Multi-Resolution Analysis (MRA): Applying Capability-Driven SoSE on the Intelligence, Surveillance, and Reconnaissance (ISR) Portfolio

System of Systems Engineering (SE/SoSE) Collaborators Information Exchange

30 May 2013

Mitch Miller
Chief Architect
HQ AFMC/EN

Doug Owens
TASC

Tim Menke
SIMAF Director
AFLCMC

CLEARED FOR PUBLIC RELEASE (Approval number AFMC-2013-0100, 29 May 2013)
Overview

• Background
• Problem
• ISR MRA Pilot
• Sample Metrics
• Process Development
• Way Forward
Background

  ✓ Baseline current systems engineering processes in use, and current policy directives (As Is)
  ✓ Survey potential SoS engineering processes within AFMC, AFSPC, DoD, other Services, and industry that address mission effectiveness in a SoS environment
    – Pilot process with selected capability gaps and multiple use case scenarios
    – Identify DOTmLPF changes from AS IS needed to implement the new process
Problem

- Air Force lacks an integrated modeling, simulation and analysis capability that provides traceability from requirements to capability and that conducts operationally relevant ISR trade-space analysis*
- No Air Force process exists to transform Mission-Specific gaps into System of System (SoS) capability requirements that can be allocated down to individual system level platforms, sensors, weapons, networks, etc…
- No organization responsible for the above

Solution

Multi-Resolution Analysis (MRA) Methodology
Capability Cost is Locked-In Early

Informed Decisions made early in the system lifecycle (e.g. solution concept) have large effect on total lifecycle cost, effectiveness, and timeliness.
MRA Pilot Strategic Vision

• Provide operationally relevant trade-space analysis (cost vs. capability) for ISR Enterprise
  – QRAs: < 4 Weeks -- Deliberate: 1 Year

• Institutionalized ISR mission area analysis process
  – Synchronize deliberate process to support POM cycle
  – Unified, tool agnostic framework
  – Process is repeatable and enduring
  – SoS mission analysis (all systems/missions)
  – Apply to other mission areas
  – Staff resources to manage execution
Strategically Adopt
Integrated Life Cycle MS&A Framework

Today

Integrated ILCM MS&A Framework
MRA
Integrated M&S Across Enterprise

• Examine Complex Trade Issues from Varied Perspectives (system, process, networks, mission, CONOPS, cost, manpower) Interactively Through Traceable Layering of High and Low Fidelity Modeling

• Apply Layered Fidelity Models
  – Suite of tailored tools vice monolithic ‘uber’ models
  – Aggregate technical details into effects while maintaining traceability and architectural context from technical performance to strategic decision
  – Benefit: Less costly analysis with greater insights for decisions

• Build Decision Response Surface
  – Grow knowledge and capture into decision tools
  – Archive results and insights from varied community sources
  – Benefit: Repeatable process that can be quickly leveraged for updates vice initiating new studies and reviews (becomes part of day-to-day business)
MRA Elements

• **Analysis of Netted Information & Integration (ANII)**
  – PCPAD Data Flows
  – C4 Network trades, Connectivity Effects, CONOPS
  – Cyber/IO impacts (blue & red)

• **Physics-based Capability & Architecting Analysis (PCA)**
  – Sensor/System effects traceability to ops impacts
  – Layered, integrated utility analysis & metrics

• **Mission Utility Analysis (MUA)**
  – Combined ANII & PCA impacts & trades (engagement, mission, & campaign levels)

• **Financial & Business Analytics (FBA)**
  – Cost estimating & risk analysis tradeoffs
  – Cost projections over planning horizons (AoAs, POM inputs)

• **Integrated Decision Analysis (IDA)**
  – Decision trades, risks, sensitivities, programmatic
ISR MRA Overview
NASB Recommended Process

**ANII**
Analysis of Netted Information & Integration

**PCA**
Physics based Capability & Architecting Analysis

**MUA**
Mission Utility Analysis

**IDA**
Integrated Decision Analysis

**FBA**
Financial/Business Analytics

**BLUE**
System & Architectures

**BLUE ON RED**
Iterative Campaign/Mission Assessments over a variety of mission types

**FORC E STRUCTURE**
Rolled up across multiple missions, campaigns, theaters for the force structure

**Network/Architecture Characterization & Performance**

- Assessing Integrated Architectures & Characterizing Results in Operational Effectiveness Metrics
- System & Architectures
- Iterative Campaign/Mission Assessments over a variety of mission types
- Rolled up across multiple missions, campaigns, theaters for the force structure

**INTegrity - SERVICE - EXCellence**

1. Arch Options
2. Integrated Arch Trades
3. System Trades
4. Summation Enterprise Force Structure
5. Enterprise Cost/Benefit Trades

[Diagram Image]
ISR MRA Overview
NASB Recommended Process

Network/Architecture Characterization & Performance

ANII
Analysis of Netted Information & Integration

∑ Systems

rch Options

Integrated Arch Trades

MUA
Mission Utility Analysis

∑ Summation Enterprise Capabilities

∑ Summation Enterprise Benefits

Enterprise Cost/Benefit Trades

IDA
Integrated Decision Analysis

FBA
Financial/Business Analytics

FORCt STRUCTURE
Rolled up across multiple missions, campaigns, theaters for the force structure

PCA: Physics Based Capability and Architecting Analysis:
Systems and Sensor configurations, interactions, and performance characterization.
ANII: Analysis of Netted Information and Integration: Area where I define the architectures, network topologies necessary for the Blue force to communicate properly to support their planned missions.

FORCE STRUCTURE
Rolled up across multiple missions, campaigns, theaters for the force structure

BLUE ON RED
Iterative Campaign/Mission Assessments over a variety of mission types
**ISR MRA Overview**
**NASB Recommended Process**

**ANII**
Analysis of Netted Information & Integration

**Network/Architecture Characterization & Performance**

**MUA**
Mission Utility Analysis

**Summation Enterprise Cost/Benefit Trades**

**FBA**
Financial/Business Analytics

**FORCE STRUCTURE**
Rolled up across multiple missions, campaigns, theaters for the force structure

**BLUE**
System & Architectures

**FORCE STRUCTURE**
Iterative Campaign/Mission Assessments over a variety of mission types
ISR MRA Overview
NASB Recommended Process

MUA: Mission Utility Analysis: Campaign and Mission level assessment tools that allow the user to assess mission effectiveness, and/or campaign effectiveness for the integrated information architecture under assessment.

BLUE
System & Architectures

BLUE ON RED
Iterative Campaign/Mission Assessments over a variety of mission types

FORCE STRUCTURE
Rolled up across multiple missions, campaigns, theaters for the force structure

INTEGRITY - SERVICE - EXCELLENCE
ISR MRA Overview
NASB Recommended Process

LOOP: MUA ANII Iterative Loop: Allows the analyst to understand the network topology tradespace (sensitivity of network topology parameters and options) with mission effectiveness for various missions/mission threads.

System Representation & Performance Characteristics

BLUE
System & Architectures

BLUE ON RED
Iterative Campaign/Mission Assessments over a variety of mission types

FORCE STRUCTURE
Rolled up across multiple missions, campaigns, theaters for the force structure
ISR MRA Overview
NASB Recommended Process

Network/Architecture Characterization & Performance

ANII
Analysis of Netted Information & Integration

Integrated Arch Trades

Summation Enterprise Capabilities

IDA
Integrated Decision Analysis

Enterprise Cost/Benefit Trades

FBA
Financial/Business Analytics

LOOP: MUA PCA Iterative Loop: Allows the analyst to understand the systems and sensors within a fixed network topology and what their effect on mission effectiveness.

System Representation & Performance Characteristics

BLUE
System & Architectures

BLUE ON RED
Iterative Campaign/Mission Assessments over a variety of mission types

FORCE STRUCTURE
Rolled up across multiple missions, campaigns, theaters for the force structure

1 2 3 4 5

Cost/Benefit

Generating Enterprise Cost/Benefit Relationships

Graph: Cost

Arch A Arch B Arch C
ISR MRA Overview
NASB Recommended Process

FBA: Financial/Business Analytics: Provides a means to assess the costs of various force structures rolled up from a summation of the missions (via the MUA) across all theaters.
ISR MRA Overview
NASB Recommended Process

Network/Architecture Characterization & Performance

ANII: Analysis of Netted Information & Integration

IDC: Integrated Decision Analysis: Provides the final assessment allowing the analyst to compare Cost/Benefits for various Information Architecture Options for the force structure.

PCI: Physics based Capability & Architecting Analysis

MUA: Mission Utility Analysis

Summation of Enterprise Capabilities

Optimizing System Performance

Summation of Enterprise Force Structure

Optimizing Cost/Tradeoffs

Enterprise Cost/Benefit

System Representation & Performance Characteristics

BLUE
System & Architectures

BLUE ON RED
Iterative Campaign/Mission Assessments over a variety of mission types

FORCE STRUCTURE
Rolled up across multiple missions, campaigns, theaters for the force structure

Integration - Service - Excellence
ISR MRA Overview
NASB Recommended Process

**ANII**: Analysis of Netted Information & Integration

1. **Arch Options**: Optimizing Architecture
2. **Integrated Arch Trades**: Assessing Integrated Architectures & Characterizing Results in Operational Effectiveness Metrics
3. **System Trades**: Threat Systems, CONOPs/TTPs, and Information Architectures
4. **Summation Enterprise Force Structure**
5. **Optimizing Enterprise Benefits**

**PCA**: Physics Based Capability & Architecting Analysis

**MUA**: Mission Utility Analysis

**IDA**: Integrated Decision Analysis

**FBA**: Force Structure Analysis

**LOOP**: FBA MUA Iterative Loop: Allows the analyst to optimize cost across the force structure by altering force structure numbers, previously assessed system configurations, or previously assessed architecture options.

**FORCE STRUCTURE**: Rolled up across multiple missions, campaigns, theaters for the force structure

**ISR MRA Overview**

**NASB Recommended Process**

**ANII**: Analysis of Netted Information & Integration

1. **Arch Options**: Optimizing Architecture
2. **Integrated Arch Trades**: Assessing Integrated Architectures & Characterizing Results in Operational Effectiveness Metrics
3. **System Trades**: Threat Systems, CONOPs/TTPs, and Information Architectures
4. **Summation Enterprise Force Structure**
5. **Optimizing Enterprise Benefits**

**PCA**: Physics Based Capability & Architecting Analysis

**MUA**: Mission Utility Analysis

**IDA**: Integrated Decision Analysis

**FBA**: Force Structure Analysis
ISR MRA Overview
NASB Recommended Process

LOOP: IDA MUA: Allows the analysts to optimize mission & campaign effectiveness benefit across the force structure by altering force structure numbers, previously assessed system configurations, or previously assessed architecture options.
ISR MRA Overview
NASB Recommended Process

Network/Architecture Characterization & Performance

ANII
Analysis of Netted Information & Integration

PCA
Physics based Capability & Architecting Analysis

Integrated Arch Trades

Mission Utility Analysis

Summation Enterprise Capabilities

Summation Enterprise Benefits

Summation Enterprise Costs

Threat Systems, CONOPS/TTPs, and Information Architectures

Enterprise Cost/Benefit Trades

Cost/Benefit Relationships

Optimizing Enterprise Costs

Generating Enterprise Cost/Benefit Relationships

Optimizing Enterprise Benefits

Optimizing System Performance

Optimizing Architecture

Characterizing Integrated Architecture

Characterizing Integrated Architecture

System Trades

1

2

3

4

5

BLUE ON RED
Iterative Campaign/Mission Assessments over a variety of mission types

FORFORCE STRUCTURE
Rolled up across multiple missions, campaigns, theaters for the force structure

BLUE System & Architectures

Integrity - Service - Excellence
# Sample Metrics

<table>
<thead>
<tr>
<th>FIND</th>
<th>Collection</th>
<th>Quantity</th>
<th>Timeliness</th>
<th>Confidence</th>
<th>Process, Exploit, Analysis, Prod</th>
<th>Quality</th>
<th>Quantity</th>
<th>Timeliness</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIX</td>
<td>Planning &amp; Direction</td>
<td>Quality</td>
<td>Confidence</td>
<td>Quantity</td>
<td>Time Required to Collect</td>
<td>Confidence</td>
<td>Average Percent Degrade</td>
<td>Process, Exploit, Analysis, Prod</td>
<td>Quality</td>
</tr>
<tr>
<td>TRACK</td>
<td>Planning &amp; Direction</td>
<td>Quantity</td>
<td>Confidence</td>
<td>Quantity</td>
<td>Time to Disseminate</td>
<td>Quality</td>
<td>Percent Tracked</td>
<td>Timeliness</td>
<td>Link Availability</td>
</tr>
</tbody>
</table>

Based on assessment of past studies, ops reports, CFMP
Sample Metrics & Measures
Employing NCW Theory

Event Objectives
Survivability
Lethality
Situational Awareness
Responsiveness
Collaboration
Crew Perception
Route Timing / Adherence

Campaign Objectives
Force Multiplier
Ops Tempo

Outcome:
Achieving the desired effects

Cognitive:
Understanding the Environment

Ability to Act:
Utilizing the available data to adjust mission parameters
Capability-Driven SoSE Process

Operational context
Defined by Experiment objectives
Defined by individual system requirements

Software Repository
- Organized by system/component

Results & Conclusions
- Rqmts Development
- S/W Development

Final Analysis Report
- Results & Conclusions

Analytic Requirements
ATM
Defined by Experiment objectives

Functional Requirements
RTM
Defined by individual system requirements

1. Assemble existing components
2. Modify existing components as required
3. Build new components
4. Integrate components
5. Test components, sub-assemblies, assemblies
6. Execute event

Define operational needs & relationships
Allocate rqsmts to systems

Results map to analytic objectives
<table>
<thead>
<tr>
<th>Tools</th>
<th>Analysis</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Network Integration</strong></td>
<td>Limited ISR info architecture analysis tools</td>
<td>Lack of established AF process for netted effects analysis</td>
</tr>
<tr>
<td><strong>Mission Utility</strong></td>
<td>Limited modular structure in MUA models to assess traceability of ISR effects to ops</td>
<td>Limited flexibility to assess adaptive trades across sensors, network, CONOPS, TTP</td>
</tr>
<tr>
<td><strong>Physics Models</strong></td>
<td>No tools to assess real-time OITL integrated systems &amp; networks w/i mission threads</td>
<td>Lack of key component models and assessment capabilities</td>
</tr>
<tr>
<td><strong>Organization</strong></td>
<td>Lack of integrated roles &amp; collaborative culture across HAF, MAJCOMs, AFISRA, AFLCMC, AFRL. No enterprise integrator.</td>
<td></td>
</tr>
</tbody>
</table>

*MRA Product: Identification of MRA Implementation Gaps*
Way Forward

• **Continue to implement NAS Recommendations**
  — USAF Adopt an ISR CP&A process
  — Evolve to an integrated overarching ISR investment process
  — Conduct MRA pilots

• **Execute Tasks**
  — Develop/Build ISR Environment; Assess Mission Effectiveness
  — Integrate LVC environment including PCPAD-X, DCGS

• **Align pilot with FY14 ISR Development Planning efforts**

• **Outputs:**
  — Inform Should-Be Information Architecture
  — Assist POM Guidance Development
  — Identify Key Capability Opportunities
  — Develop Non-material Solution Vector
For additional information:

Mitch Miller
Chief Architect
Engineering & Technical Management Directorate
HQ AFMC, Wright-Patterson AFB OH
937-257-5245
mitchel.miller@wpafb.af.mil
Proposed ISR CP&A Process

Problem Definition & Approach

Analytical Framework

Needs Analysis

Focused Needs

Multi-Resolution Gap Analysis

Mission Perspective

Collection Perspective

Infotecture Perspective

Comms Perspective

Integrated Perspective

Utility, Cost, Risk Trade Space

Iterate As Needed

Pilot

AF Corp Process

Solution Analysis

Prioritized Gaps

Proposed Solutions

Iterate As Needed

Process Duration

<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quick Look</td>
<td>N/A</td>
<td>&lt; 4 wks</td>
</tr>
<tr>
<td>Deliberate Look</td>
<td>2 yrs</td>
<td>&lt; 1 yr</td>
</tr>
</tbody>
</table>

THE NATIONAL ACADEMIES
Advisors to the Nation on Science, Engineering, and Medicine

Integrity - Service - Excellence