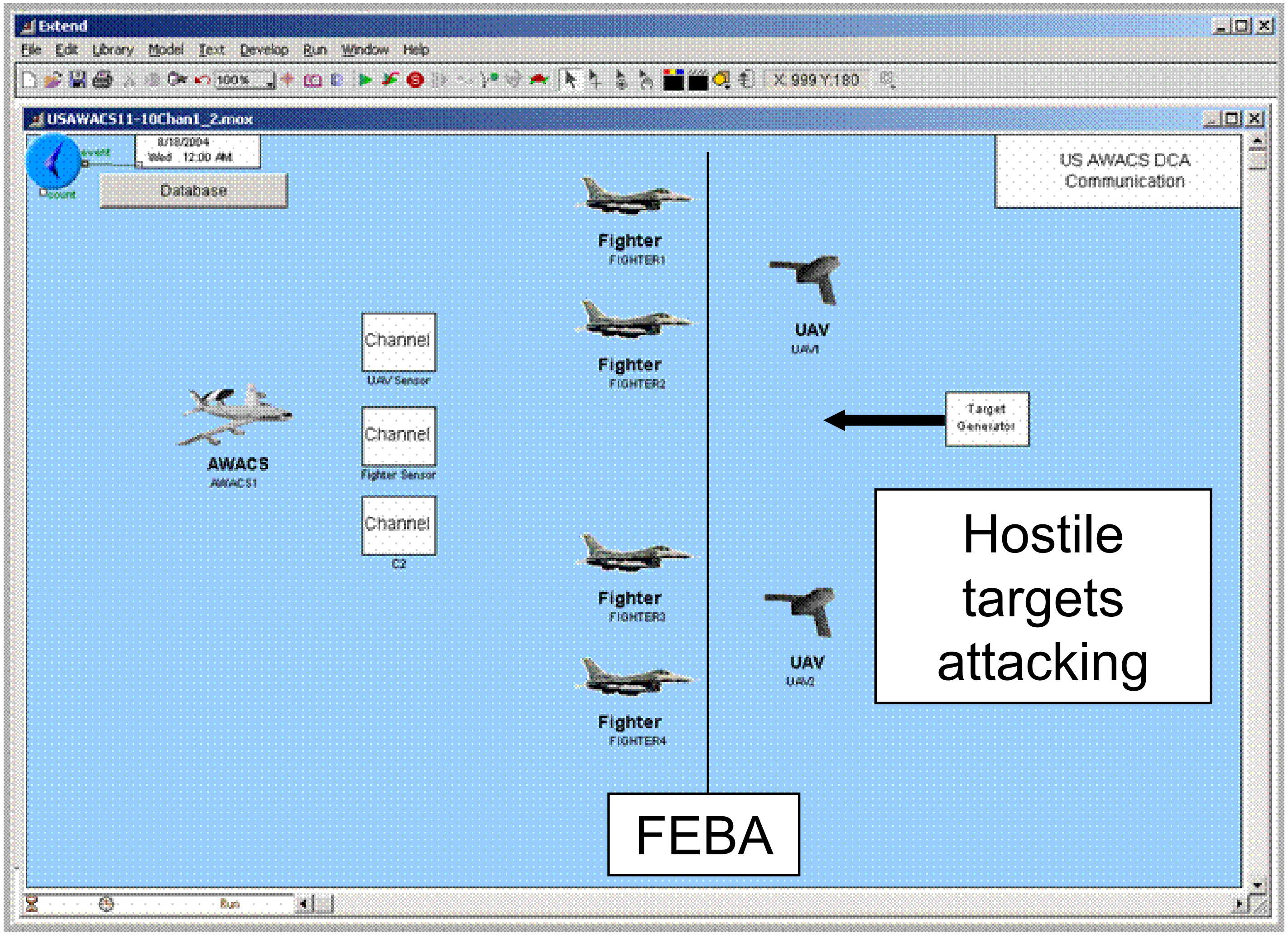
Initial Results for TST Processing

- Standalone AWACS can be effective in prosecuting TSTs
- Enhanced AWACS + CAOC is more effective because of AWACS resource constraints
- In work: communications performance required to support functional allocations
  - No degradation in operational effectiveness (e.g., # TSTs effectively processed) or system performance (detection-engagement latency)



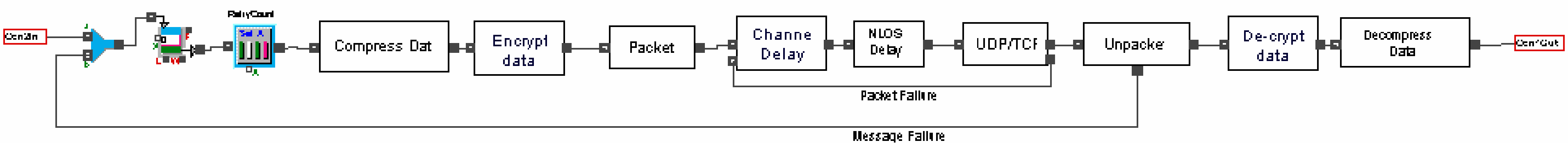
2. Communications Performance Requirements* – Defensive Counter Air Scenario

- Forward deployed, netted aerial-surveillance UAVs and fighters
- AWACS as C2 node for DCA
- Critical MOE
  - Detect-engage time



- *Supported by USAF ESC/AWH

Parametric Communications Models

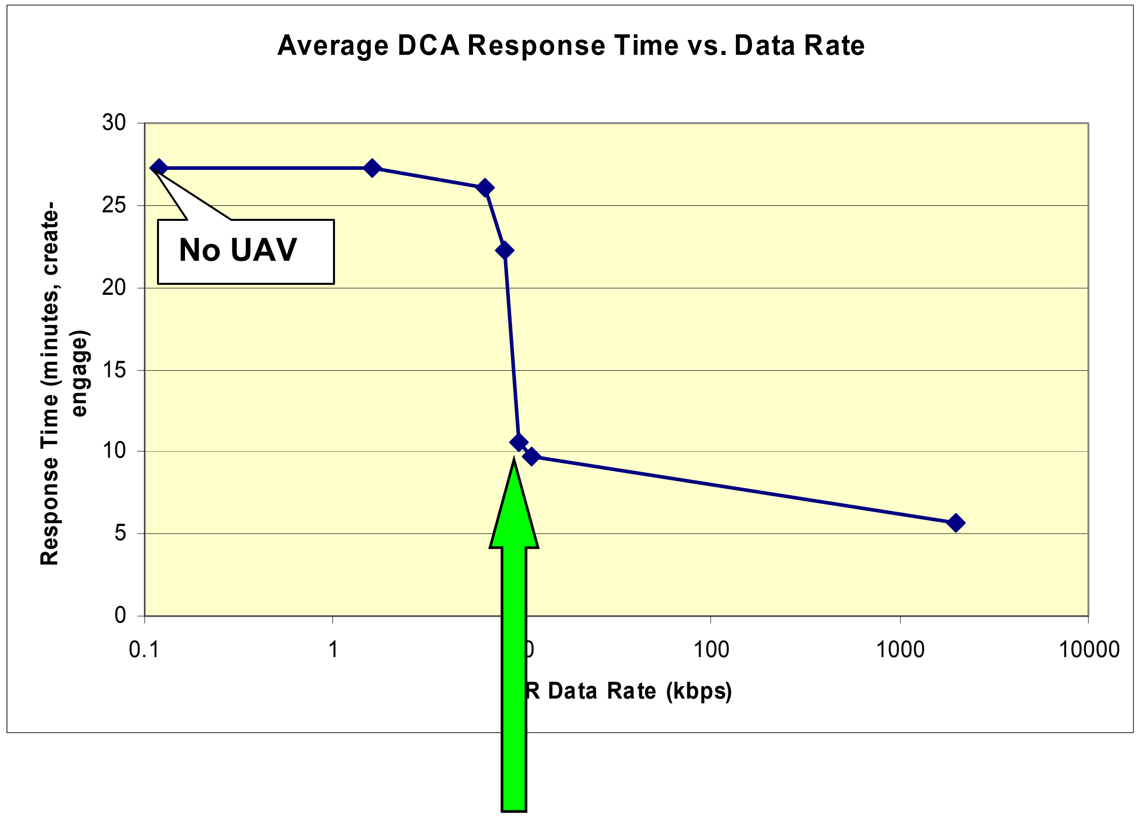


- Functional decomposition of communications processes (including reliability, protocol, encryption, and compression) which affect latency

Parameter	Use/Value
Message priority	Enables prioritization within queues to effectively manage limited communications throughput for highest-priority messages. Excessively “stale” messages can be deleted.
Protocol	Packetized (IP), Transmission Control Protocol (TCP; handshaking with packetized resending), UDP (User Datagram Protocol: broadcast mode, no transport-level resending); Message-oriented (non-packetized; the message is handled as a unit).
Availability	This calculation is based on %Area Coverage * %Time Available. The latter term is the probability of no-failure x (outage time)/(time between outages).
Compression	Compression enables a reduction in the number of bits transmitted at a “cost” of additional channel delay. Factors of 1-200x are possible. Decompression occurs at the receiving end and adds additional delay.
Encryption	Encryption/decryption add channel delay, but no other effects.
Latency	This is a calculation based on the actual time it takes to send a complete message through the channel. Latency = MessageSize/DataRate + CommunicationDistance/SpeedOfLight + EncryptionTime + DecryptionTime + CompressionDecompressionTime + (PacketLoss%*MaxTransmissionUnit/ DataRate). Packet loss can arise from such operational effects as jamming or low link margin at long distrances.
Effective Data Rate	This is a calculated as MessageSize/Latency
Message Reliability	This is calculated as Probability(message delivered within defined timeout).

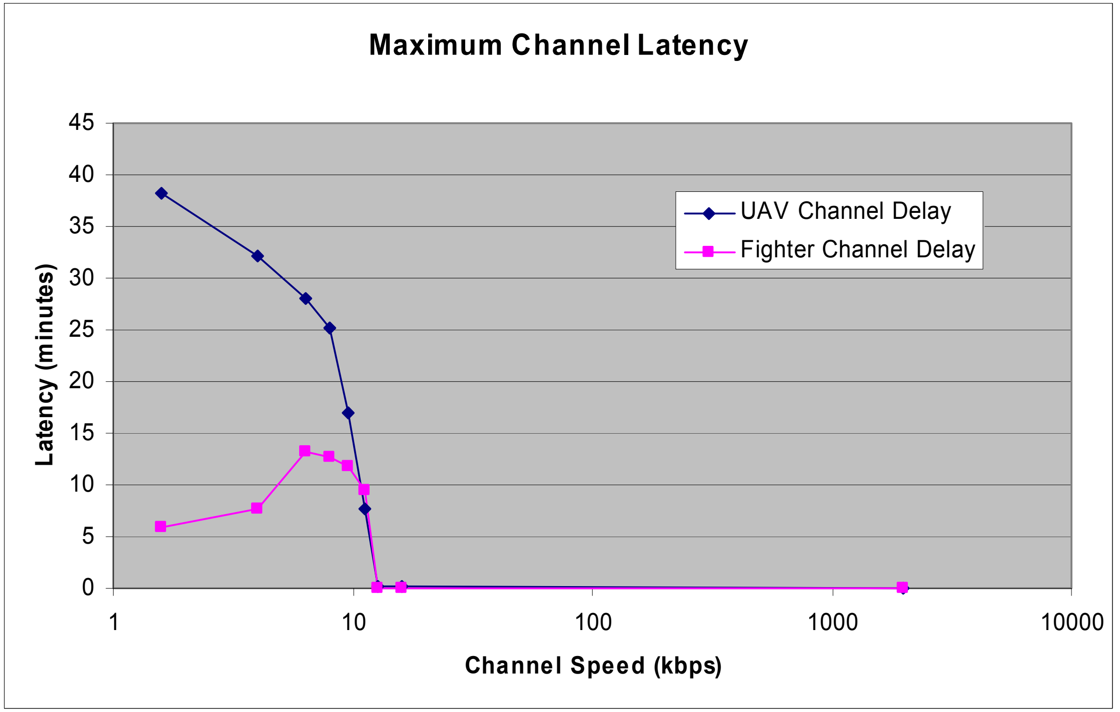
Operational Effectiveness: Engagement Time vs. Data Rate

- At low data rates from UAVs to AWACS the engagement time reduces to the “no UAV” condition
- At high data rates, additional 50% improvements are possible
- There exists a <u>steep</u>, scenario-dependent <u>threshold</u> separating the two end points (26 minutes → 10 minutes)



System Measure of Performance (MOP): Communication Channel Latency

- Operational effectiveness is tied to system performance in communication channel latency
  - Fighter channel delays initially increase with increasing channel speed as more sensor reports are forwarded from UAVs via AWACS



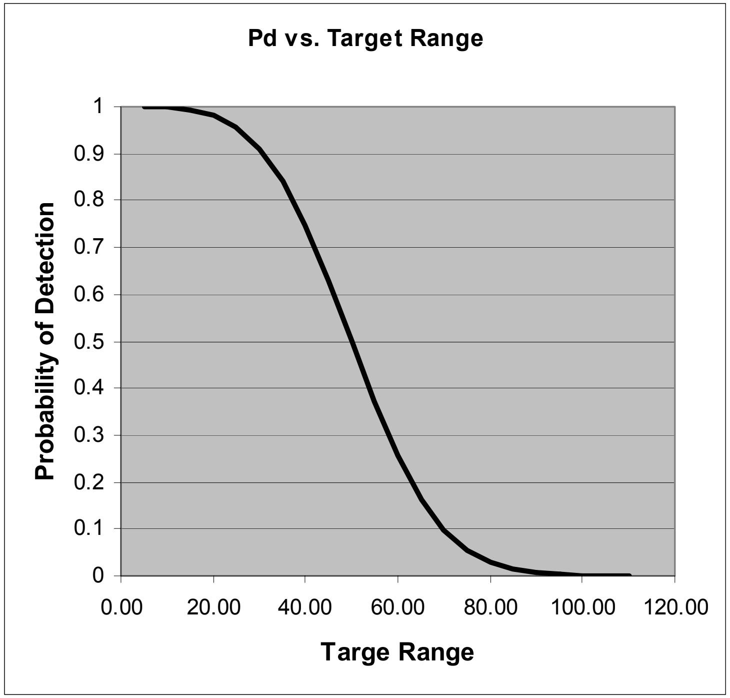
Quality of Service: LIFO vs. FIFO

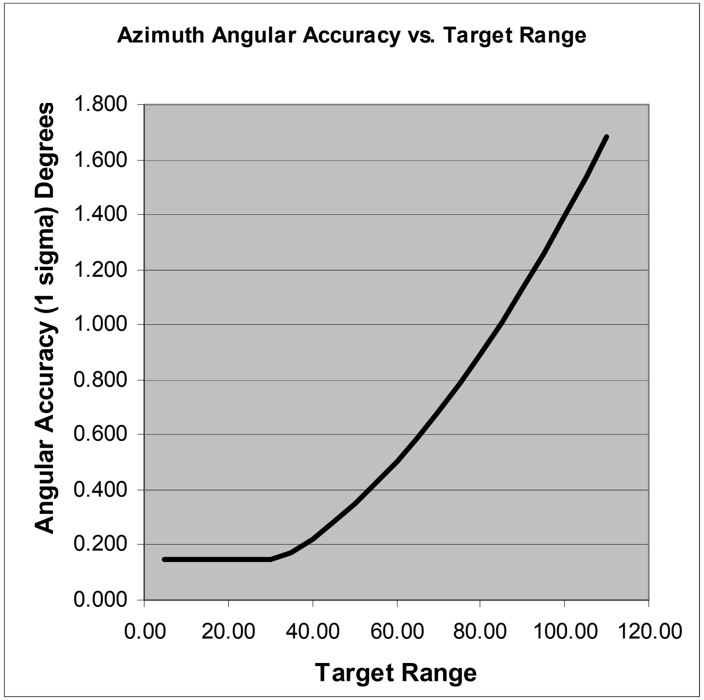
- Dependency on achieving high Track Quality limits allowable latency of sensor reports – they can become “stale”
- FIFO (first-in, first-out) queuing ensures all messages are eventually transmitted
- LIFO (last-in, first-out) queuing improves “freshness” of target attributes by sending latest data
  - Reduces “clogging” of channel by unusable data
  - Some messages might never be transmitted (continuously pushed to bottom of queue)

Summary

- Analysis can generate data to make decisions regarding effectiveness of architectures
  - Different architectures (allocation of functions) have different performance based on assessment of MOEs
  - Results are scenario dependent
- Analysis can drive out requirements for MOPs based on force-level MOEs
  - “More” data rate does not always provide better value when communications requirements are examined

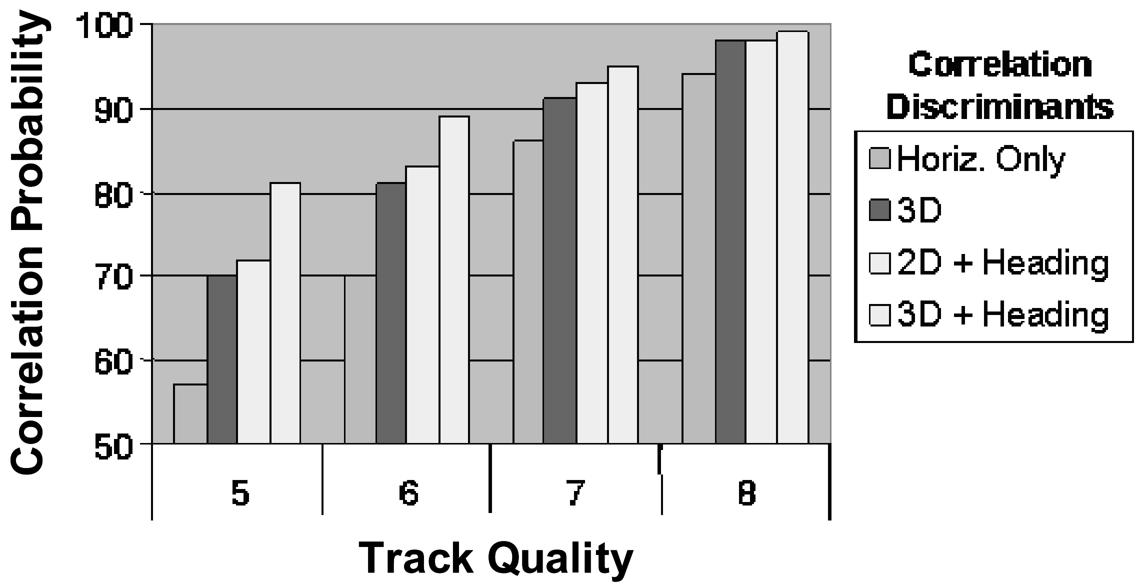
Simple Sensor Models





- Probability of detection and accuracy scale with target range
- Model focus is on C2 and communications

Track Quality Threshold for Engagement



- Fighters can be engaged against target for TQ ≥ 8 using fused sensor reports from UAVs, AWACS, and fighters
- Correct combat identification is assumed