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

Sponsor: ODASD(SE)

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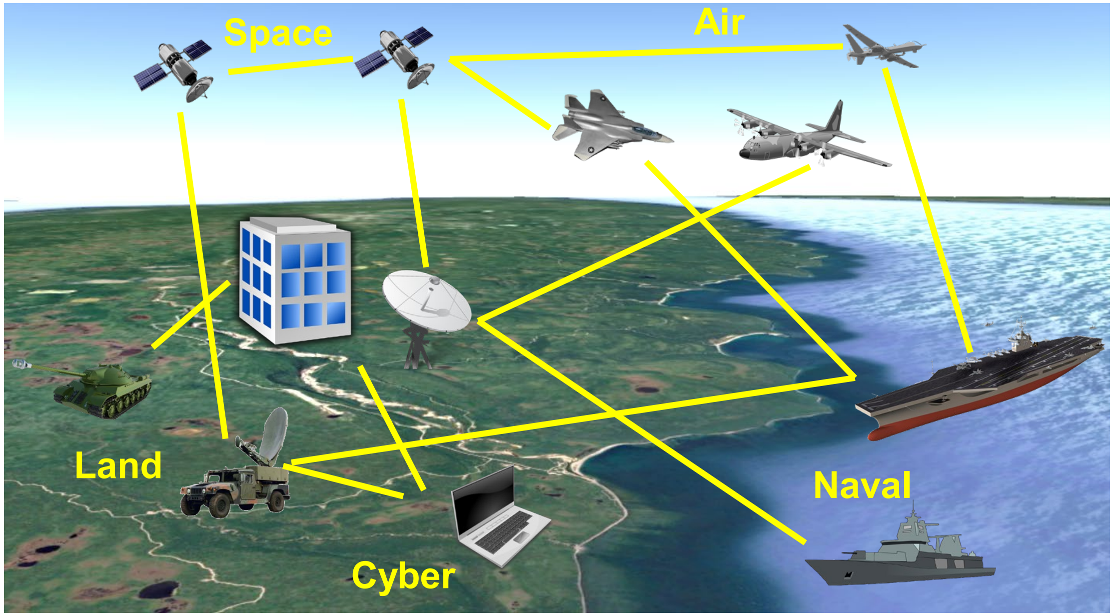
"The" Problem: challenges in a multi-domain battle scenario

- 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"

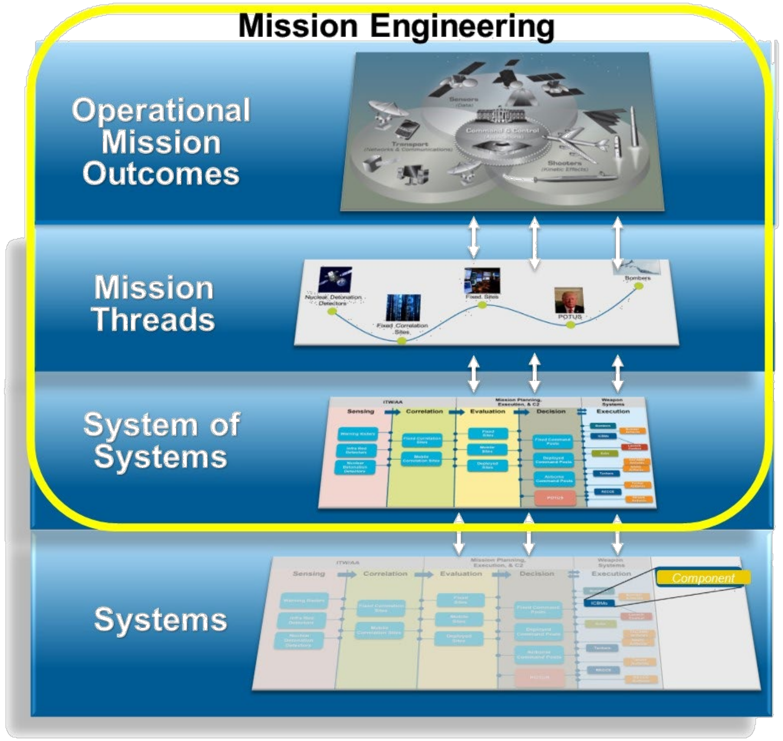


In this context, DOD acquisition challenges are significant:

- **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: <u>strategies and tools </u>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?

WRT-1002 Research Team

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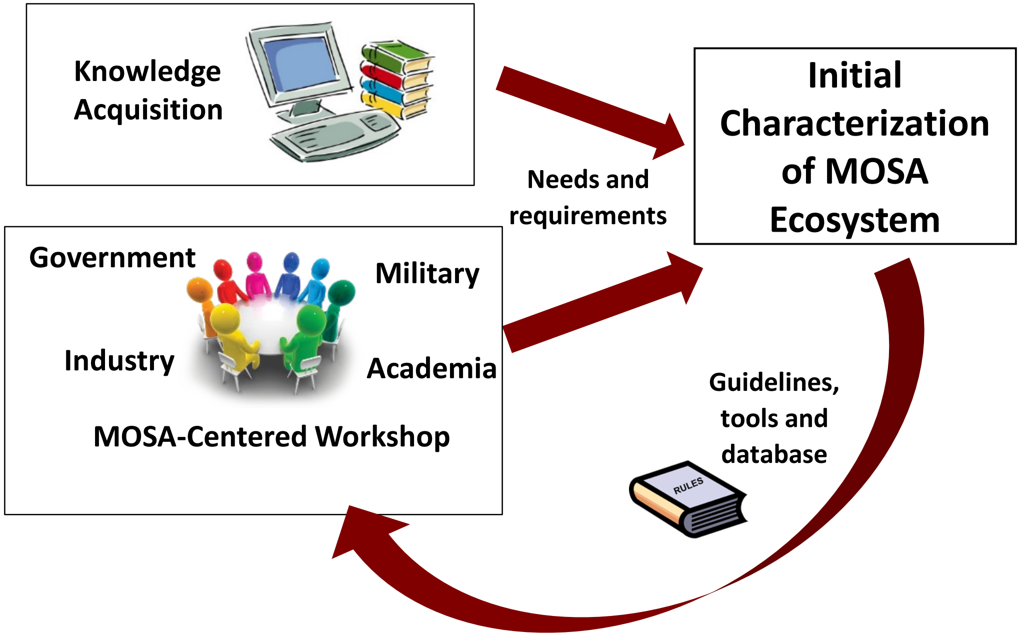
Previous Learning & Findings (1)



- **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

Previous Learning & Findings (2)

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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**

Inputs

QFD Cascading Matrices

Outputs

Context

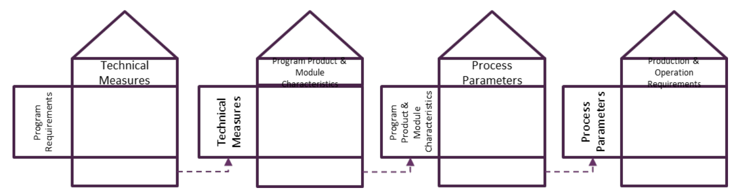
Acquisition
Environment
Details of mission
('-illities')

Organizational Disposition

Who is integrator?
Support Team? WGs?

Resources Available

Cost
Data, Interfaces,
Interactions
Stakeholders



Translate knowledge from AoA, JCIDS, OSA contract guidebook, and case studies into cascading dependencies, PM guidance document and prototype software

Cost, Schedule, Risk Implications

Adherence to MOSA principles

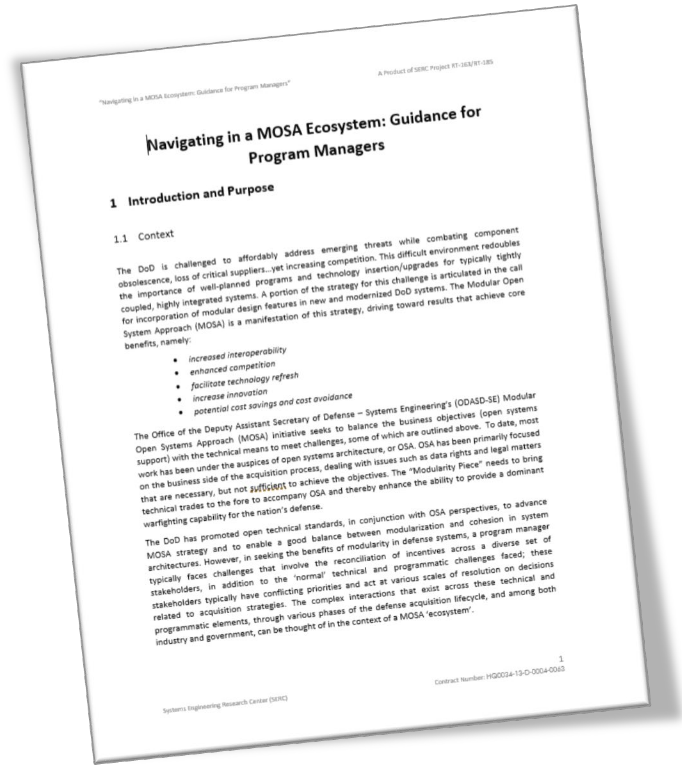
Product - Organizational Structure Relationships

Previous Learning & Findings (3): 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



"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'.

1

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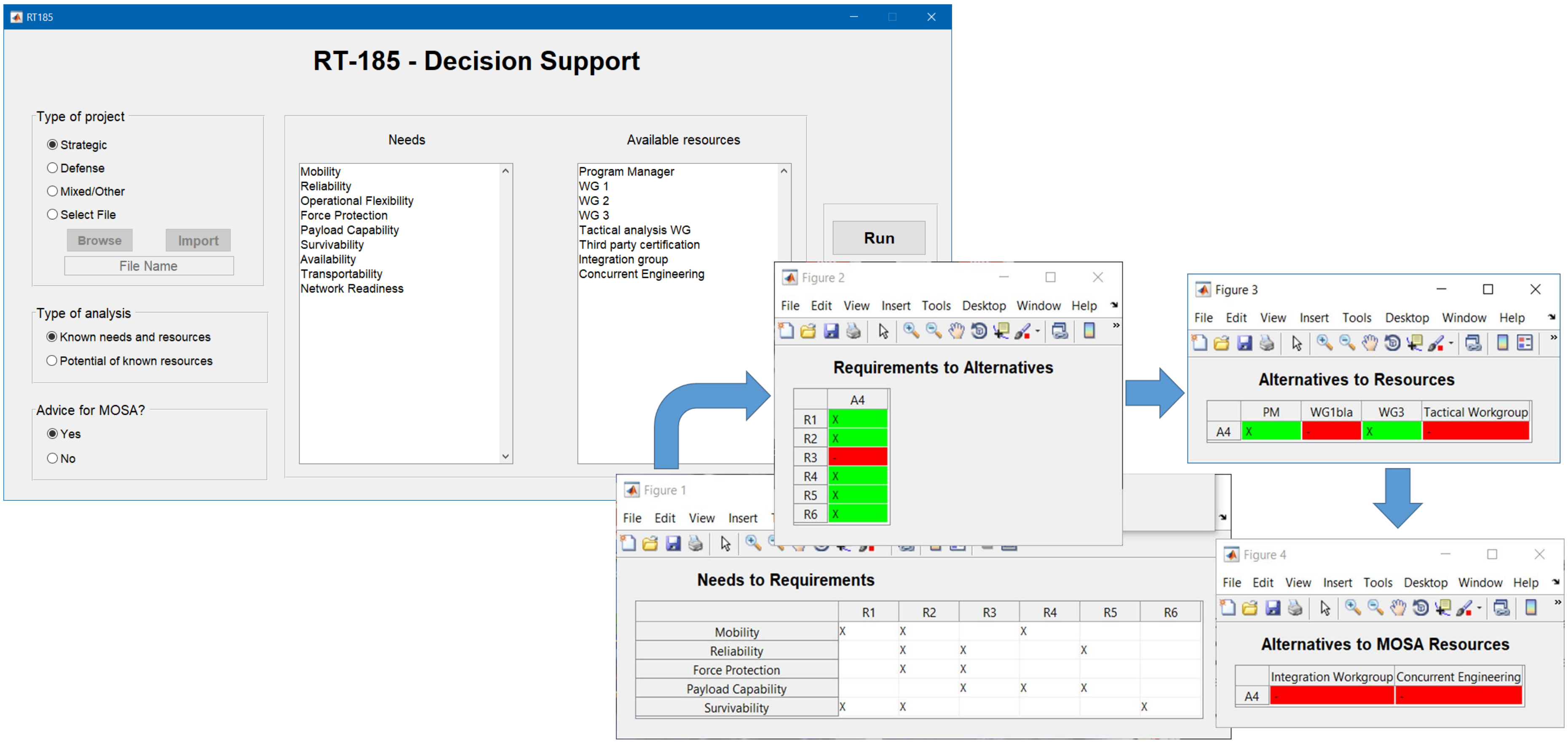
Previous Learning & Findings (4): DSF software 1.0

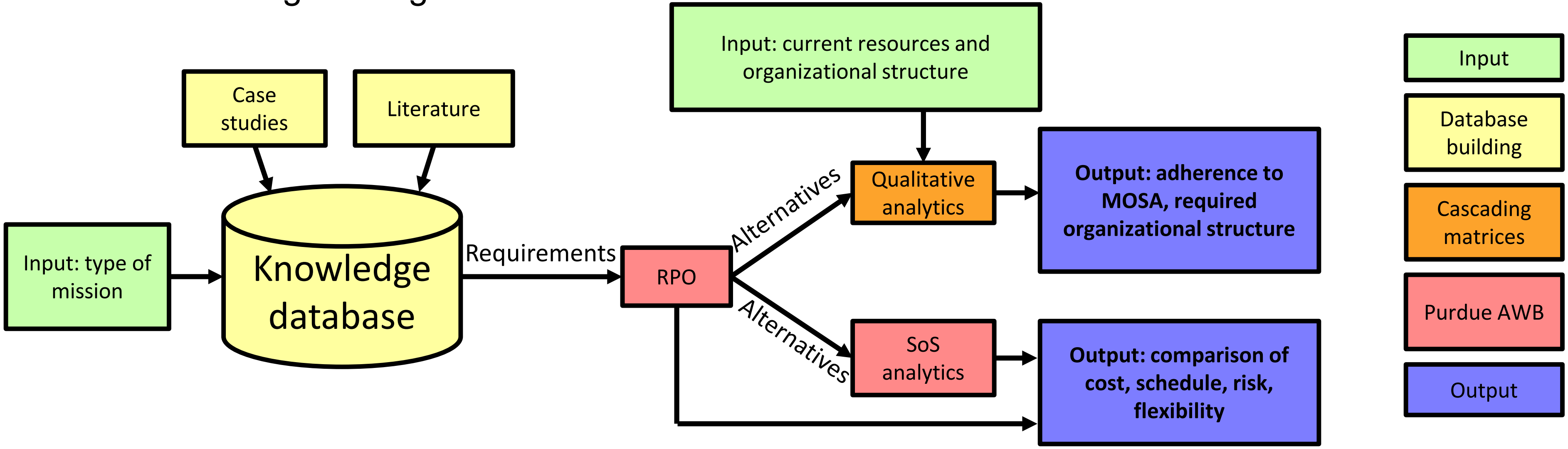
- Prototype decision support software
  - Simple cascade traceability *needs* → *requirements* → *alternatives* → *required resources* ***including organizational requirements***
  - Oriented to early phase and AoA



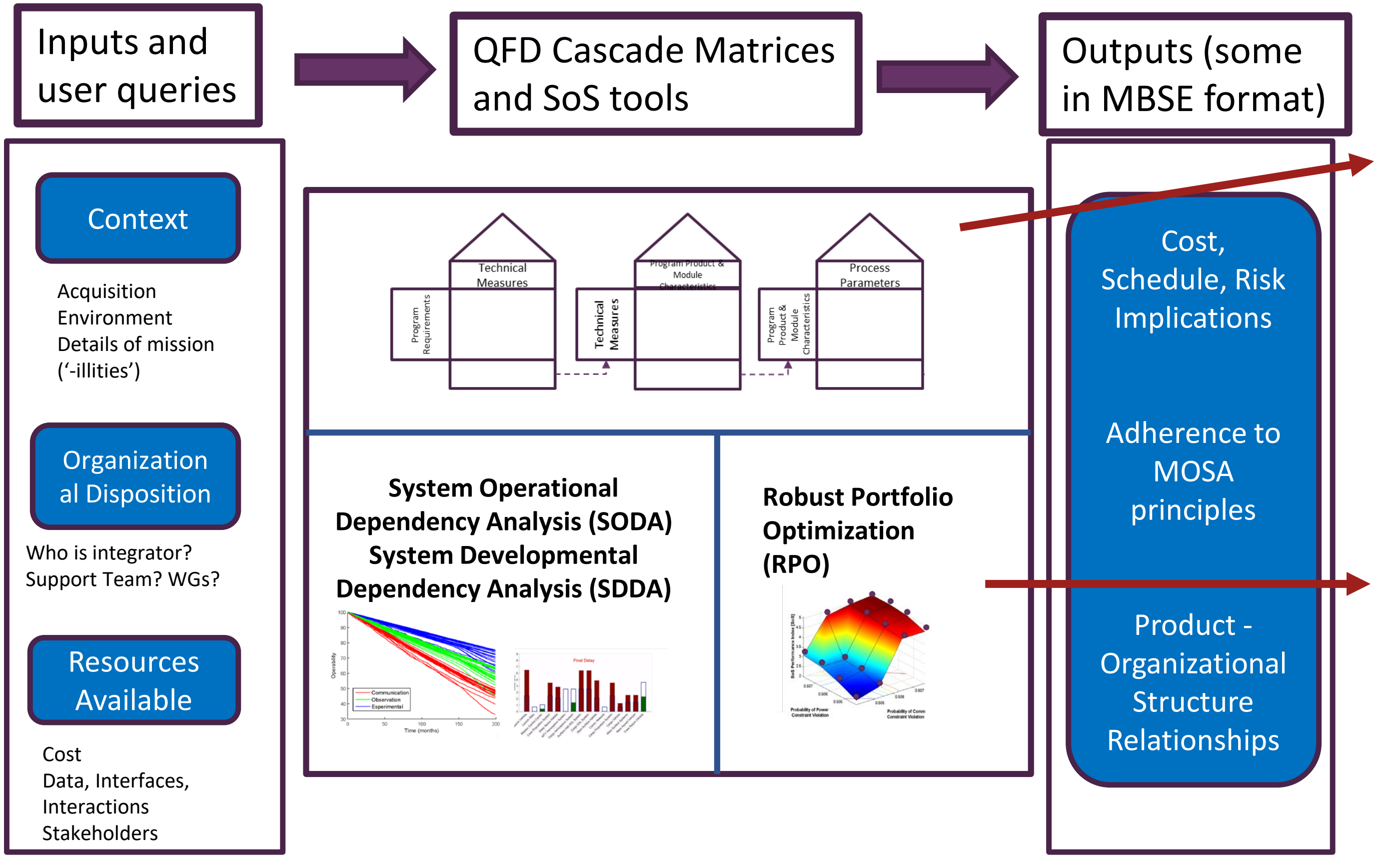
WRT-1002: objectives and workflow

- 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 verity 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

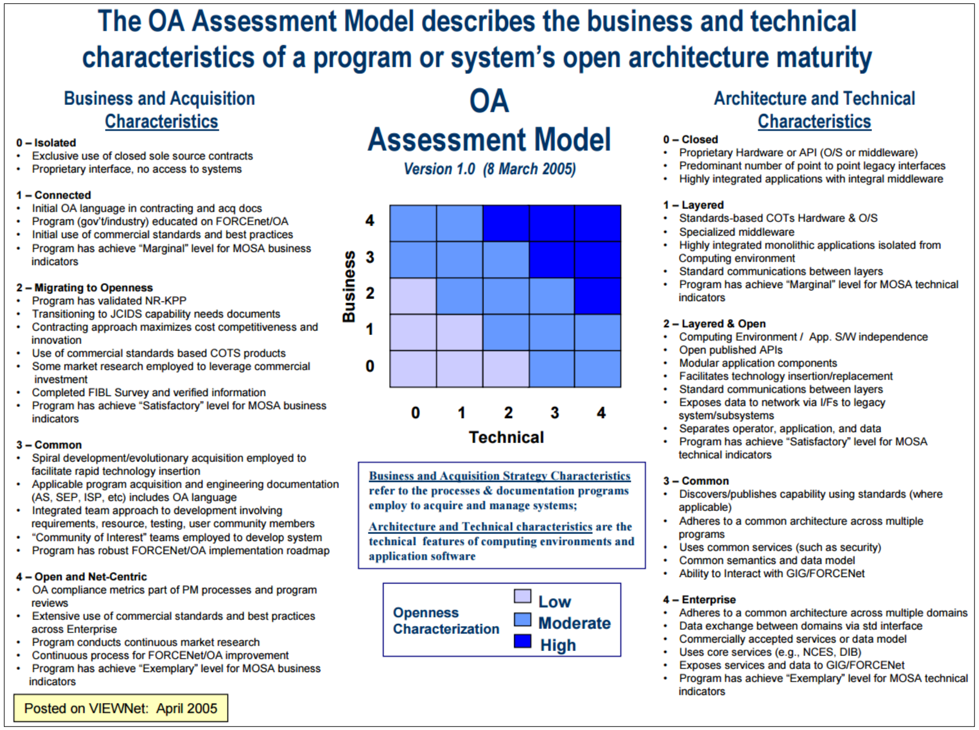


- **Qualitative**
- Aimed at adherence to MOSA principles and **organizational structure**
- Based on cascading matrices to relate program requirements to management and production requirements

- **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

Analysis of historical reporting data and/or case studies

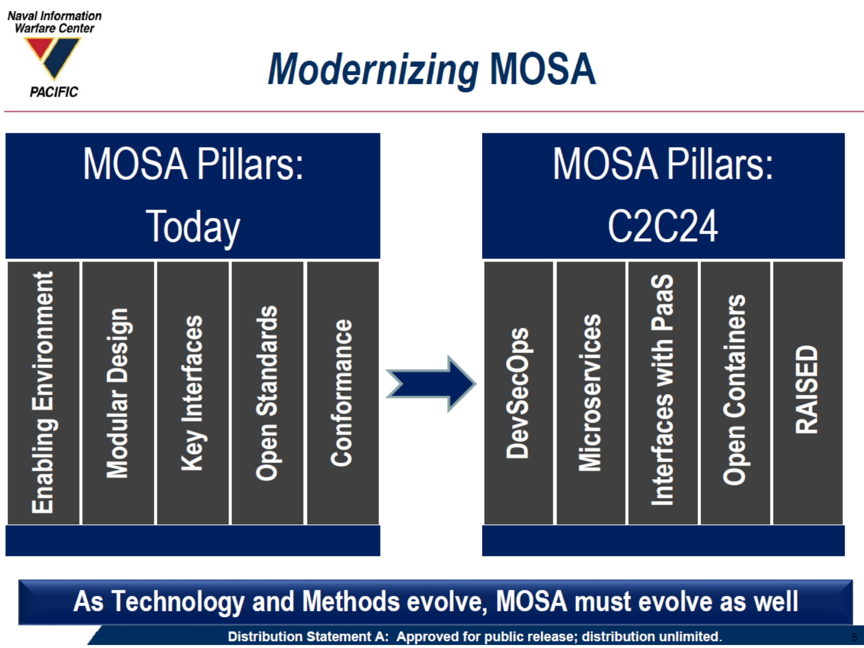
- MOSWG
  - — Experience on required assets towards MOSA ecosystem
  - — How to evaluate “amount” of adherence to MOSA principles and benefits of MOSA
- VICTORY program
  - — VICTORY provides a standard electronic systems architecture for ground vehicles
  - — Defines standard modules and interfaces, 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 point 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)

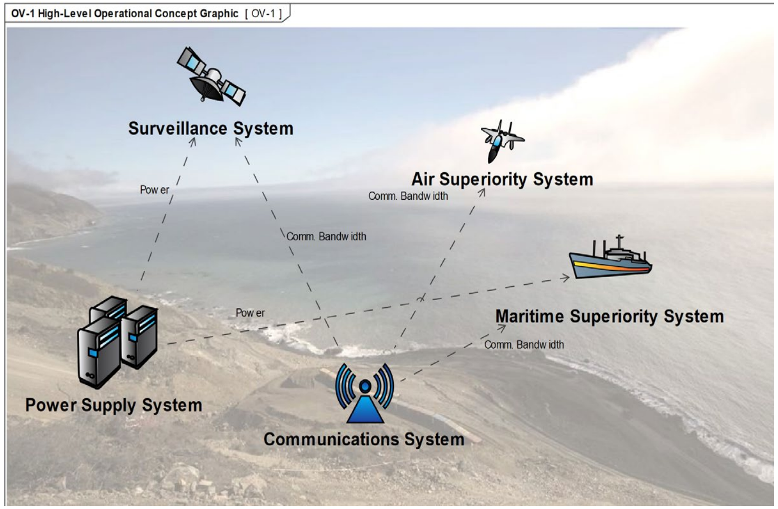


Recent Learnings from the VICTORY interaction

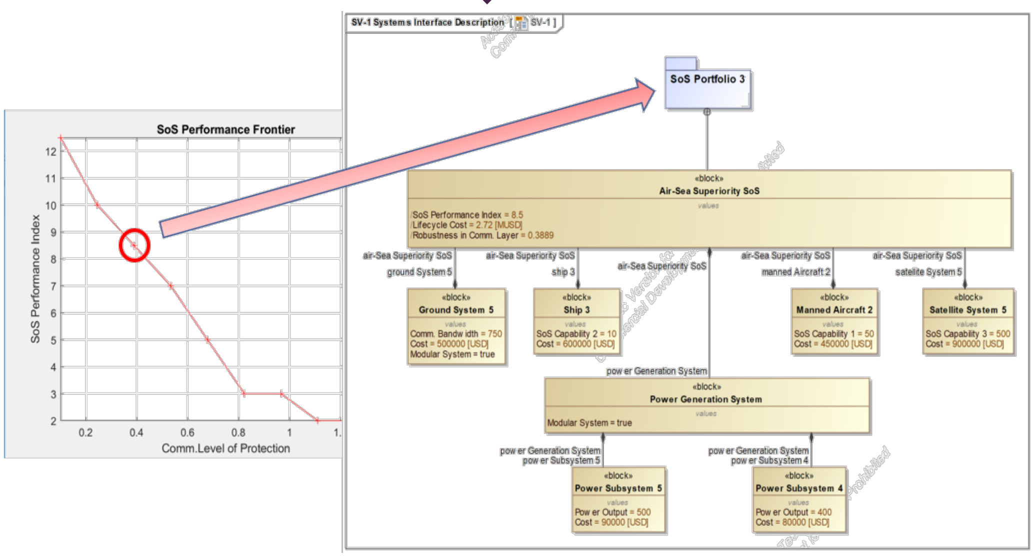
Deep Dive into VICTORY conducted by project collaborator Dr. Gary Witus

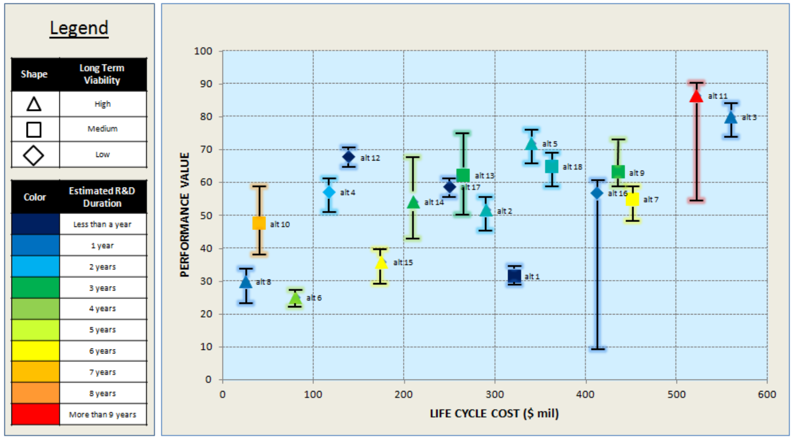
- The VICTORY architecture is a set of open standards for networking and communication
  - Meant to be adaptable as needed by different vehicle system development programs
  - Some of the standards allow variable fields, to be specified by the project, subcontractors and departmental teams with additional 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

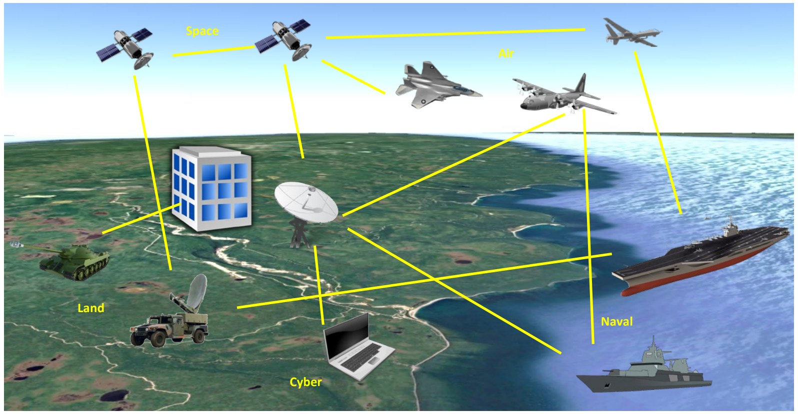
Deep Dive into OAAT conducted by project collaborator Dr. Charles Domercant

- 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

Area or Section	Section	Total Questions Applicable	Total Questions Not Applicable	Max Score	Achieved	Normalized
A	Open Systems Approach	2	0	8	2	25.0%
B	Open Architecture	2	0	8	2	25.0%
C	Open Modular Design	3	0	12	3	25.0%
D	Interface Design and Management	4	0	16	4	25.0%
E	Treatment of Proprietary Elements	4	0	16	4	25.0%
F	Open Business Practices	4	0	16	4	25.0%
G	Peer Review Rights	3	0	12	3	25.0%
H	Technical Insertion	4	0	16	4	25.0%
I	Commercial Standards	1	0	4	1	25.0%
J	Compliance	18	0	72	18	25.0%
	Combined Programmatic Rating	**40**	**0**	**252**	**63**	**25.0%**
K	Design Tenet: Interoperability	5	0	20	0	0.0%
L	Design Tenet: Maintainability	2	0	8	0	0.0%
M	Design Tenet: Extensibility	3	0	12	0	0.0%
N	Design Tenet: Composability	2	0	8	0	0.0%
O	Design Tenet: Reusability	4	0	16	0	0.0%
P	General Design Tenets	13	0	52	0	0.0%
	Combined Technical Rating	**29**	**0**	**196**	**0**	**0.0%**

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

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

			Support Input		Support Output		System Capabilities (Outputs)					SoS Capabilities (Outputs)			Cost
No.	System Type	System Name	Resupply	Power	Resupply	Power	SC1 = Attack Air - Air	SC2 = Attack Air-Ground	...	SC19 = Mobility Sea	SC20 = Mobility Air	Air Superiority SOS1 = f(SC1, SC20, SC22)	Reconnaissance SOS2 = f(SC19-SC23)	Naval Superiority SOS3 = f(SC9,SC18, SC19)	Cost [$]
1	Ground Systems	Infantry Platoon	10	0	0	0	10	10		[30, 5]	[M1, M2]	a*SC1 + b*SC20 + c*SC22	0	0	
2		Combat Engineers								[10, 20]	[M1, M2]	0	0	0	
3		Airborne Infantry										0	0	0	
6		Jeep Willis	0	0	10	0						0	0	0	
7		"Deuce and a half" (supply truck)										0	0	0	
8	Air Systems	P-51 Mustang										0	0	0	
9		Boeing B-17										0	0	0	
10		C-47										0	0	0	
11	Naval Systems	Allen M. Sumner Destroyer										0	0	0	
14		Battleship										0	0	0	
15	Space Systems	Earth Observation Satellite										0	0	0	
16		Communication Relay Satellite										0	0	0	

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

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		Support Input Requirement				Support Output Requirement							
System Type	System Name	Transport	Refuel	Communication Relay	Operator	Transport	Refuel	Communication Relay	Operator	SC1 = Attack Air - Air	SC2 = Attack Air-Ground	SC3 = Attack Air-Sea	SC4 = Attack Ground - Air
-	-	[Transport range (mi), transport capacity (lb)]	[Fuel capacity (lb)]	[Rating (n.d.)]	[Number of Operators]	[Transport range (mi), transport capacity (lb)]	[Fuel capacity (lb)]	[Rating (n.d.)]	[Number of Operators]	[Weapons Range (mi), Stopping power (n.d.)]	[Weapons Range (mi), Stopping power (n.d.)]	[Weapons Range (mi), Stopping power (n.d.)]	[Weapons Range (mi), Stopping power (n.d.)]
Air Systems	P-51 Mustang	[0, 2000]	2795	0	1	[0, 0]	0	0	0	[3, 4]	[3, 4]	[3, 4]	[0, 0]
	B-17 Flying Fortress	[0, 6000]	18500	0	10	[0, 0]	0	0	0	[2, 5]	[2, 5]	[2, 5]	[0, 0]
	C-47	[0, 0]	5369	0	4	[3800, 6000]	0	0	0	[0, 0]	[0, 0]	[0, 0]	[0, 0]
	B-52H Stratofortress	[0, 60000]	321000	1	5	[0, 0]	0	0	0	[1500, 6]	[1500, 6]	[1500, 6]	[0, 0]
	B-2 Spirit	[0, 40000]	167000	1	2	[0, 0]	0	0	0	[8, 6]	[8, 6]	[8, 6]	[0, 0]
Ground Systems	Infantry Platoon	[10, 1845]	0	0	42	[0,0]	0	0	0	[0,0]	[0,0]	[0,0]	[1, 1]
	M114 155mm Howitzer	[0, 12480]	0	0	4	[0,0]	0	0	0	[0,0]	[0,0]	[0,0]	[0, 0]
	M-4 Sherman	[150, 1251]	869	0	5	[0,0]	0	0	0	[0,0]	[0,0]	[0,0]	[2, 2]
	M8 Greyhound	[175, 274]	353	0	4	[0,0]	0	0	0	[0,0]	[0,0]	[0,0]	[2, 2]
	Jeep Willis	[0, 0]	95	0	1	[150, 360]	0	0	0	[0,0]	[0,0]	[0,0]	[0,0]
	"Deuce and a half" (supply truck)	[0, 0]	378	0	1	[150, 7600]	0	0	0	[0,0]	[0,0]	[0,0]	[0,0]
	Advanced Targeting Pod	[0, 0]	0	1	0	[0,0]	0	0	0	[0,0]	[0,0]	[0,0]	[0,0]
	TARDEC Chassis	[0, 0]	378	0	1	[100, 5000]	0	0	0	[0,0]	[0,0]	[0,0]	[0,0]
	TARDEC Anti Air Module	[100, 879]	0	0	4	[0,0]	0	0	0	[0,0]	[0,0]	[0,0]	[2, 2]
	TARDEC Artillery Module	[100, 1750]	0	0	4	[0,0]	0	0	0	[0,0]	[0,0]	[0,0]	[0, 0]
	TARDEC Personal Module	[100,0]	0	0	0	[0, 3000]	0	0	0	[0,0]	[0,0]	[0,0]	[0,0]
	Bofors 40 mm gun (L60)	[100, 4800]	0	0	4	[0,0]	0	0	0	[0,0]	[0,0]	[0,0]	[3, 2]
	Refuel Depot	[0,0]	0	0	0	[0,0]	100000	0	0	[0, 0]	[0, 0]	[0, 0]	[0, 0]
	Resupply Depot	[0,0]	0	0	0	[0, 100000]	0	0	0	[0, 0]	[0, 0]	[0, 0]	[0, 0]
Naval Systems	Allen M. Sumner Destroyer	[0, 0]	0	0	336	[0, 0]	0	0	0	[0, 0]	[0, 0]	[0, 0]	[0, 0]
	Higgins Boat (LCVP)	[0, 17850]	0	0	3	[10, 8100]	0	0	0	[0, 0]	[0, 0]	[0, 0]	[0, 0]
	Landing Ship, Tank (LST)	[0, 0]	0	0	140	[10000, 107100]	0	0	0	[0, 0]	[0, 0]	[0, 0]	[0, 0]
	Battleship	[0, 0]	0	0	2,220	[0, 0]	0	0	0	[0, 0]	[0, 0]	[0, 0]	[0, 0]

Database of required/provided support

Database of systems capabilities

Modular systems

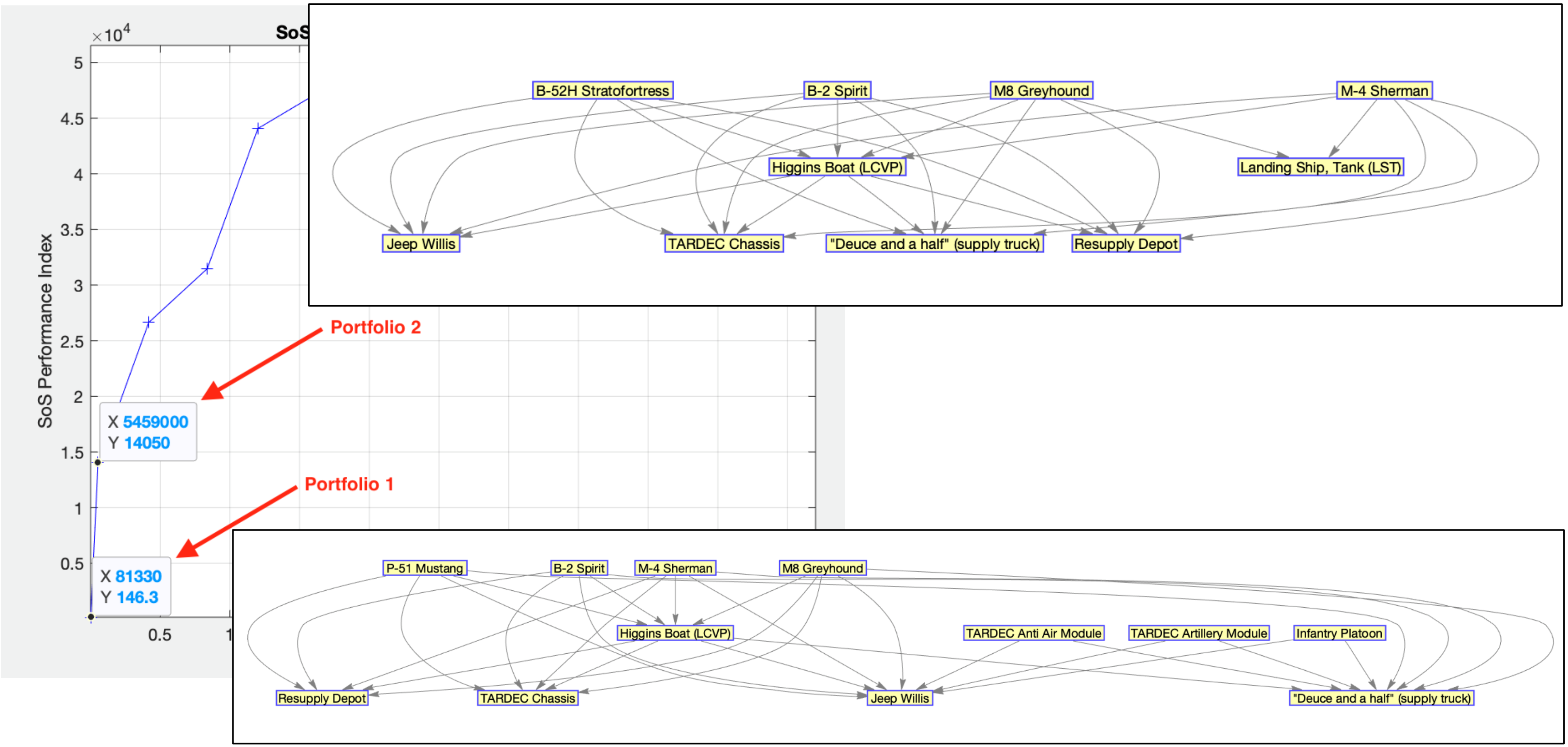
For initial assessment (or future technologies), set-based design is ideal

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

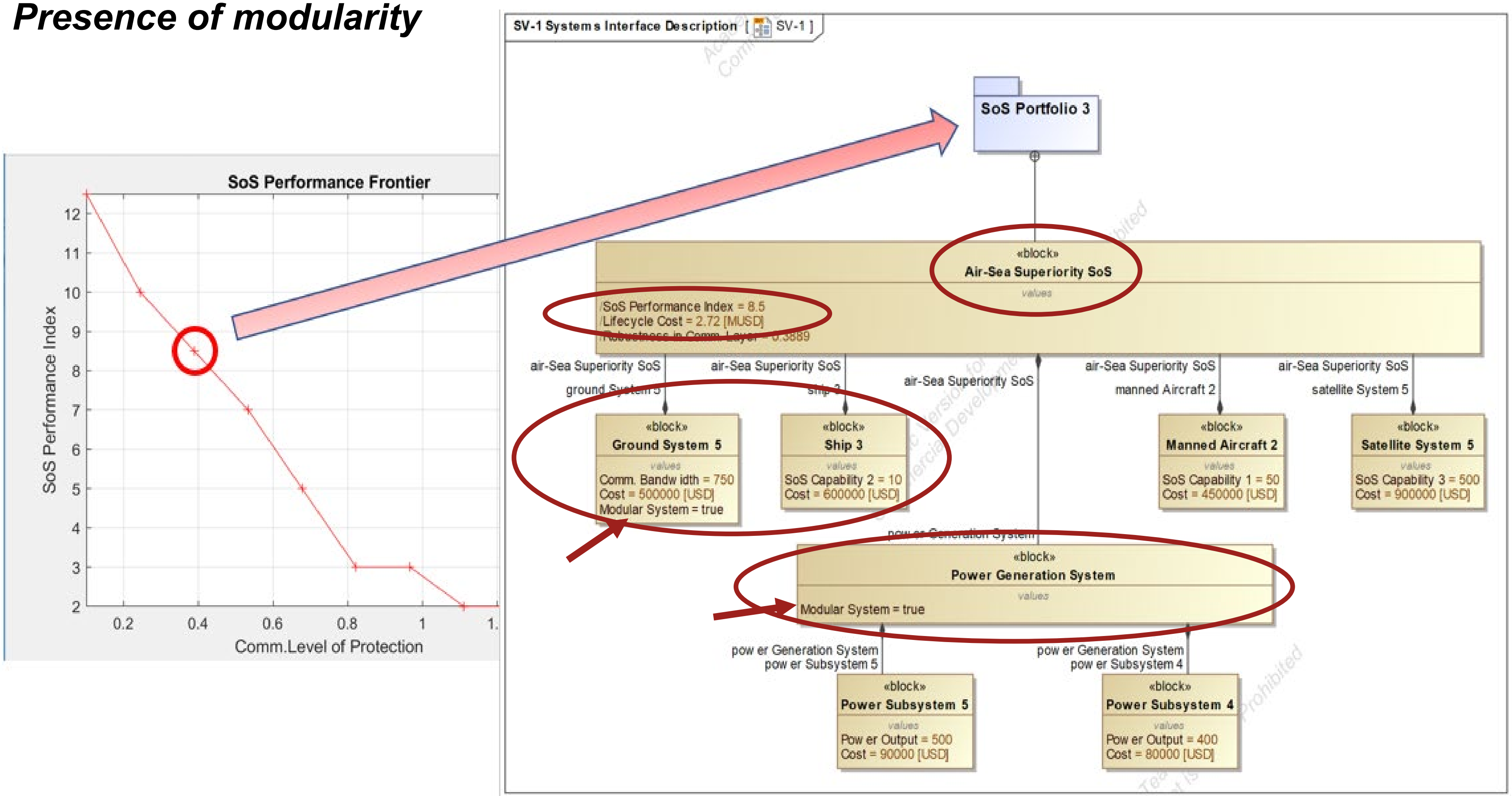
Outputs of the DSF 2.0 (1)

- 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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