Architecture-Based Concept Evaluation in Support of JCIDS

Dave Jacques, Ph.D.
John Colombi, Ph.D.

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Architecture Based Concept Evaluation

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Major Adrian Schuettke, Major Mark Slocum
Architecture versus M&S?


Concordance?
Bridge the Gap
Architecture and M&S

Ops Concept ➔ System Architecture (DODAF) ➔ Simulation / Evaluation

System

Concordance Requirement
Demonstrate an improved process of using architectures to evaluate/refine a proposed system concept

Application:
Weapon Borne Battle Damage Assessment (WBBDA)
System Concept (2015-2025 time frame)

- Develop DODAF system architectures (both “as-is” and “to-be”)
  - Key Products: OV-1, OV-2 (nodes), OV-5 (activities), OV-6a (rules), OV-6b (state transition diagram, or discrete event sim), OV-7 (data)
- Develop evaluation models directly from the system architectures
- Analyze results to identify key design parameters that can translate to system requirements and Key Performance Parameters in the JCIDS
Methodology

- Develop Architecture **based on joint ops concept**
  - DoDAF architecture views
  - Compare AS-IS and TO-BE architectures

- Develop and use simulations **based on architecture**
  - Analytical Model – Excel, with Decision Analysis add-in
  - Discrete Event Simulation– Rockwell Arena

- Evaluate the system concept based on the results
Current BDA Ops Concept
OV-1
The BDA Cycle

- Means of Attack
  - Tasking (C2 BDA Utilization)
  - Attack Effects (Targets)

- C2 BDA Utilization
- BDA Assessment
- Attack Assessment and Recommendation

- Targets
  - Sensed Effects
- BDA Collection
  - Packaged Effects Data
So what is WBBDA?

“To-Be” OV-1
The WBBDA enabled BDA Cycle

- **Means of Attack**
  - Tasking
  - C2 BDA Utilization
  - BDA Assessment
  - Attack Assessment and Recommendation

- **Targets**
  - Attack Effects
  - Sensed Effects

- **BDA Collection**
  - Packaged Effects Data
  - WBBDA Automated BDA Results

- **WBBDA Collection and Assessment**
  - WBBDA Automated BDA Results
At ESD Level…

Major Combat Operations

…and System Level

Perform BDA
## MOEs Established in ICD

<table>
<thead>
<tr>
<th>Measure of Effectiveness</th>
<th>Numerator</th>
<th>Denominator</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. AOR Coverage (AORC) – % of targets that receive BDA results</strong></td>
<td># targets BDA is collected on</td>
<td># of targets attacked per package</td>
</tr>
<tr>
<td><strong>2. Total Time-Obscured Target (TT-OT)–Looks at total time from the completion of the attack strike (on obscured targets) to the point when all BDA assessment and dissemination is complete.</strong></td>
<td>time</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>3. Total Time– Subsurface Targets (TT-ST) Looks at total time from the completion of the attack strike (on subsurface targets) to the point when all BDA assessment and dissemination is complete.</strong></td>
<td>time</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>4. Package Effectiveness (PE)</strong></td>
<td># targets killed</td>
<td># of packages</td>
</tr>
<tr>
<td><strong>5. Package Planning Effectiveness (PPE)</strong></td>
<td># targets attacked</td>
<td># of packages</td>
</tr>
<tr>
<td><strong>6. Attack Effectiveness (AE)</strong></td>
<td># targets killed</td>
<td># targets attacked</td>
</tr>
<tr>
<td><strong>7. Weapons per Target Kill (WPTK)</strong></td>
<td>total # of weapons dropped</td>
<td># targets killed</td>
</tr>
</tbody>
</table>
Initial system views did not capture MOE’s

Built additional views at higher level of abstraction for visibility (ESD)

Established Traceability

MOEs measured at Perform C2 Activity

MOPs measured at Perform BDA

WBBDA Automated BDA Results
Purpose: Construct analytical model based on architecture to evaluate the WBBDA system concept

Model outputs values for the following MOEs:

- Package Planning Effectiveness (PPE) = # of targets attacked
- Package Effectiveness PE = # of targets destroyed
- Attack Effectiveness AE = # targets destroyed / # targets attacked
- WPTK = # weapons used per target destroyed
**P**_k – probability of kill (hit) based on all non-WBBDA factors (weapon performance, delivery system performance, etc.)

**Accuracy** – probability WBBDA correctly determines a hit / miss

**Reliability** – probability WBBDA correctly transmits and displays a hit / miss
**Single Package Model**

**Scenarios**

- **AS-IS**
  - 2 bombs / target, simultaneous
  - A/C RTB w/ 0 bombs

- **TO-BE: WBBDA**
  - 1 bomb / target, repeat until WBBDA “hit”
  - A/C RTB w/ remaining bombs
  - Same # of targets, less bombs

- **TO-BE: WBBDA + Doctrine (W+D)**
  - DOT_LPF doctrine change (WBBDA + drop remaining bombs on additional/secondary tgts)
  - A/C RTB w/ no bombs
  - More targets, same # of bombs
Drop 100 bombs on 100 targets
Assume: $P_k = 0.80$, Reliability = 0.95, Accuracy = 0.90
WBBDA Reliability

- WBBDA results on 76 hits
- No WBBDA results on 4 hits
- WBBDA results on 19 misses
- No WBBDA results on 1 miss

WBBDA Accuracy

- Correctly assess 68 hits as hits
- Incorrectly assess 8 hits as misses
- Correctly assess 17 misses as misses
- Incorrectly assess 2 misses as hits

WBBDA Results (Accuracy)

<table>
<thead>
<tr>
<th>State of Nature</th>
<th>Hit Tgt</th>
<th>Miss Tgt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assess Hit</td>
<td>68</td>
<td>2</td>
</tr>
<tr>
<td>Assess Miss</td>
<td>8</td>
<td>17</td>
</tr>
</tbody>
</table>

Lack of WBBDA Results (due to Reliability)

- No WBBDA results = assumed miss on 5 tgt

Dropped 100 bombs

- 95 bombs
- 5 bombs

Acc.=0.9
Results of 1st attack—implications to further targeting
\( P_k = 0.8, \ Rel. = 0.95, \ Acc. = 0.9 \)

- **Drop 100 bombs**
  - WBBDA results on 95
  - No WBBDA on 5

- **Lack of WBBDA Results**
  - No WBBDA results = assumed miss on 5 tgts

<table>
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<th>WBBDA</th>
<th>Assess Hit</th>
<th>State of Nature</th>
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<td></td>
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- **Type I Errors**
  - Retire targets (targets survive)

- **Type II Errors**
  - Reattack targets (all hit)
  - Reattack targets (80% already destroyed)

- **Retire targets**
  - (tgts destroyed)
Results after all reattacks (≤ 4 passes...100, 30, 5, 2)

- Strike package departs with 100 WBBDA “hits”
- Overall: 97 targets destroyed, 3 missed (Type I Errors)
**Single Package Model**

**Actual Results w/ Inputs at Baseline**

<table>
<thead>
<tr>
<th>INPUTS: Components WBBDA Effectiveness (all baseline)</th>
<th>μ</th>
<th>σ</th>
<th>WBBDA</th>
<th>μ</th>
<th>σ</th>
<th>% improve in μ</th>
<th>WBBDA w/ doctrine change</th>
<th>μ</th>
<th>σ</th>
<th>% improve in μ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weapon Pk</td>
<td>0.80</td>
<td>0.051</td>
<td>normal distribution</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>PPE (planned)</td>
<td>100</td>
<td>0.0</td>
<td>100</td>
<td>0.0</td>
<td>0.0%</td>
<td></td>
<td></td>
<td>145</td>
<td>0.0</td>
<td>45%</td>
</tr>
<tr>
<td>PE (destroyed)</td>
<td>95</td>
<td>2.1</td>
<td>98</td>
<td>1.0</td>
<td>2.4%</td>
<td></td>
<td></td>
<td>139</td>
<td>4.7</td>
<td>45%</td>
</tr>
<tr>
<td>AE (PE / PPE)</td>
<td>0.952</td>
<td>0.021</td>
<td>0.975</td>
<td>0.0</td>
<td>2.4%</td>
<td></td>
<td></td>
<td>0.956</td>
<td>0.032</td>
<td>0.3%</td>
</tr>
<tr>
<td>WPTK</td>
<td>2.10</td>
<td>0.04</td>
<td>1.41</td>
<td>0.0</td>
<td>-33%</td>
<td></td>
<td></td>
<td>1.42</td>
<td>0.09</td>
<td>-33%</td>
</tr>
</tbody>
</table>

**WBBDA capabilities improve on the AS-IS scenario**
Single Package Model
Sensitivity to Weapon Pk

Strengthened argument to implement **doctrine change**

**PE Vs. Pk (% improvement relative to As-Is)**

![Graph showing PE vs. Pk comparison with different weapon Pk levels and two models: WBBDA and WBBDA+Doctrine.](image-url)

- **WBBDA**
- **WBBDA+Doctrine**
Single Package Model
Sensitivity to WBBDA Reliability

WPTK Vs. WBBDA Reliability (% improvement relative to As-Is)

% improvement in Weapons per Target Killed

0% 10% 20% 30% 40%

WBBDA Reliability

0.50 0.60 0.70 0.80 0.90 1.00

0.62 0.64

Supports establishment/study of a Reliability requirement
Single Package Model
Sensitivity to WBBDA Accuracy

Supports establishment/study of an Accuracy requirement
Does WBBDA capability favor either scenario?
- More weapons per jet of lower $P_k$ (SDB scenario)
- Fewer weapons per jet of higher $P_k$ (JDAM scenario)

Analysis of model results forced reconsideration of MOEs, architecture, and model
Architecture Based Evaluation Process (ABEP)

- STEP 1: Design Ops Concept (OV-1) of System to be Evaluated
- STEP 2: Identify MOE’s Relevant to the Decision/Evaluation
- STEP 3: Identify Required Level of Abstraction for Architecture to Show Traceability to MOE’s
- STEP 4: Identify Architecture Views Necessary to Capture Structure/Relationships. NOT VIEWS, BUT DATA
- STEP 5: Develop Architecture Views NOT VIEWS, BUT DATA
- STEP 6: Modeling/ Simulation consistent with Architecture
- STEP 7: Evaluate Model Completeness
- STEP 8: Evaluate MOE
Conclusion
ABEP vs DODAF

Figure 5-1. The Six-Step Process of Building an Architecture

1. Determine the intended use of the architecture
   - Purpose
   - Critical uses
   - Target objectives
   - Key tradeoffs
   - Probable analysis methods

2. Determine scope of architecture
   - Geographical/operational bounds
   - Time phases
   - Functional bounds
   - Technology constraints
   - Architectural resources/schedule

3. Determine characteristics to be captured
   - Required characteristics (document attributes across different views) and measures of performance

4. Determine views and products to be built
   - Products and data content determined by intended use

5. Gather data and build the requisite products
   - Composed architecture (generated product set)

6. Use architecture for intended purpose
   - Investment decisions
   - Requirements identification
   - Acquisition
   - Operations planning and execution

Step 1. OPS Concept
Step 2. ID Mission Level Metrics
Step 3. ID Required Level of Abstraction for Traceability
Step 4. Determine Views to Capture Relationship
Step 5. Develop Architecture Views
Step 6. Develop Modeling Simulation
Step 7. Evaluate Model Completeness
Step 8. Evaluate Model for MOE Results

Architecture Evaluation
ABEP Step 1.
OPS Concept

Step 2.
ID Mission
Level Metrics

Step 3.
ID Required
Level of Abstraction
for Traceability

Step 4.
Determine Views to
Capture Relationship

Step 5.
Develop Architecture
Views

Step 6.
Develop Modeling
Simulation

Step 7.
Evaluate Model Completeness

Step 8.
Evaluate Model for
MOE Results

6 Step DoDAF v1.5
Conclusion

- **WBBDA Specific**
  - WBBDA + Doctrine Shift significantly increases MOE’s
  - WBBDA Performance is sensitive to Accuracy, Reliability, & Pk

- **Non-WBBDA Conclusions**
  - Architecture can be used to effectively evaluate a system concept
  - Evaluate Gaps (FNA) and Evaluate Alternatives (FSA and AoA)
  - Identify Critical Requirements, KPP’s
  - Provide Feedback for Architectural Changes & Emerging MOE’s

- **Process**
  - Evaluation w/o Architecture = Inaccurate Evaluation, redundant effort, non-Concordance
  - Architecture w/o Evaluation = Static Architecture

**Architecture can be used effectively to perform concept definition and analysis in support of JCIDS**