SYSTEMS ENGINEERING RESEARCH CENTER

CISA Center for Integrated Systems in Aerospace

Approaches to Achieve Benefits of Modularity in Defense Acquisition

Sponsor: DASD(SE)

By

Dr Daniel DeLaurentis

10th Annual SERC Sponsor Research Review

November 8, 2018

FHI 360 CONFERENCE CENTER

1825 Connecticut Avenue NW, 8th Floor

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10 YEARS of SERC

Motivation for Research

- Current DoD acquisition challenges
  - to **affordably** address emerging threats
  - component **obsolescence**
  - loss of critical suppliers, and planned **technology upgrade** for tightly coupled, highly integrated systems
- DoD acquisitions strategy
  - Implement best practices to improve productivity, affordability, capabilities, reduce unproductive states across DoD acquisitions
  - Includes **encouraged use of modularization strategies** to achieve desired end benefits…via a Modular Open Systems Approach (MOSA)
  - CHALLENGE: Need strategies and tools to be successful in a MOSA ecosystem

RT-185 Research Team

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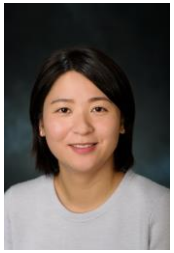

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MOSA Goals

- ODASD/SE Modular OPEN Systems Approach (MOSA)
  - Open System Architecture (OSA)

> **"§ 2446a. Requirement for modular open system approach in major defense acquisition programs; definitions**
>
> "(a) MODULAR OPEN SYSTEM APPROACH REQUIREMENT.—A major defense acquisition program that receives Milestone A or Milestone B approval after January 1, 2019, shall be designed and developed, to the maximum extent practicable, with a modular open system approach to enable incremental development and enhance competition, innovation, and interoperability.

  - Modularity (in DoD)
    - Viewed as technical approach in defense acquisitions
    - Complex system decomposition: physical and functional architecture
    - Largely separated from OSA tenets that are more business oriented
    - Modular open systems leverages business driven benefits of adopting Open Architecture standards for development

MOSA Guidelines

- **Establish an enabling environment**
  - PM to generate business practices, technology development, test and evaluate, etc. needed for development of open systems
- **Employ modular design**
  - Four main characteristics: cohesive, encapsulated, self-contained, highly binned
- **Designate Key Interfaces**
  - Module interfaces defined to enable designers and system configuration managers
- **Use Open Standards**
  - Utilization of community accepted standards that are well defined/matured
- **Certify Conformance**
  - Use rigorous assessment mechanisms, interface control management and proactive conformance testing.

"Program managers are responsible for applying open systems approaches in product designs where feasible and cost-effective."

- Section 14 DoD 5000.2 –

How to bring business and technical elements together in an ecosystem?

Research Needed

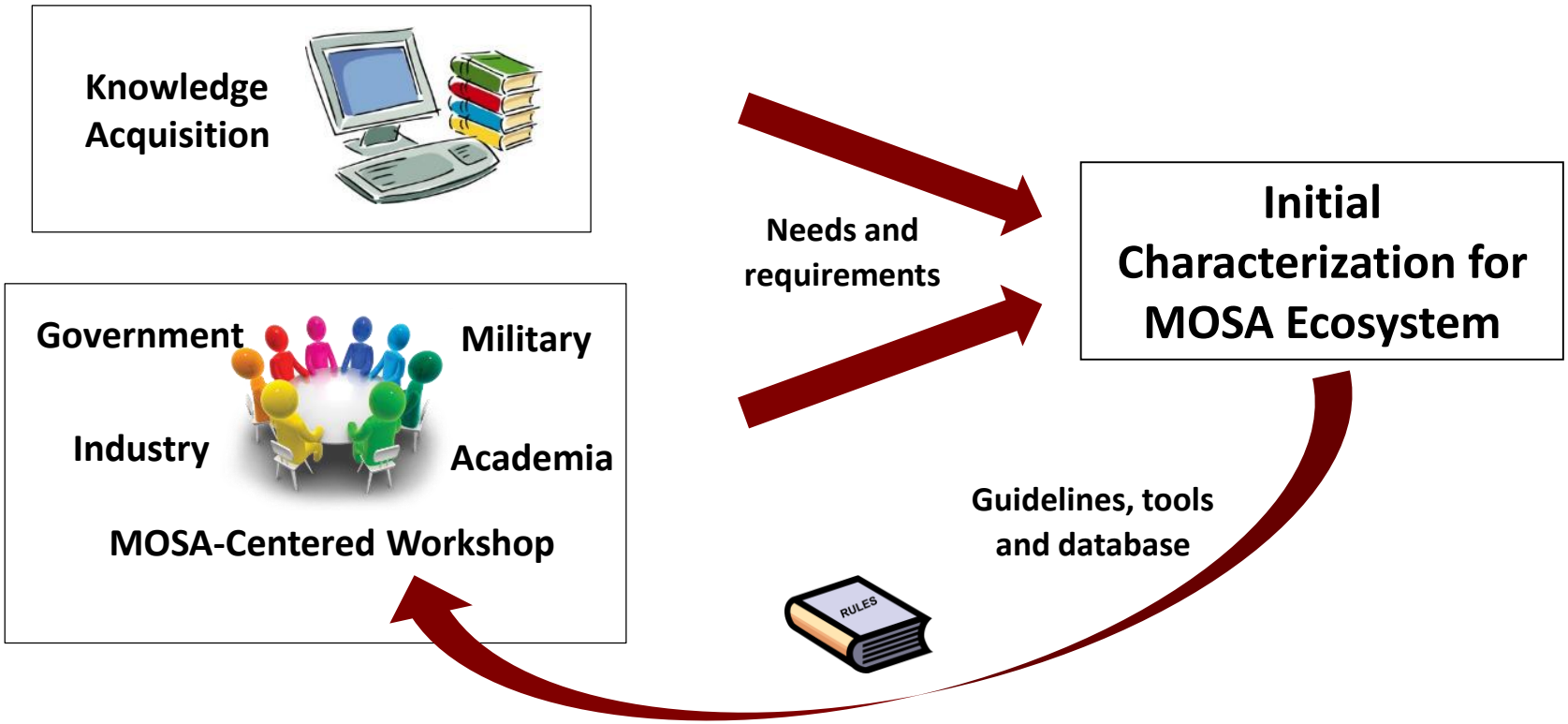
MOSA Research Tasks with SERC: FY17 RT-163, FY 18 RT-185

- Investigate development of systems to **exploit modularity** to enhance defense acquisitions and military capabilities.
- Explore **concept of an ecosystem** that facilitates adoption of modular solutions to achieve benefits (business + technical ends)
- Investigate how to **encourage modularity** to gain its benefits – conducive modular patterns, decompositions, methods, factors, catalysts etc.
- Provide **guidance and insights** to:
  - aid decision-making on modularization and achieving the intended benefits
  - Connect desired program outcomes to a MOSA goal

RT-185 objectives

- **Research Tasks for Phase I:**
  - Conduct **collaborative exchanges with key collaborators** from industry, academia, and government entities
  - **Translating knowledge artifacts** from interviews and case study deep dives into an organized repository construct
  - **Mapping** relevant knowledge artifacts **to segments of the defense acquisition lifecycle**, and to end observed benefits of modularity and openness
- **Research Tasks for Phase II:**
  - Formulate and execute a detailed plan to **map the knowledge artifacts** acquired from the deep dive and knowledge elicitation phase to an appropriate **decision-making framework**
  - Construct an **executable model,** based on decision-making framework, that captures salient dynamics and **heuristic influence mechanisms** across the range of stakeholders involved at various stages of the acquisition lifecycle

RT 163: A Prelude



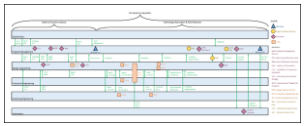
Navindran Davendralingam, Cesare Guariniello, Shashank Tamaskar, Daniel DeLaurentis, Mitchell Kerman, "Modularity research to guide MOSA implementation", The Journal of Defense Modeling and Simulation: Applications, Methodology, Technology.

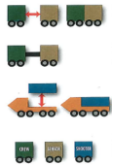
RT-185: Concept Decision-Support Framework

Literature/ Case Study Knowledge Base

Decision Support Framework

Impact on Acquisition Processes





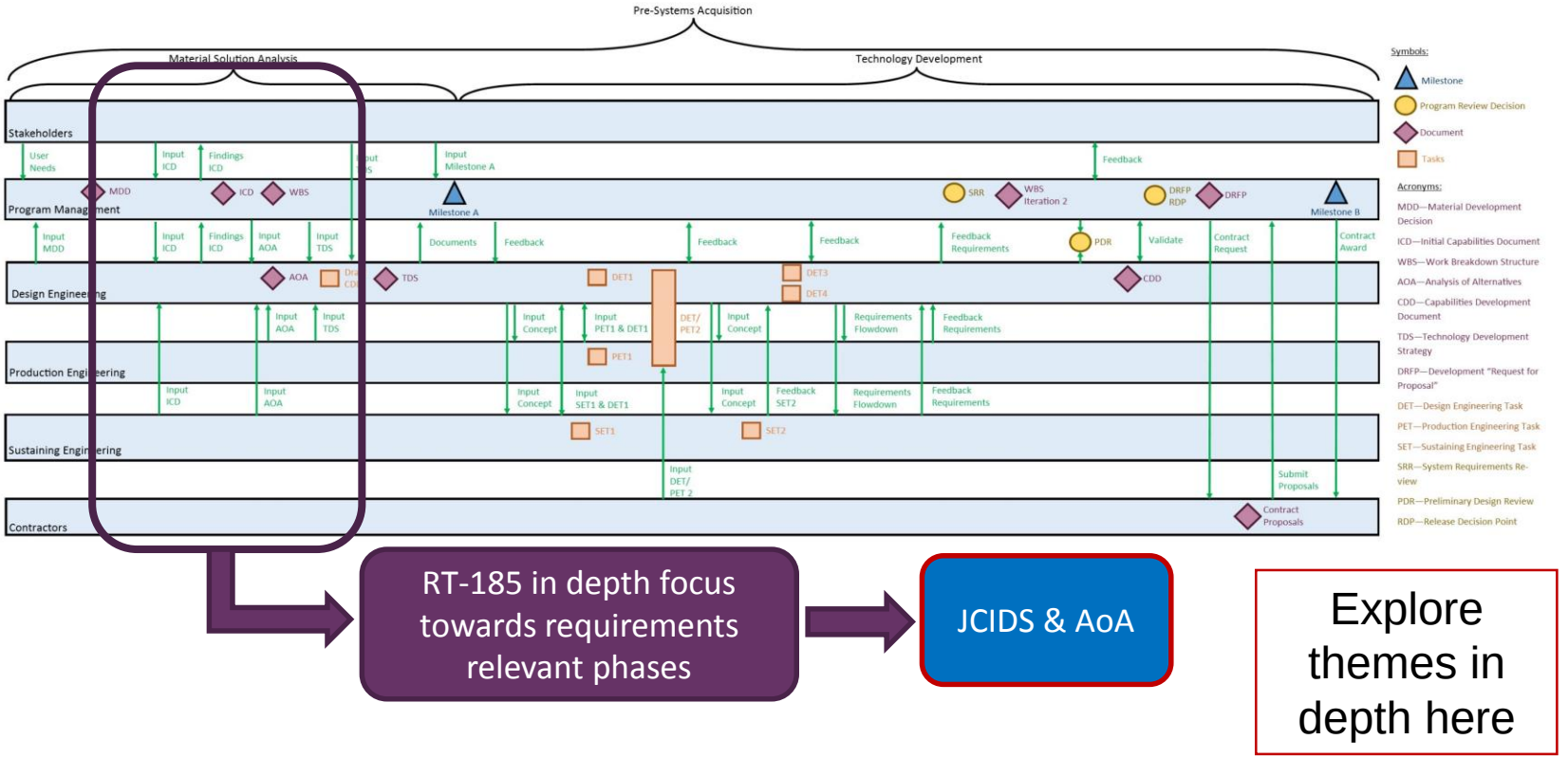
Program Manager Queries

PM Decision Feedback

Acquisition Process relevant outputs

Focusing on early stage defense acquisition lifecycle

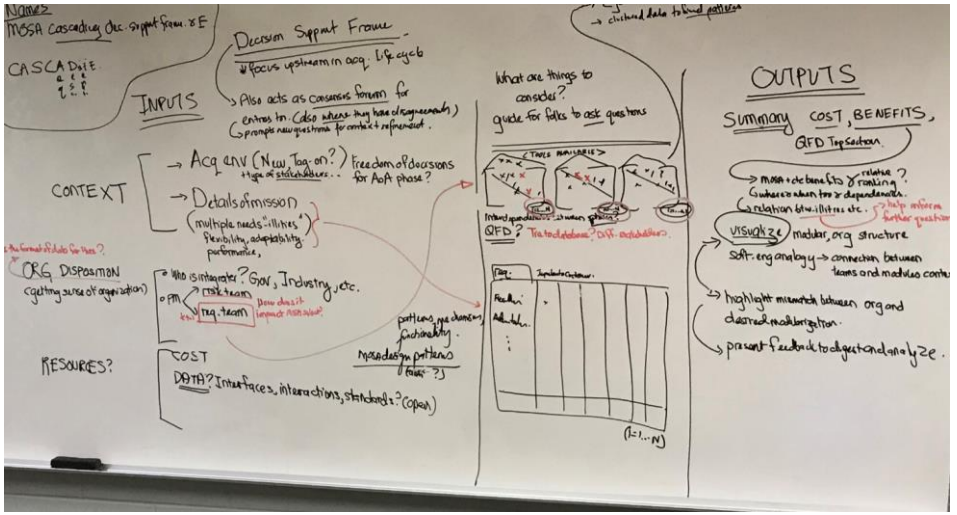
- Prior (RT-163) work looked at *overall* defense acquisition lifecycle
  - Many collaborative exchanges indicated early stage acquisition process *requirements as being key to modularity and openness*
  - MOSA adoption depends on *early support mechanisms in place*



Teamwork: On-site at Purdue

- On-site collaborative exchange between RT-185 team members
- Developed an understanding of what is required to build a MOSA decision support framework
  - —Inputs (Context, Organization Disposition, Resources)
  - —Outputs (Cost, Benefits, Relation to –ilities)
- Outcomes
  - —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

Prior Cases (e.g.) :
VICTORY
LCS
FACETS
JLTV



Decision Support Framework

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Inputs → Cascade Matrices → Outputs

Inputs

Context

Acquisition Environment
Details of mission ('-illities')

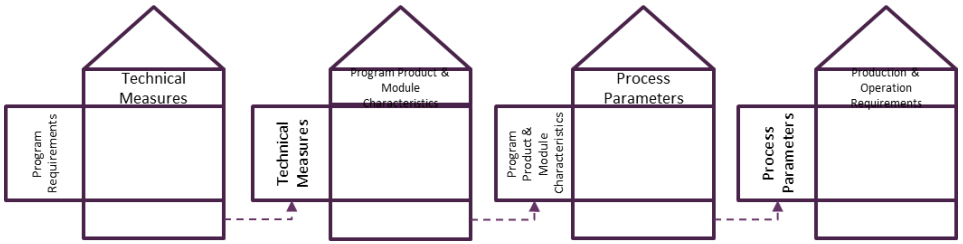
Organizational Disposition

Who is integrator?
Support Team? WGs?

Resources Available

Cost
Data, Interfaces, Interactions
Stakeholders

Cascade Matrices



Cascading interdependencies between:

- Processes in AoA phase
- Product structure and organizational units
- MOSA benefits and JCIDS/AoA phases crossover to each sub-phase?

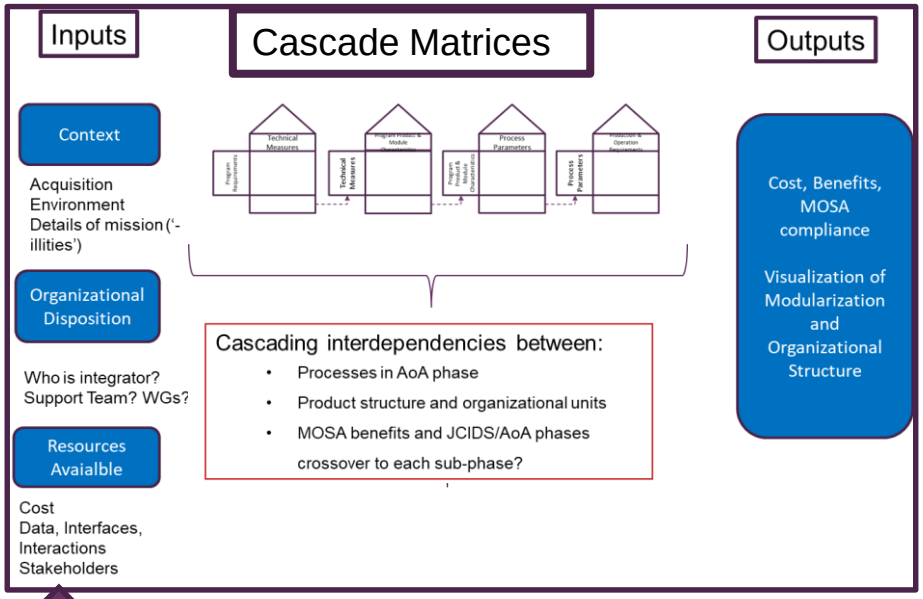
Outputs

Cost, Schedule, Risk Implications

MOSA-compliance

Product - Organizational Structure Relationships

Decision Support Framework



Envisioned User Inputs

- **JCIDS/CBA/ICD relevant information**
  - Threat type, scope of m-DotMLPf, material solution scope
  - Parent organization(s), Feasible joint organizations and WG candidates,
  - Timeline, Budget, constraints on cost

  (Reflects detailed feasible space to be explored)

Value to DSF End-User & DoD:

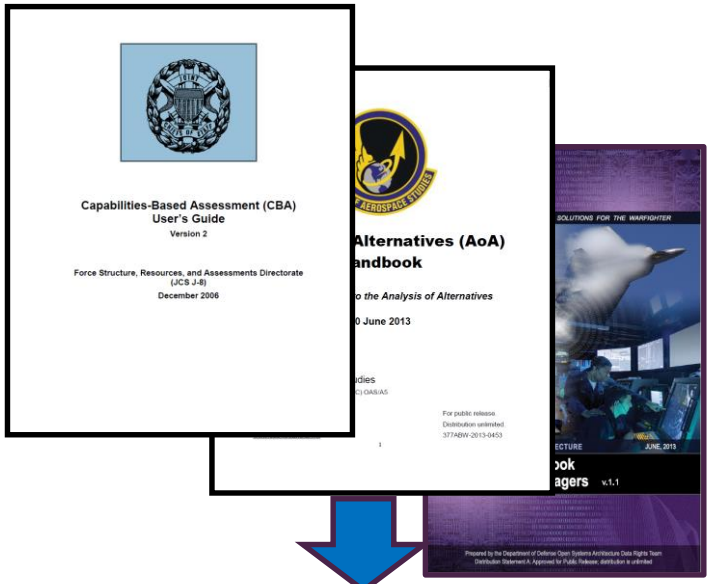
- **Tactical MOSA Value**
  (Answer questions such as)
  - What is the topology of members I want to connect to based on incentive structure?
  - How to minimize bias in MOSA decision-making by selecting most diverse and feasible set in WG w/ experience?
  - How to introduce MOSA rationalizations earlier (i.e., here in the AoA phase) in the AoA and prior phase…
- **Strategic MOSA Value**
  (Consequence of repeated use)
  - MOSA decisions more explicitly connect early stage with downstream (maybe even down to OSA language)
  - Cross AoA analysis now includes crossover with strategic contributions

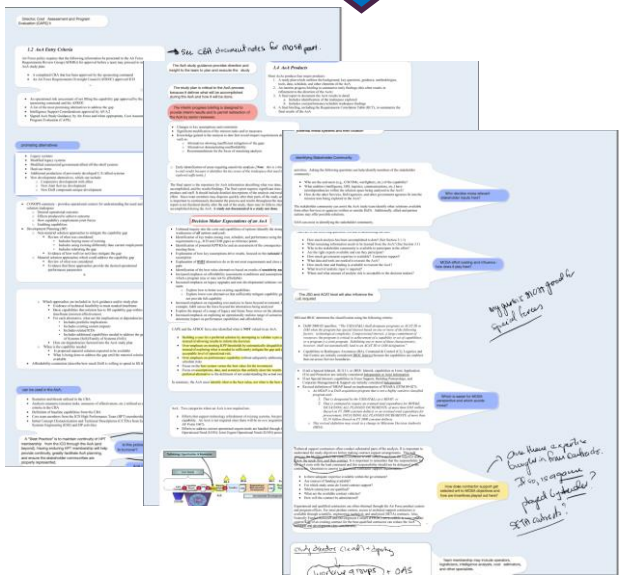
Looking at JCIDS (CBA) and AoA in Detail

- Detailed exploration of guidelines in AoA, JCIDS (CBA) process and OSA contract guidebook to determine MOSA dependencies
- Question database to inform categories and levels

Key Questions	Potential MOSA Implication	Source in AoA Guidance
Prior to AoA		
What **language is used in CBA** today from JCIDS? Are MOSA relevant terms expressed there? (Army document says there are already problem here in CBA)	Early stage 'what is the problem' is not expressed in a way that can unbiasedly admit potential MOSA solutions	AoA Guidance Chapter 1.2
What **language is used in ICD** on top of CBA input that precludes MOSA upfront? How dependent on organization?	ICD description can preclude alternatives. (E.g. JLTV already called for modular type systems early in JCIDS processs). **Classes of problems here: already done MOSA before, kinda done MOSA before, never done MOSA before**	AoA Guidance Chapter 1.2
Can AoA look at **requirements beyond just the operational material?** Typically the lifecycle part is only looked at as an afterthought. Exception: maintenance for vehicles and swap outs.	Some programs intuitively MOSA (e.g. gun w/ picatinny rails, vehicles)..others not a clear path. Need to show connection to possibilities if micro-ecosystem of MOSA doesn't exist here.	AoA Guidance Chapter 1.2
How does turnover dynamics occur when MOSA is considered? Are HPT teams changing due to something related to MOSA teams?	Changing teams alters MOSA relevant analysis, perspectives, incentives.	AoA Guidance Chapter 1.2
What **cost models exist that are relevant to MOSA** (modules, openness and their pricing) in DoD? Are they well accepted and validated?	If **cost models are not mature, risk is high**. Also cost may depend on type of program (e.g. prior existing modules, start from scratch, half way modular). **CAPE req. may be infeasible for AoA to even be conducted?**	

Question Databank MOSA

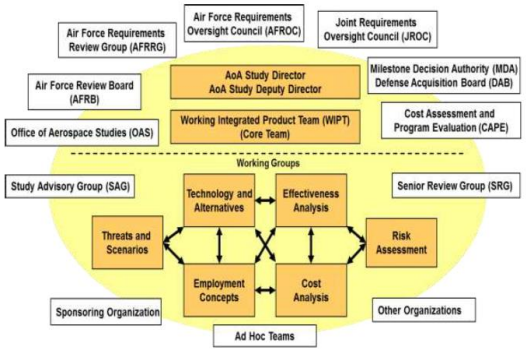




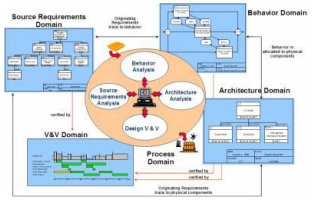
Canvass AoA/CBA\OSA

Key Elements of JCIDS/AoA (Some)

- **Organizational Elements**



- **SE Tools Elements**



Engineering Systems Group Expertise / MBSE enabled?

- **Databases and Information Elements**

- ACEIT (integrated)
- COCOMO (software)
- CRYSTAL BALL (risk)
- LSC (logistics)
- SEER (software/hardware)
- SEM (software)

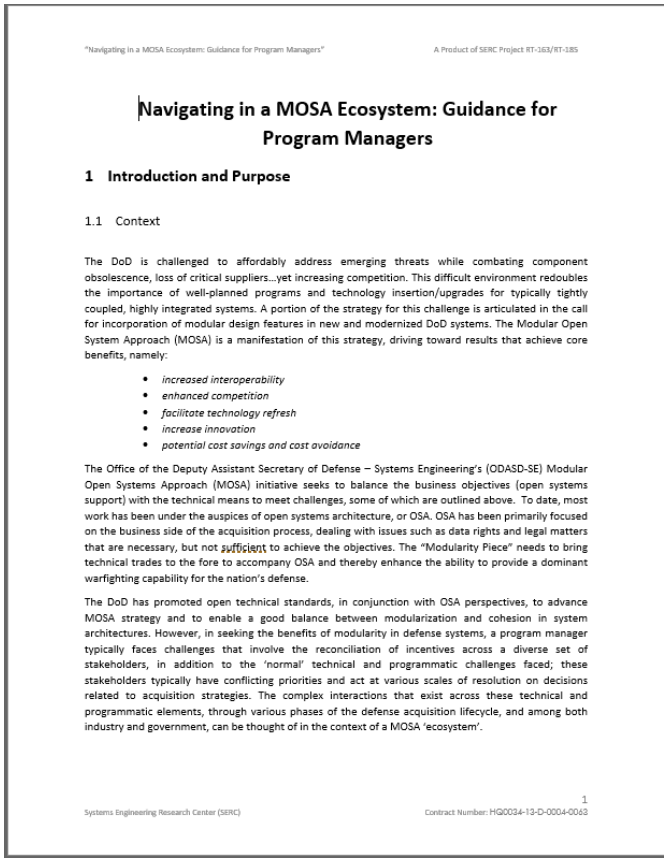
- **Prior Knowledge Elements**

- AF/A9
- Institute for Defense Analysis (IDA)
- RAND
- Defense Technical Information Center (DTIC)
- AF Knowledge Now/Intelink
- J8 Study Repository (currently known as KM/DS)
- CAPE
- Army Training and Doctrine Command's (TRADOC) Army Experiment and Study Information System https://cac.arcicportal.army.mil/ext/aesis/aesis/default.aspx)
- AT&L's Acquisition Information Repository (https://www.dodtechipedia.mil/AIR)

- **Cost-Schedule-Performance and relevant metrics**

Q: What elements we can mix and match for objective decisions related to MOSA? Impacts downstream?

Products of RT-185 Research: Publications and PM Guidance Document 2.0



"Navigating in a MOSA Ecosystem: Guidance for Program Managers" A Product of SERC Project RT-163/RT-185

Navigating in a MOSA Ecosystem: Guidance for Program Managers

1 Introduction and Purpose

1.1 Context

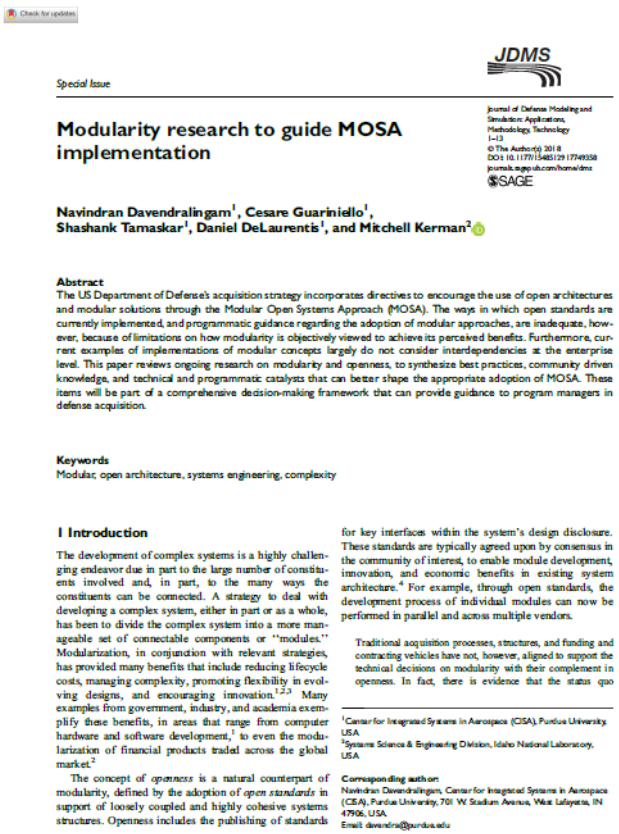
The DoD is challenged to affordably address emerging threats while combating component obsolescence, loss of critical suppliers…yet increasing competition. This difficult environment redoubles the importance of well-planned programs and technology insertion/upgrades for typically tightly coupled, highly integrated systems. A portion of the strategy for this challenge is articulated in the call for incorporation of modular design features in new and modernized DoD systems. The Modular Open System Approach (MOSA) is a manifestation of this strategy, driving toward results that achieve core benefits, namely:

- *increased interoperability*
- *enhanced competition*
- *facilitate technology refresh*
- *increase innovation*
- *potential cost savings and cost avoidance*

The Office of the Deputy Assistant Secretary of Defense – Systems Engineering's (ODASD-SE) Modular Open Systems Approach (MOSA) initiative seeks to balance the business objectives (open systems support) with the technical means to meet challenges, some of which are outlined above. To date, most work has been under the auspices of open systems architecture, or OSA. OSA has been primarily focused on the business side of the acquisition process, dealing with issues such as data rights and legal matters that are necessary, but not sufficient to achieve the objectives. The "Modularity Piece" needs to bring technical trades to the fore to accompany OSA and thereby enhance the ability to provide a dominant warfighting capability for the nation's defense.

The DoD has promoted open technical standards, in conjunction with OSA perspectives, to advance MOSA strategy and to enable a good balance between modularization and cohesion in system architectures. However, in seeking the benefits of modularity in defense systems, a program manager typically faces challenges that involve the reconciliation of incentives across a diverse set of stakeholders, in addition to the 'normal' technical and programmatic challenges faced; these stakeholders typically have conflicting priorities and act at various scales of resolution on decisions related to acquisition strategies. The complex interactions that exist across these technical and programmatic elements, through various phases of the defense acquisition lifecycle, and among both industry and government, can be thought of in the context of a MOSA 'ecosystem'.

Systems Engineering Research Center (SERC) Contract Number: HQ0034-13-D-0004-0063



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JDMS

Special Issue

Modularity research to guide MOSA implementation

Journal of Defense Modeling and Simulation: Applications, Methodology, Technology
1–13
© The Author(s) 2018
DOI: 10.1177/1548512917749358
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Navindran Davendralingam[1], Cesare Guariniello[1], Shashank Tamaskar[1], Daniel DeLaurentis[1], and Mitchell Kerman[2]

Abstract
The US Department of Defense's acquisition strategy incorporates directives to encourage the use of open architectures and modular solutions through the Modular Open Systems Approach (MOSA). The ways in which open standards are currently implemented, and programmatic guidance regarding the adoption of modular approaches, are inadequate, however, because of limitations on how modularity is objectively viewed to achieve its perceived benefits. Furthermore, current examples of implementations of modular concepts largely do not consider interdependencies at the enterprise level. This paper reviews ongoing research on modularity and openness, to synthesize best practices, community driven knowledge, and technical and programmatic catalysts that can better shape the appropriate adoption of MOSA. These items will be part of a comprehensive decision-making framework that can provide guidance to program managers in defense acquisition.

Keywords
Modular, open architecture, systems engineering, complexity

I Introduction

The development of complex systems is a highly challenging endeavor due in part to the large number of constituents involved and, in part, to the many ways the constituents can be connected. A strategy to deal with developing a complex system, either in part or as a whole, has been to divide the complex system into a more manageable set of connectable components or "modules." Modularization, in conjunction with relevant strategies, has provided many benefits that include reducing lifecycle costs, managing complexity, promoting flexibility in evolving designs, and encouraging innovation.[1,2,3] Many examples from government, industry, and academia exemplify these benefits, in areas that range from computer hardware and software development,[1] to even the modularization of financial products traded across the global market.[2]

The concept of *openness* is a natural counterpart of modularity, defined by the adoption of *open standards* in support of loosely coupled and highly cohesive systems structures. Openness includes the publishing of standards for key interfaces within the system's design disclosure. These standards are typically agreed upon by consensus in the community of interest, to enable module development, innovation, and economic benefits in existing system architecture.[4] For example, through open standards, the development process of individual modules can now be performed in parallel and across multiple vendors.

> Traditional acquisition processes, structures, and funding and contracting vehicles have not, however, aligned to support the technical decisions on modularity with their complement in openness. In fact, there is evidence that the status quo

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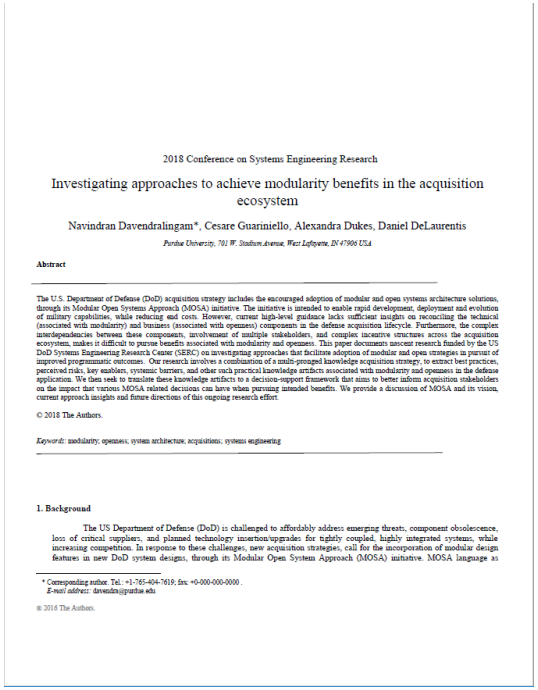

2018 Conference on Systems Engineering Research

Investigating approaches to achieve modularity benefits in the acquisition ecosystem

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Abstract

The U.S. Department of Defense (DoD) acquisition strategy includes the encouraged adoption of modular and open systems architecture solutions, through its Modular Open Systems Approach (MOSA) initiative. The initiative is intended to enable rapid development, deployment and evolution of military capabilities, while reducing end costs. However, current high-level guidance lacks sufficient insights on reconciling the technical (associated with modularity) and business (associated with openness) components in the defense acquisition lifecycle. Furthermore, the complex interdependencies between these components, involvement of multiple stakeholders, and complex incentive structures across the acquisition ecosystem, makes it difficult to pursue benefits associated with modularity and openness. This paper documents nascent research funded by the US DoD Systems Engineering Research Center (SERC) on investigating approaches that facilitate adoption of modular and open strategies in pursuit of improved programmatic outcomes. Our research involves a combination of a multi-pronged knowledge acquisition strategy, to extract best practices, perceived risks, key enablers, systemic barriers, and other such practical knowledge artifacts associated with modularity and openness in the defense application. We then seek to translate these knowledge artifacts to a decision-support framework that aims to better inform acquisition stakeholders on the impact that various MOSA related decisions can have when pursuing intended benefits. We provide a discussion of MOSA and its vision, current approach insights and future directions of this ongoing research effort.

Keywords: modularity; openness; system architecture; acquisitions; systems engineering

1. Background

The US Department of Defense (DoD) is challenged to affordably address emerging threats, component obsolescence, loss of critical suppliers, and planned technology insertion/upgrades for tightly coupled, highly integrated systems, while increasing competition. In response to these challenges, new acquisition strategies, call for the incorporation of modular design features in new DoD system designs, through its Modular Open Systems Approach (MOSA) initiative. MOSA language as

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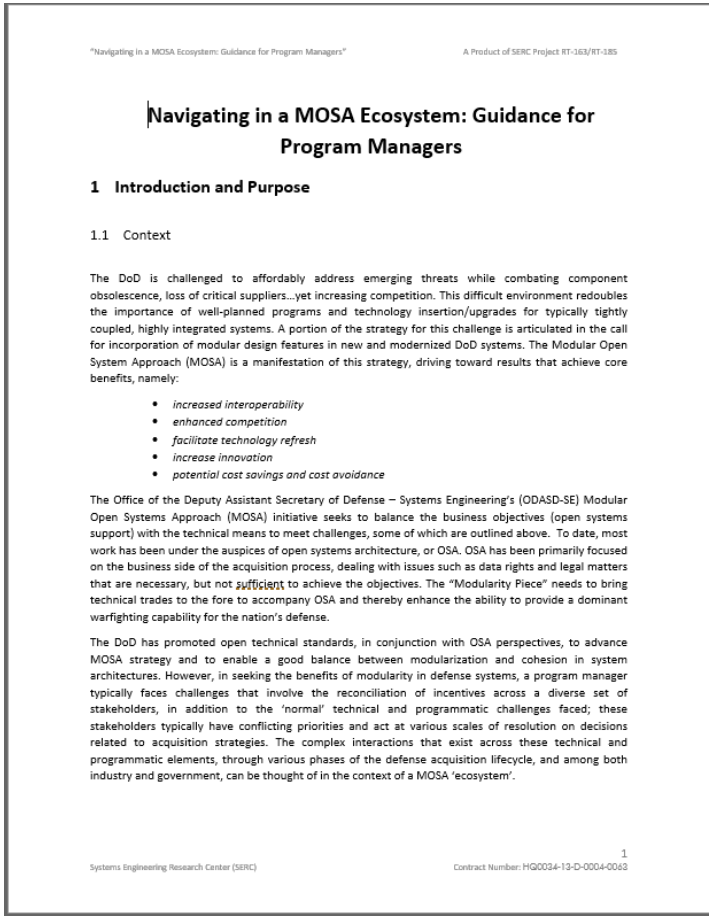
Products of RT-185 Research: Publications and PM Guidance Document 2.0

- 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, …*



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Navigating in a MOSA Ecosystem: Guidance for Program Managers

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The Office of the Deputy Assistant Secretary of Defense – Systems Engineering's (ODASD-SE) Modular Open Systems Approach (MOSA) initiative seeks to balance the business objectives (open systems support) with the technical means to meet challenges, some of which are outlined above. To date, most work has been under the auspices of open systems architecture, or OSA. OSA has been primarily focused on the business side of the acquisition process, dealing with issues such as data rights and legal matters that are necessary, but not sufficient to achieve the objectives. The "Modularity Piece" needs to bring technical trades to the fore to accompany OSA and thereby enhance the ability to provide a dominant warfighting capability for the nation's defense.

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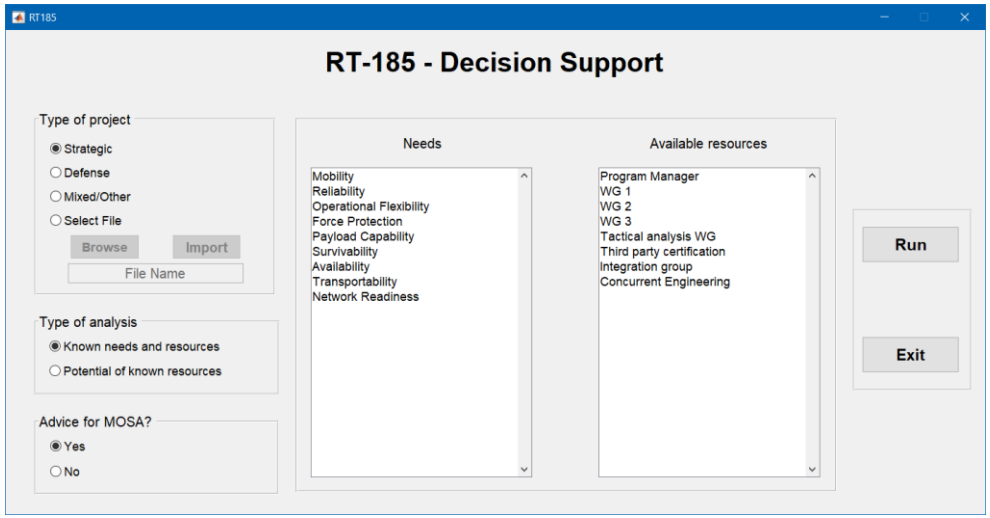
1

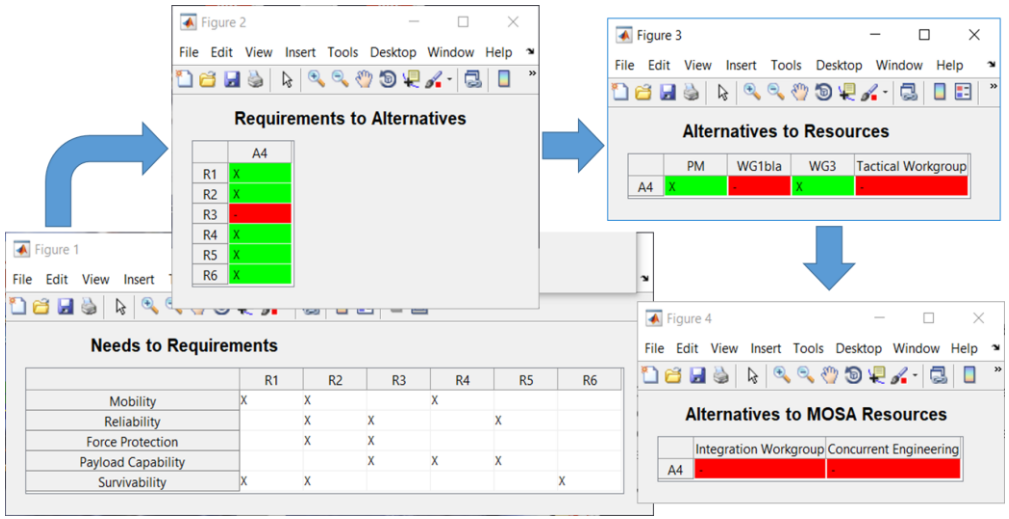
Systems Engineering Research Center (SERC) Contract Number: HQ0034-13-D-0004-0063

LCS, SWFTS, Software Engineering, AMRAP, JLTV…

Products of RT-185 Research: Prototype Decision-Support Framework Software

- Prototype Decision Support Software
  - —Choice of program needs and declaration of available resources
  - —Establishes simple cascade traceability from *needs* → *requirements* → *alternatives* → *resources* → *MOSA resources*





Potential Future Work

- **Further enrichment of knowledge repository**
  - Case studies and tacit knowledge artifacts related to early stage defense acquisition lifecycle sourced from defense acquisition community (academia, gov, industry)
- **Partnered development of prototype toolset and PM document towards specified program outcomes**
  - Alignment of activities to benefits immediate 'customer' and have future benefits for other organizations
- **Expand context to beyond early stage defense lifecycle considerations**
  - e.g. MOSA implications on post-Milestone A, supply chain, sustainability.

Thank you

This material is based upon work supported, in whole or in part, by the U.S. Department of Defense through the Systems Engineering Research Center (SERC) under Contract HQ0034-13-D-0004-0063. SERC is a federally funded University Affiliated Research Center managed by Stevens Institute of Technology.

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