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Architectural Operations Analysis based Operations Analysis - An Extension of Classical Operations Analysis

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Architecture-based Operations Analysis
An Extension of Classical Operations Analysis
Dickerson, Brady, Canterbury, Cordell, Fortunato, Peppers, et al

C.E. Dickerson, Technical Fellow

Presented to the 73rd MORS Symposium
21 – 23 June 2005

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Purpose

• Establish key concepts

• Introduce a proposed definition

• Give one simple quantitative example
  – Based on GIG Block 4 Scenario, NCOW Reference Model and UJTL
  – Suitable for tools like Telelogic System Architect, OPNET, EADSIM
  – Illustrating the key concepts and proposed definition

The need for an architecture-based approach to operations analysis has arisen from architecture-based systems engineering, which seeks to engineer systems at the system of systems and family of systems level*.

*Using Architectures for Research, Development, and Acquisition by Dickerson, Soules, Sabins, and Charles
Available via DTIC: (www.dtic.mil) AD Number ADA427961
Definition of Terms

• Architecture is*
  the structure of components, their relationships, and the principles and guidelines
governing their design and evolution over time.

• Integrated Architecture
  has products whose constituent architecture data elements are such that the
architecture data elements defined in one view are the same (i.e. the same names,
definitions, and values) as the architecture data elements referenced in another.

• Operations Analysis is**
  “the application of scientific principles and quantitative methods in the analysis of
complex real-world systems; to include the study of military problems undertaken to
provide responsible commanders and staff agencies with a sound scientific basis for
decision on actions to improve military operations”

• A capability***
  is the ability to execute a specified course of action [sequence of activities].

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*IEEE STD 610.12. In this briefing, the DoDAF 1.0 will be used as the DoD standard for architectures.
**Composite definition JP 1-02 and assorted government sources
***JP 1-02, DoD Dictionary of Terms
Relation of Architecture to Operations

**Architectural Model of an Operational Capability**

- The DoDAF OV-6c gives an architectural model of capability
  - Integration of OV-6c with OV-2 highlights interoperability
    - Dependencies of capabilities on interoperability become traceable
- Operational nodes (OV-2) aggregate operational activities.
- Systems nodes (SV-1) aggregate systems functionality.
- The OV-6c supports concordance between M&S of capabilities and the assessment of interoperability.

Interoperability exists at the nodal level and enables operational capabilities.
Operational Concept in an Integrated Architecture

Fleet Battle Experiment – India (FBE-I)

• Enterprise level Operational Concept for the mission should
  – Integrate OV-4 and OV-5 in context
  – Highlight details of special interest

• Scenario events can be related to operational activities.

• This allows the OV-1 to be regarded as part of the data repository for the Integrated Architecture.

DoDAF Nomenclature
  OV-1: High Level Operational Concept Graphic
  OV-4: Organizational Relationships Chart
  OV-5: Operational Activity Model

Frederick P. Brooks, The Mythical Man-Month, 1974 and 1995:
“… the critical need [is] the preservation of the conceptual integrity of the product.”
Realizing Operational Capabilities

An integrated architecture using a capability model as the reference model can provide the basis for operations analysis.
**Architecture-based Operations Analysis**

*Proposed Definition*

*Architecture-based operations analysis* relates to an analysis of operations that can be used to demonstrate changes in operational capabilities that are attributable to changes in the integrated architecture, e.g. changes in:

- Structure
- Relations
- Rules
- Governance

Examples include: the creation or elimination of nodes, the interoperability between nodes, changes in technical standards, changes in C2, etc.

*Architecture-based operations analysis* should support the systems engineering of a Family of Systems (FoS)* to achieve specified capabilities through the individual operation and collective interoperation of the systems in the FoS.

*Using Architectures for Research, Development, and Acquisition, C.E. Dickerson, et al*
West-Central Sudan Scenario
Fleeting and Deceptive Target

- Theater assets tasked to locate WMD targets suspected to be operating in west-central Sudan
- Expeditionary Strike Group, JSOTF embarked in Red Sea
- Surveillance assets tasked with wide area observation
  Sensor Capability: Global Hawk, Predator, MIUGS
- Objective: hold a fleeting and deceptive WMD target at risk
West-Central Sudan Order of Battle

Red OOB
Threat Vehicles

- Two Scud TELs
- One SA-6 SAM
- Three supply trucks
- Two ZSU-23-4 Anti-Aircraft systems
- Three civilian trucks
- Two military support vehicles

Blue OOB
Theater Sensors

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Altitude (km)</th>
<th>Sensor Range (km)</th>
<th>Probability of Detection</th>
<th>Range Accuracy (m)</th>
<th>Azimuth Accuracy</th>
<th>Speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIUGS</td>
<td>0</td>
<td>3</td>
<td>1.0</td>
<td>100</td>
<td>100m</td>
<td>Emplaced</td>
</tr>
<tr>
<td>Predator B</td>
<td>13</td>
<td>5</td>
<td>1.0 with zoomed FOV</td>
<td>10</td>
<td>3 mrad</td>
<td>Enroute 60</td>
</tr>
<tr>
<td>Global Hawk*</td>
<td>20</td>
<td>100*</td>
<td>0.9 @ 100km</td>
<td>10</td>
<td></td>
<td>Loiter 35</td>
</tr>
</tbody>
</table>

* MTI only
Key Performance Parameter: Track Time (Location with ID)

Primary KPP: Time in Continuous Track
- Maximum track length (i.e. continuous) > 30 minutes
- Classification ID Confidence > 0.9

Secondary KPP: Total Time in Track (i.e. with interruptions)
- Requirement depends on weapons, scenario events, ...
Operational Concept (ref: GIG Block 4 SWA)
Fleeting and Deceptive Target

Joint Special Operations Area

Sudan

National Assets (Reach Back)

JSOTF

SOF AV-8B Strike

• Vehicles detected by MIUGS [Cue]
• Vehicles acquired by MTI sensor [Find]
• EO Sensor re-tasked to establish ID [Fix]
• Target location updated/ID maintained [Track]

The architectural change analyzed will be the creation of a new node for sensor fusion.
Sensor Fusion Node Description

External View of the Node (Relation to the C3ISR Architecture)

Reach Back

Global Hawk (MTI)

Predator (Video)

LHA/LHD

SACC

JIC

Fusion Node

Ground Station B

Fusion Node

Data

Task

CDL

LOS Line of Sight

CDL Common Data Link

Ground Station A

Theater SATCOM

Fusion Node

Theater SATCOM/LOS

MIUGS

(Acoustic, Seismic)

21-23 June 05
C3ISR Architecture Supports Sensor Fusion

*Increased Track throughput peaks at only 20-30% of one channel*

MIUGS-Global Hawk-Predator (736bps peak)

**OPNET modeling provides communications loading estimates and preliminary validation of interoperability**

* UHF SATCOM was the lowest throughput node in the C3ISR architecture (providing 16-20 2.4 kbps channels).
Sensor Fusion Node Description
Internal View of the Node

BAE-AIT Fusion Performance Model Predicts Fusion Node Performance
Global Hawk, MIUGS & Predator Scenario

SE&I Center of Excellence
500m, $P_d = 1.0$

3000m, $P_d = 0.65$

MIUGS Acoustic/Seismic detection ranges

Emplaced MIUGS field

TEL Hide Site
TEL Engine

Start

MIUGS Detection

Range

MIUGS Detection
Elapsed Time: 11 sec
MIUGS Initial Detection Report
Elapsed Time: 21 sec
MIUGS Fix TEL Positions and Report
Elapsed Time: 59.2 sec

Mission Time (min)
60/0
45
30
15

SE&I Center of Excellence

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MIUGS Detection Range

TEL Engine Start
TELs Emerge from Hide

Time (min)

Mission Time

60/0

15

30

45

TELs Emerge after Engine Start

Elapsed Time: 225 sec

Periodic MIUGS updates (30 sec intervals)

Initial Global Hawk Detection of TELs

Elapsed Time: 300.8 sec

TELs in GH & MIUGS track

Elapsed Time: 353 sec

TELs in GH & MIUGS track

Elapsed Time: 481 sec

TELs in GH & MIUGS track

Elapsed Time: 609 sec

TELs in GH & MIUGS track

Elapsed Time: 737 sec

TELs out of MIUGS Detection Range

Elapsed Time: 966 sec

Predator tasked to collect TEL data

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Mission Time (min)

Elapsed Time: 1094 sec

TELs in Global Hawk Track

Elapsed Time: 1334 sec

Global Hawk MTI loses track

Predator B

BAE SYSTEMS
Predator locates TELs and reports.
Predator Video
Elapsed Time: 1380 sec

Predator orbit commanded from Ship
Global Hawk re-establishes track
TELs move to launch site
Elapsed Time: 1980 sec

Mission Time (min)

60/0

45
30
15

Predator Video
Global Hawk and Predator maintain track
Elapsed Time: 2440 sec
TELs at launch site
Elapsed Time: 2900 sec

Mission Time (min)
60/0
45
30
15

Predator Video
Mission Time (min) 60/0 45 30 15

TELs depart launch site
Elapsed Time: 3120 sec

Predator Video
TELs arrive at hide site
Elapsed Time:  3353.9 sec
Predator and Global Hawk tracking ceases
### Measures of Performance*

* Statistical average of two TELs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MIUGS Only</th>
<th>Global Hawk Only</th>
<th>MIUGS &amp; Global Hawk</th>
<th>Global Hawk &amp; Predator</th>
<th>MIUGS, Global Hawk &amp; Predator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to Find (min)</td>
<td>0.7</td>
<td>5.3</td>
<td>0.5</td>
<td>5.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Time to Fix (min)</td>
<td>1.0</td>
<td>5.6</td>
<td>0.8</td>
<td>5.7</td>
<td>0.9</td>
</tr>
<tr>
<td>Total Time in Track (min)</td>
<td>15.9</td>
<td>35.1</td>
<td>42.2</td>
<td>44.3</td>
<td>50.2</td>
</tr>
<tr>
<td>Maximum Track length</td>
<td>9.2</td>
<td>9.2</td>
<td>9.4</td>
<td>16.5</td>
<td>15.5</td>
</tr>
<tr>
<td>Track Length following ID</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>16.5</td>
<td>15.3</td>
</tr>
<tr>
<td>Time of first ID Declaration</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>22.7</td>
<td>20.4</td>
</tr>
<tr>
<td>ID Confidence</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.99</td>
<td>0.96</td>
</tr>
<tr>
<td>Tracking Accuracy (m)</td>
<td>56.0</td>
<td>8.3</td>
<td>8.3</td>
<td>6.4</td>
<td>6.4</td>
</tr>
</tbody>
</table>

**Key Performance Parameters (KPPs):**

- Primary: Maximum Track Length, Classification ID Confidence
- Secondary: Total Time in Track

21-23 June 05
Conclusions

- For the sensors and GIG scenario analyzed,
  - Fusion allowed the sensor architecture to support the operational objective for the secondary KPP (i.e. to hold a fleeting and deceptive target at risk with interrupted track)
  - The operational objective was not met for the primary KPP
  - Aggregation of the minimal functionality needed was achieved by creating a new systems node for sensor fusion
  - The new node was supportable within the existing C3ISR architecture
- An Integrated Architecture can provide the basis
  - For the analysis of operations and capabilities
  - To attribute changes in operational capabilities that are caused by changes in the architecture
Architecture-based Operations Analysis

You have now seen the tip of the iceberg …

In a new area of operations analysis!
Find, Fix and Track (F2T) Phase Duration for High Value Targets

Sensor Complement
21-23 June 05
UHF SATCOM link usage (16-20 2.4kbps channels)

- MIUGS Only (376bps peak)
- Global Hawk Only (456bps peak)
- Predator-GH (640bps peak)
- MIUGS-GH (736bps peak)
- MIUGS-GH-Predator (736bps peak)
Fusion Related Definitions

• Open-Loop
  – Open loop tasking involves a sensor constellation performing its collection plan as predetermined during the planning phase of the mission.

• Closed-Loop
  – Closed loop tasking involves changing a sensor constellation’s collection plan in near real time to focus collection assets on objects of interest as they are discovered by the constellation.
Fusion Related Acronyms

- BAE-AIT
  - BAE Advanced Information Technologies, Burlington, MA, USA
- ATIF
  - BAE AIT All-source Track and ID Fuser
- FPM
  - BAE AIT Fusion Performance Model
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