Approaches to Achieve Benefits of Modularity in Defense Acquisition (WRT-1002)

Sponsor: ODASD(SE)

Presented on behalf of team by:
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“The” Problem: challenges in a multi-domain battle scenario

• Complexity
  — Multiple, diverse systems
  — Size of problem
  — Interactions
  — Dynamic environment

• Modularity Trade space
  — Mission level, SOS level, system level
  — Competing metrics: cost, performance, flexibility, reusability

• Uncertainty
  — Performance/cost
  — Future missions
  — “Stable intermediate forms”

In this context, DOD acquisition challenges are significant:
  • Affordably address emerging threats
  • Component obsolescence
  • Planned technology upgrade for tightly coupled, highly integrated systems and dynamic missions
Potential, Partial Solution: Benefits of Modular Open Systems Approach (MOSA)

- MOSA encourages adoption of modularization and open architectures
  - DoD is prioritizing speed of delivery, continuous adaptation, frequent modular upgrades (Secretary of Defense Mattis’ testimony before congress, 26 April 2018)
  - Increased flexibility
  - Cost reduction, not only by used COTS components, but also by adoption of standards
  - Incremental commitment and intermediate capabilities

- Imperatives we have uncovered so far:
  - Modularity not as an “output” but as a means to achieve benefits
  - “Doing MOSA” is “Doing Good Architecting”…but organizational readiness to adopt and mirroring to the modular architecture of the product is critical
  - MOSA approach supports Mission Engineering and is facilitated by Robust Portfolios, Set-Based Design, etc.
Motivation for Research

- MOSA is “in the law” and might be good, but many programs don’t know how to actualize the benefits:
  - Current MOSA guidelines provide limited insight into
    - the “what”: specific potential benefits of modularity and openness
    - the “how”: which levers to play and decision problems to solve to realize the benefits of modularity and openness
    - the “why”: how can programs improve their evidence for specific MOSA implementations

- Challenge: strategies and tools to be successful in MOSA ecosystem

- Our goals in MOSA research with SERC over last 2.5 years
  - Identify and suggest guidelines for MOSA implementation: how to encourage and achieve modularity and openness
  - Provide quantification of the achieved benefits in terms of cost, performance, risk, ability to change when requirements change
  - Support both technical and managerial aspects: what organizational structure to better implement MOSA principles?
Previous Learning & Findings (1)

- **2017 Workshop** with government, military, academia, and industry suggested needs and requirements
- **Interviews** to Program Managers to learn about their perspective

- Some key findings:
  - MOSA is a means to achieve benefits
  - Early stage acquisition process key to modularity and openness
  - Early support mechanisms in place
  - Need to address both managerial and technical needs
  - Organization needs to be ready to deal with the solution
  - Tools to assess consequences of modularization choices
  - Feedback mechanisms to help stakeholders understand consequence of actions
An interactive tool to provide further guidance to program managers: prototype Decision Support Framework

Chose to pursue cascading matrices to create a visual analysis of how the inputs translate to the outputs throughout the program lifecycle.

Established a potential path forward for data collection and case studies.

Translate knowledge from AoA, JCIDS, OSA contract guidebook, and case studies into cascading dependencies, PM guidance document and prototype software.
• What’s in Ver 2.0?

Case study summaries related to early stage lifecycle implications on MOSA and lessons learned:

– **Early stage acquisitions** systems engineering, pursuit of reachable core requirements upfront

– Due diligence across each segment of the acquisition lifecycle is important for traceability

– …need to consider their (modular and open solution) impact on the organization that’s employing it – **Is the organization using this solution ready to deal with it?**

– Having appropriate systems engineering **artifacts** (e.g. MBSE) at early stages can improve the pursuit of MOSA benefits

– It is never too early to **think about how** contracting can support MOSA objective
Previous Learning & Findings (4): DSF software 1.0

- Prototype decision support software
  - Simple cascade traceability needs → requirements → alternatives → required resources including organizational requirements
  - Oriented to early phase and AoA
WRT-1002: objectives and workflow

• Objectives
  — Building upon previous efforts, refine MOSA Decision Support Framework
  — Translate knowledge from specific programs into functional features of DSF
  — Explore practically informed tradeoffs between and among metrics of interest to partner programs (e.g. cost, schedule, risks) against various strategies for openness and modularization
  — Validate and verify the effectiveness of prototype DSF

• Organization of work (two-pronged approach)
  — Analysis of historical reporting data and/or case studies
  — Analysis of representative synthetic problem; explore the use of set-based design in a mission engineering environment
Expanding research in WRT-1002: DSF 2.0

- Qualitative
  - Aimed at adherence to MOSA principles and organizational structure
  - Based on cascading matrices to relate program requirements to management and production requirements

- Quantitative
  - SoSE-based
  - Focused on trade-offs (cost, schedule, flexibility)
  - RPO for generation of alternatives
  - SDDA for analysis of schedule
  - SODA for analysis of performance

**Inputs and user queries**

**QFD Cascade Matrices and SoS tools**

**Outputs (some in MBSE format)**

**Context**
- Acquisition
- Environment
- Details of mission (‘ilities’)

**Organization al Disposition**
- Who is integrator?
- Support Team? WGs?

**Resources Available**
- Cost
- Data, Interfaces, Interactions
- Stakeholders

**System Operational Dependency Analysis (SODA)**
**System Developmental Dependency Analysis (SDDA)**

**Robust Portfolio Optimization (RPO)**

**Cost, Schedule, Risk Implications**

**Adherence to MOSA principles**

**Product - Organizational Structure Relationships**
Analysis of historical reporting data and/or case studies

• MOSWG
  – Experience on required assets towards MOSA ecosystem
  – How to evaluate “amount” of adherence to MOSA principles and benefits of MOSA

• VICTORY program
  – VICTORY provides a standard electronic systems architecture for ground vehicles
  – Defines standard modules and interfaces, then each program takes pieces of this standards as suited for their program

• Leveraging MBSE, MCE
  – Learning from SERC RT-187
  – Our work on MBSE and reusability in DSF

• Open Architecture Assessment Tool
  – How well suited is an organization to adopt MOSA
  – Key drivers
Recent Learnings from the MOSWG

Participants in MOSWG range from first-time users to experienced practitioners who are pushing the boundaries. Some of the key points include:

- **Guidelines by NDIA**
  - Develop MOSA strategy early
  - Define MOSA evaluation and implementation approach, including incentives
  - Digital Engineering in support of MOSA
  - Create library of MOSA certified systems and interfaces

- **MOSA to avoid “skipping a generation” due to obsolescence**

- **Navy using modular COTS architecture with common information standards and common source library**

- **Use of MBSE and automated testing**

- **Identification of possible evolution of MOSA** (Naval Information Warfare Center)
Recent Learnings from the VICTORY interaction

- The VICTORY architecture is a set of open standards for networking and communication
  - Meant to be adaptable as needed by different vehicle system development programs
  - Some of the standards allow variable fields, to be specified by the project, subcontractors and departmental teams with additional data elements hidden from external interfaces
  - While this enhances the application domain and flexibility, it introduces additional challenges. Less agile than commercial concepts, based on standards like CAN or SCADA
- JLTV used some elements of VICTORY, but employed modular open architecture not only in electronics but in all major subsystems
- Practical steps to advance appropriate use of MOSA
  - Acquiring families of vehicles with multiple variants
  - Including requirement language about mission modules
  - Favor subsystem functions which are not tightly coupled
- Methods, procedures and tools are evolving. More from the bottom up (tools and capabilities lead evolution of procedures and methods)
MBSE environment for the MOSA DSF

• Learning from SERC RT-187:
  ― Multi-information graphics
  ― MBSE for visualization of output
• Architectures with different type and level of modularity can be analyzed in detail with different representations
• This aspect of the project has been submitted as paper for CSER 2020
Recent Learnings from Open Architecture Assessment Tool

- OAAT v3.0: Excel-based tool that aids the user in applying the Open Architecture Assessment Model

- A 0%-100% score is produced to describe the level of openness with respect to programmatic and technical factors

- Manager & SME input can help quickly estimate the acquisition and technical characteristics of each system for a rough order of magnitude (ROM) scoring

OAAT provides rationale and factors for consideration to support a decision making process from a program management and business case perspective

Deep Dive into OAAT conducted by project collaborator
Dr. Charles Domercant
WRT-1002 – Synthetic problem for development and V&V of DSF 2.0

- Based on Mission Engineering and addressed using Set-Based Design
- RPO used to identify alternative sets / architectures, then SDDA for analysis of schedule, and flexibility tool
- Useful to study different future missions (flexibility), as well as modular vs. non-modular sets / architectures

Example of problem setup for RPO. Mission scenarios require SoS capabilities, provided by systems that also have I/O support requirements and associated costs. This approach also populate the DSF matrices

<table>
<thead>
<tr>
<th>No.</th>
<th>System Type</th>
<th>System Name</th>
<th>Power</th>
<th>Resupply</th>
<th>Support Input</th>
<th>Support Output</th>
<th>System Capabilities (Outputs)</th>
<th>SoS Capabilities (Outputs)</th>
<th>Cost [S]</th>
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<tbody>
<tr>
<td>1</td>
<td>Ground Systems</td>
<td>Infantry Platoon</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>SC1 = Attack Air-Air</td>
<td>(30, 5)</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Ground Systems</td>
<td>Combat Engineers</td>
<td></td>
<td></td>
<td>0</td>
<td>10</td>
<td>SC2 = Attack Air-Ground</td>
<td>[M1, M2]</td>
<td>0</td>
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<tr>
<td>3</td>
<td>Ground Systems</td>
<td>Airborne Infantry</td>
<td></td>
<td></td>
<td>10</td>
<td>0</td>
<td>SC1 = Mobility Sea</td>
<td>[10, 20]</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Air Systems</td>
<td>Jeep Willys</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>[M1, M2]</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Air Systems</td>
<td>&quot;Deuce and a half&quot; (supply truck)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>[M1, M2]</td>
<td>0</td>
<td>0</td>
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<td>6</td>
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<td>P-51 Mustang</td>
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<td></td>
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<td>0</td>
<td>SC1 = Mobility Air</td>
<td>0</td>
<td>0</td>
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<tr>
<td>7</td>
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<td>Boeing B-17</td>
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<td></td>
<td>0</td>
<td>0</td>
<td>SC1 = Mobility Air</td>
<td>0</td>
<td>0</td>
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<td>8</td>
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<td>C-17</td>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td>SC1 = Mobility Air</td>
<td>0</td>
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<tr>
<td>9</td>
<td>Naval Systems</td>
<td>Alien M. Sumner Destroyer</td>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td>SC1 = Mobility Air</td>
<td>0</td>
<td>0</td>
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<td>10</td>
<td>Naval Systems</td>
<td>Battleship</td>
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<td></td>
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<td>0</td>
<td>SC1 = Mobility Air</td>
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<tr>
<td>11</td>
<td>Space Systems</td>
<td>Earth Observation Satellite</td>
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<td></td>
<td>0</td>
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<td>SC1 = Mobility Air</td>
<td>0</td>
<td>0</td>
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<td>Communication Relay Satellite</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td></td>
</tr>
</tbody>
</table>

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### Synthetic problem for development and V&V of DSF 2.0 (2)

**Outputs:**
- Alternative feasible architectures (system portfolios)
- Cost, performance
- Matrix of architectures to be used to feed quantitative and qualitative analysis in DSF → not only Pareto fronts, because architectures used in other tools

**Modular systems**

For initial assessment (or future technologies), set-based design is ideal

<table>
<thead>
<tr>
<th>System Type</th>
<th>System Name</th>
<th>Transport Range (m), Transport Capacity (lb)</th>
<th>Fuel Capacity (lb)</th>
<th>[Rating (n.d.)]</th>
<th>Number of Operators</th>
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<tbody>
<tr>
<td><strong>Air Systems</strong></td>
<td>P-51 Mustang</td>
<td>[0, 2000]</td>
<td>2795</td>
<td>0</td>
<td>1</td>
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<tr>
<td></td>
<td>B-17 Flying Fortress</td>
<td>[0, 6000]</td>
<td>13800</td>
<td>0</td>
<td>10</td>
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<tr>
<td></td>
<td>C-47</td>
<td>5509</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>B-29 Stratofortress</td>
<td>[0, 6000]</td>
<td>52000</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>B-2 Spirit</td>
<td>20000</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td><strong>Ground Systems</strong></td>
<td>Infantry Platoon</td>
<td>[10, 1845]</td>
<td>0</td>
<td>0</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>M1A1 105mm Howitzer</td>
<td>[0, 12480]</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>M-4 Sherman</td>
<td>[150, 2251]</td>
<td>899</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>M60 Greyhound</td>
<td>[125, 234]</td>
<td>535</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Jeep Willys</td>
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<td>95</td>
<td>0</td>
<td>1</td>
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<tr>
<td></td>
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<td>[0, 378]</td>
<td>378</td>
<td>0</td>
<td>1</td>
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<tr>
<td></td>
<td>Advanced Targeting Pod</td>
<td>[0, 378]</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>TARDIC Chavez</td>
<td>[100, 378]</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>TARDIC Anti Air Module</td>
<td>[100, 378]</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td></td>
<td>TARDIC Artillery Module</td>
<td>[100, 375]</td>
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<td>TARDIC Personal Module</td>
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<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>B-29 40 mm gun (L.60)</td>
<td>[100, 400]</td>
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<td>0</td>
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<td><strong>Naval Systems</strong></td>
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<td>[0, 0]</td>
<td>0</td>
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<tr>
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<td>Beef stock Depot</td>
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<td>0</td>
<td>1</td>
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<tr>
<td></td>
<td>Allen M. Sumner Destroyer</td>
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<td>336</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Higgins Boat (LVP)</td>
<td>[0, 0]</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Landing Ship, Tank (LST)</td>
<td>[0, 0]</td>
<td>140</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Battleship</td>
<td>[0, 0]</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

Database of required/provided support

Database of systems capabilities
• RPO uses database to generate Pareto fronts of architectures against competing metrics
• Each dot on the Pareto front is a portfolio of systems
• RPO-generated architectures provide only part of the quantitative results: the corresponding network of interdependent systems are used as input to other SoS tools
Outputs of the DSF 2.0 (2)

- Plots can be queried for information:
  - SoS capabilities
  - Performance and cost
  - Systems providing capability
  - Systems providing support
  - **Presence of modularity**
Upcoming Milestones

• Working version of DSF software (Dec 2019)
  – Production of architectures with RPO based on database for synthetic problem
  – Partnered testing of DSF software and PM document, e.g., users can run the tool, interpret outcomes, and provide feedback
  – Provide quantification of some of the achieved benefits (cost, performance) and how those change with architecture with different levels of modularity / openness
  – Benefit immediate customers

• Integration of DSF software with SoS tools (Feb 2020)
  – Use of architectures in cascading matrices together with case study-based database to identify organizational requirements
  – Use of SoS tools for quantitative analysis of risk and schedule
  – Case studies related to mission engineering and defense acquisition
Thank you

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