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

Allocation Trade Study Process

- Define Conops
- Define required capabilities for platforms
- Determine information exchange requirements

Implementation Trade Study Process

- Identify candidate system solutions
- Define integration impacts
- Assess and select solution

- Develop implementation plan

- 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

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**Scenario-Level**

**CAOC**

**Courses of Action**

**Targeting**
Activities that are defined as active in the Database will appear in this form.

Activities that are defined as Standby in the Database will appear in this form.

"Truth" of the modeled architecture is captured in the database which drives the simulation.

Relocatable Functions enable quick architecture changes without "rewiring" the models.

Next Functional Process is Manage Engagement.
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

Legend:
- Wide Band BLOS
- LINK 16
- Wideband LOS
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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Use/Value</th>
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<tbody>
<tr>
<td>Message priority</td>
<td>Enables prioritization within queues to effectively manage limited communications throughput for highest-priority messages. Excessively “stale” messages can be deleted.</td>
</tr>
<tr>
<td>Protocol</td>
<td>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).</td>
</tr>
<tr>
<td>Availability</td>
<td>This calculation is based on %Area Coverage * %Time Available. The latter term is the probability of no-failure x (outage time)/(time between outages).</td>
</tr>
<tr>
<td>Compression</td>
<td>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.</td>
</tr>
<tr>
<td>Encryption</td>
<td>Encryption/decryption add channel delay, but no other effects.</td>
</tr>
<tr>
<td>Latency</td>
<td>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 distances.</td>
</tr>
<tr>
<td>Effective Data Rate</td>
<td>This is a calculated as  MessageSize/Latency</td>
</tr>
<tr>
<td>Message Reliability</td>
<td>This is calculated as Probability(message delivered within defined timeout).</td>
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</tbody>
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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 steep, scenario-dependent threshold 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 $TQ \geq 8$ using fused sensor reports from UAVs, AWACS, and fighters.
- Correct combat identification is assumed.