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

Sponsor: ODASD(SE)

Presented on behalf of research team by:
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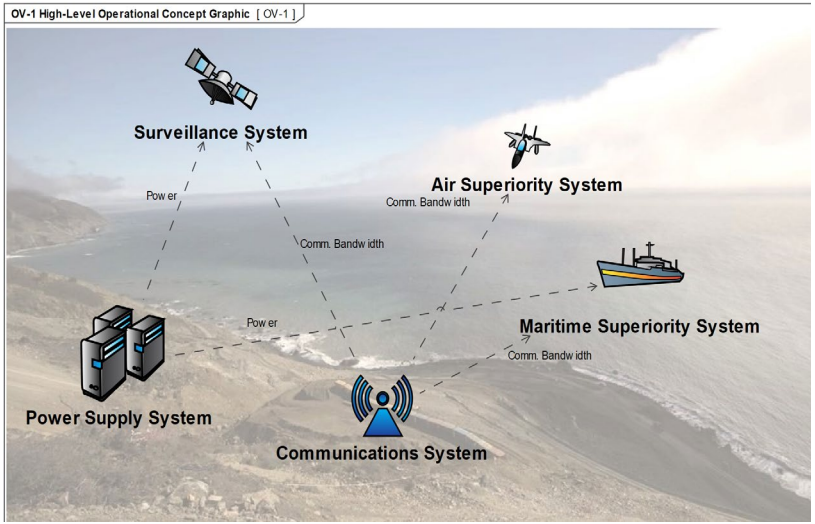
"The" problem: limitations of current approach in multi-domain battle scenario

- Complexity
  - Size
  - Interactions
  - Dynamics
- **Trade space for modularity**
  - **Mission level, SoS level, system level**
  - **Competing metrics**
- Uncertainty
  - Performance/cost
  - Future missions
  - Gradual development

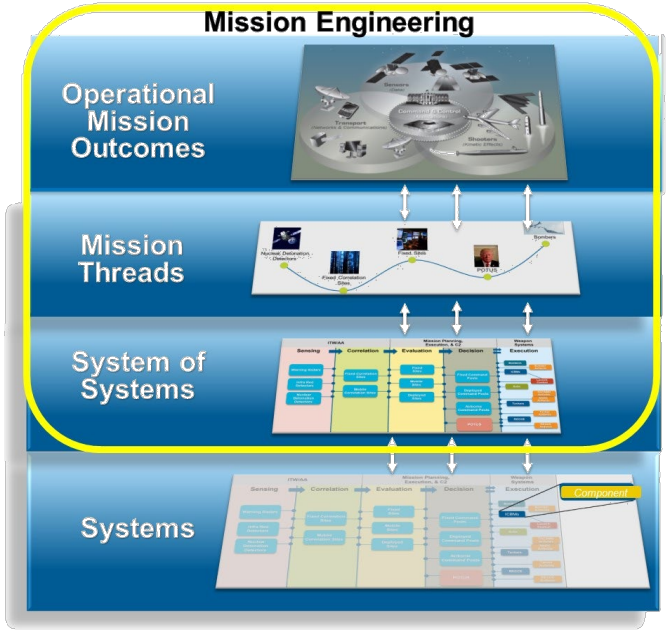


In this context, DOD acquisition challenges:

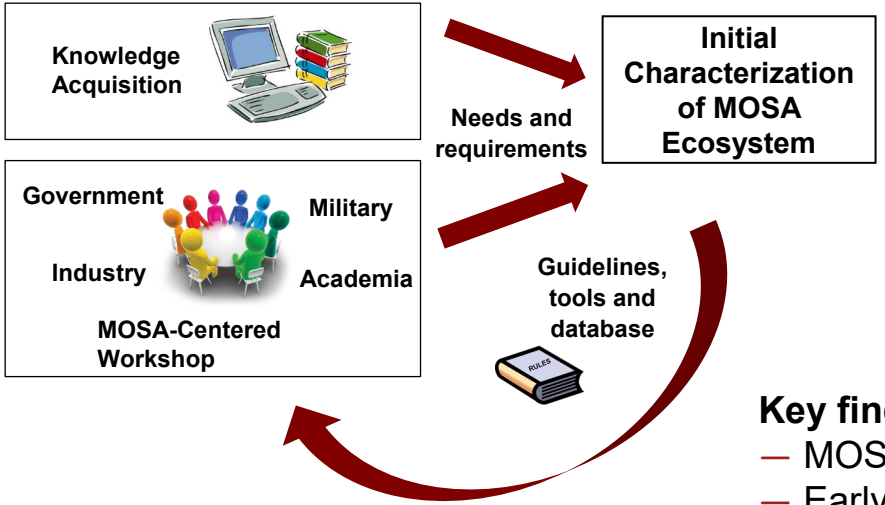
- **Affordably** address emerging threats
- Component **obsolescence**
- Planned **technology upgrade** for tightly coupled, highly integrated systems and dynamic missions

Why Modular Open Systems Approach (MOSA)?

- MOSA encourages adoption of modularization and open architectures
  - Speed of delivery
  - Flexibility
  - Cost reduction
- Findings from previous research tasks:
  - Modularity is not a goal but a means to achieve benefits
  - "Doing good MOSA" is not only about the architecture but about readiness of organizations
- Objectives
  - Develop strategies and tools to be successful in MOSA ecosystem
  - Identify guidelines for implementation
  - Quantify the benefits
  - Support both technical and managerial aspects



Identify user needs: a MOSA workshop



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

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

Prototype Decision Support Framework (DSF)

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

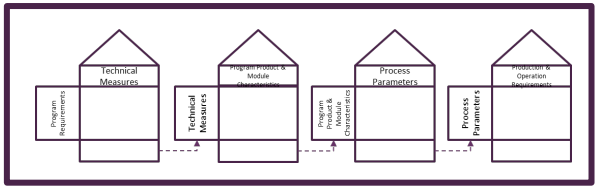
Acquisition Environment
Details of mission ('-illities')

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

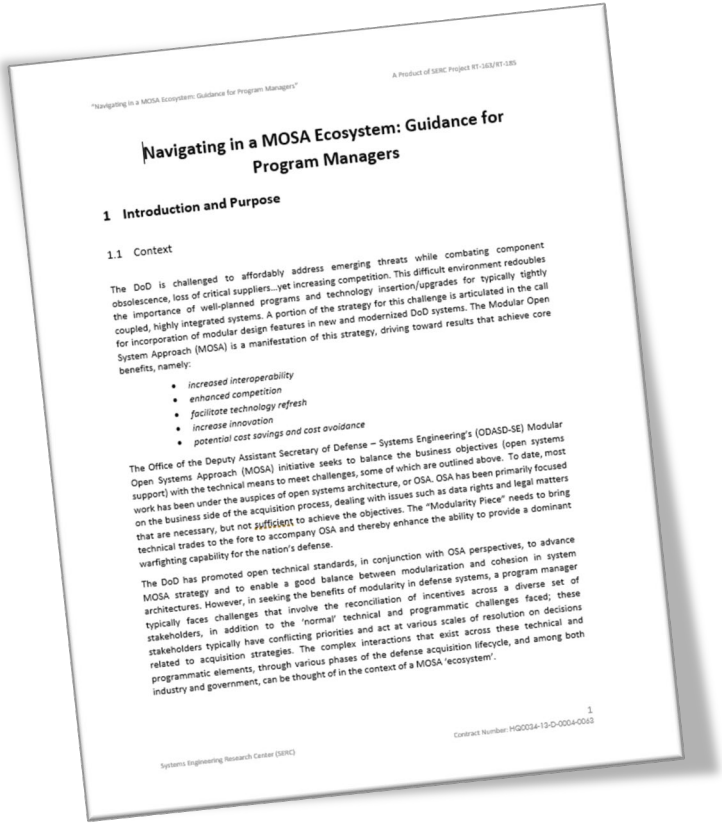
Adherence to MOSA principles

Product - Organizational Structure Relationships

Program Manager Guidance Document

Based on lessons learned, contains case study summaries related to early stage lifecycle implications on MOSA:

- **Early stage acquisitions** SE
- Due diligence across each segment of the acquisition lifecycle
- …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
- 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'.

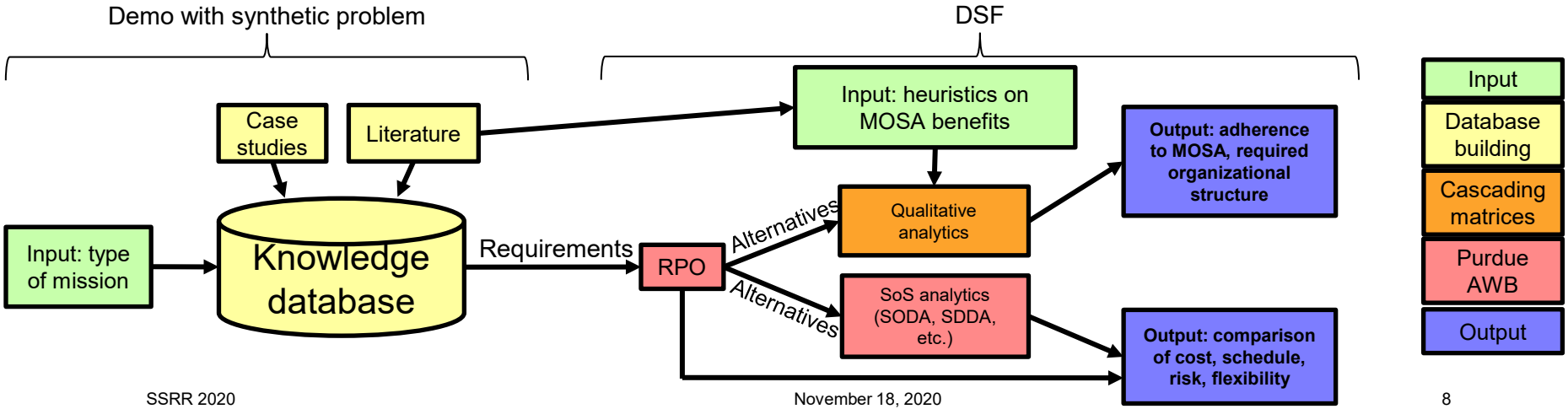
1

Contract Number: HQ0034-13-D-0004-0063

Systems Engineering Research Center (SERC)

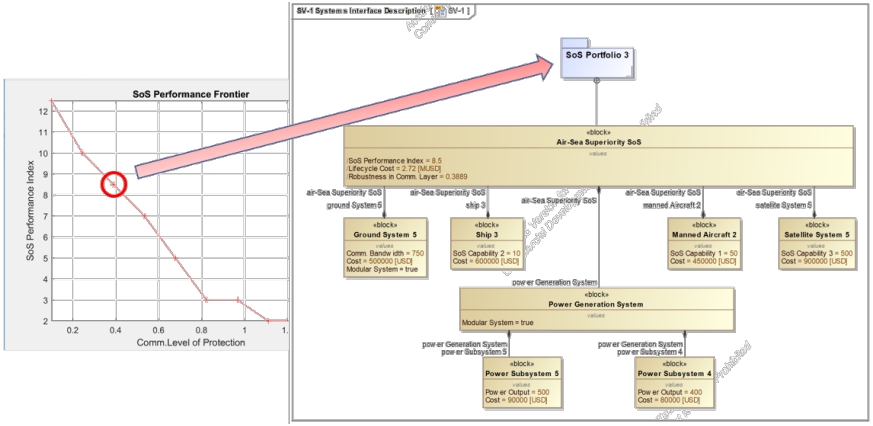
Objectives of WRT-1002 MOSA research

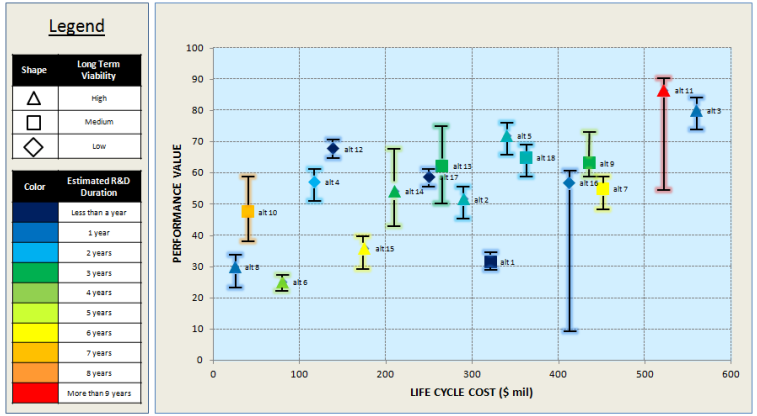
- Building upon previous efforts, **refine MOSA Decision Support Framework (DSF)**
  - **Quantitative analysis,** SoS-based and focused on cost, risk, schedule trade-offs
  - **Qualitative analysis,** based on cascading matrices and organizational structure
- **Translate knowledge from specific programs** into functional features of DSF
- Explore **tradeoffs between metrics of interest against various strategies**
- **Validate and verity the effectiveness of prototype DSF**



Continuous learning

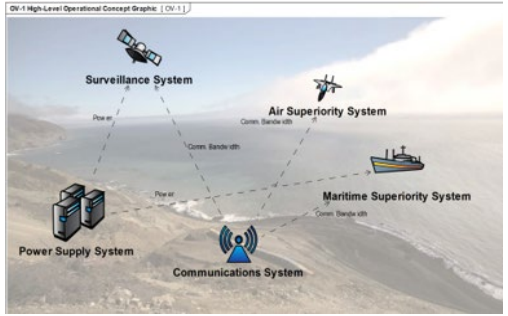
- Interaction with stakeholders, analysis of historical data, case studies
  - **MOSWG** (MOSA pillars by Naval Information Warfare Center, NDIA guidelines)
  - **VICTORY program** (standard electronic systems architecture for ground vehicles)
  - **MBSE for MOSA** (including lessons learned from RT-187, presented at CSER 2020)
  - **Open Architecture Assessment Tool** (OAAT)





Dai, Guariniello, and DeLaurentis, *Implementing a MOSA Decision Support Tool in a Model-Based Environment*, CSER 2020

Decision Support Framework (DSF) 2.0 – case study



- Multi-domain battle scenario. Requirements based on Mission Engineering
  - RPO to identify alternative sets / architectures
  - SODA for analysis of criticality
  - Cascading matrices of capabilities
  - Analysis of applicable MOSA principles
- 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 and uncertainty.

			Support Input Requirement		Support Output Requirement		System Capabilities						Support/System Capability Uncertainties						
No.	System Type	System Name	Transport Range	Transport Capacity	Transport Range	Transport Capacity	SC1 = Attack Air-Ground	SC2 = Defend Air - Against Ground	SC3 = Mobility Air	SC4 = Communication	Cost	Modular System?	Transport Range	Transport Capacity	SC1 = Attack Air-Ground	SC2 = Defend Air - Against Ground	SC3 = Mobility Air	SC4 = Mobility Ground	SC5 = Communication
-	-	-	Range (mi)	Capacity (lb)	Range (mi)	Capacity (lb)	Weapons Range (mi), Stopping power (n.d.)	Weapons Range (mi), Stopping power (n.d.), Robustness (n.d.)	Combat Radius (mi), Operational Speed (mph)	Communications Rating (n.d.)	($USD 2019)	Y/N	Uncertainty (+/- delta)	Uncertainty (+/- delta)	Uncertainty (+/- delta)	Uncertainty (+/- delta)	Uncertainty (+/- delta)	Uncertainty (+/- delta)	Uncertainty (+/- delta)
1	Air Systems	B-17 Flying Fortress	0	6000	0	0	2, 5	2, 5, 2	400, 150	1	$3,399,600.00	N	0	0	10	10	10	0	10
2		C-47	0	0	3800	6000	0, 0	0, 0, 0	3800, 160	1	$2,173,800.00	N	0	200	0	11	11	0	11
3	Ground Systems	Infantry Platoon	10	1845	0	0	0, 0	0, 0, 1	0, 0	0	$8,876.91	N	0	0	0	0	0	23	0
4		M-4 Sherman	150	1251	0	0	0, 0	0, 0, 0	0, 0	1	$701,849.94	N	0	0	0	0	0	50	50
5		TARDEC Chassis	0	0	100	5000	0, 0	0, 0, 0	0, 0	0	$142,404.01	Y	0	200	0	0	0	10	0
6		TARDEC Artillery Module	100	1750	0	0	0, 0	0, 0, 0	0, 0	1	$25,000.00	Y	0	0	0	0	0	0	10
7		TARDEC Personal Module	100	0	0	3000	0, 0	0, 0, 0	0, 0	0	$20,000.00	Y	0	100	0	0	0	0	0
8		Refuel Depot	0	0	0	0	0, 0	0, 0, 0	0, 0	0	$0.00	N	0	0	0	0	0	0	0
9		Resupply Depot	0	0	0	100000	0, 0	0, 0, 0	0, 0	0	$0.00	N	0	100	0	0	0	0	0
10	Naval Systems	Allen M. Sumner Destroyer	0	0	0	0	0, 0	0, 0, 0	0, 0	1	$152,000,000.00	N	0	0	0	0	0	0	10
11		Landing Ship, Tank (LST)	0	0	10000	107100	0, 0	0, 0, 0	0, 0	1	$36,320,100.00	N	0	1000	0	0	0	0	0.25
12	Space Systems	Wideband Global Satellite Communication Satellite (WGS)	0	0	0	0	0, 0	0, 0, 0	0, 0	2	$300,000,000.00	N	0	0	0	0	0	0	10
13	Human Systems	General Personnel	0	0	0	0	0, 0	0, 0, 0	0, 0	0	$170.00	N	0	0	0	0	0	0	0

Input to DSF

In current version, input through spreadsheet

	A	B	C	D	E	F	G	H
1				Support Input Requirement				
2	No.	System Type	System Name	Transport Range	Transport Capacity	Refuel	Communication Relay	Operator
3	-	-	-	Range (mi)	Capacity (lb)	Fuel capacity (lb)	Rating (n.d.)	Number of Operators
4	1	Air Systems	P-51 Mustang	0	2000	2795	0	1
5	2		B-17 Flying Fortress	0	6000	18500	0	10
6	3		C-47	0	0	5369	0	4
7	4		B-52H Stratofortress	0	60000	321000	1	5
8	5		B-2 Spirit	0	40000	167000	1	2
9	6	Ground Systems	Infantry Platoon	10	1845	0	0	42
10	7		M114 155mm Howitzer	12480	12480	0	0	4
11	8		M-4 Sherman	150	1251	869	0	5
12	9		M8 Greyhound	175	274	353	0	4
13	10		Jeep Willis	0	0	95	0	1
14	11		"Deuce and a half" (supply truck)	0	0	378	0	1
15	12		Advanced Targeting Pod	0	0	0	0	0
16	13		TARDEC Chassis	0	0	378	0	1
17	14		TARDEC Anti Air Module	100	879	0	0	4
18	15		TARDEC Artillery Module	100	1750	0	0	4
19	16		TARDEC Personal Module	100	0	0	0	0
20	17		Bofors 40 mm gun (L60)	100	4800	0	0	4
21	18		Refuel Depot	0	0	0	0	0
22	19		Resupply Depot	0	0	0	0	0
23	20	Naval Systems	Allen M. Sumner Destroyer	0	0	0	0	336
24	21		Higgins Boat (LCVP)	0	0	0	0	3
25	22		Landing Ship, Tank (LST)	0	0	0	0	140
26	23		Battleship	0	0	0	0	2,220
27	24	Space Systems	Ultrahigh Frequency Follow-on (UFO) Communication Satellite	0	0	0	0	100
28	25		Wideband Global Satellite Communication Satellite (WGS)	0	0	0	0	100
	26	Human	General Personnel	0		0	0	0

1 Main Sheet | 2 SoS Capabilities | 3 Compatibility Constraints | 4 "Must Have" Systems | 5 Conditional Must Ha

Systems

Support requirements

System capabilities

Cost

Modular properties

Uncertainty

	A	B	C	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN
1																
2	No.	System Type	System Name	SC15 = Defend Ground - Against Sea	SC16 = Defend Sea Against Air	SC17 = Defend Sea Against Ground	SC18 = Defend Sea Against Sea	SC19 = Mobility Air	SC20 = Mobility Ground	SC21 = Mobility Sea	SC22 = Surveillance	SC23 = Communication	Cost	Modular System?	Transport Range	Transpo Capaci
3	-	-	-	Weapons Range (mi), Stopping power (n.d.), Robustness (n.d.)	Weapons Range (mi), Stopping power (n.d.), Robustness (n.d.)	Weapons Range (mi), Stopping power (n.d.), Robustness (n.d.)	Weapons Range (mi), Stopping power (n.d.), Robustness (n.d.)	Combat Radius (mi), Operational Speed (mph)	Combat Radius (mi), Operational Speed (mph)	Combat Radius (nmi), Operational Speed (knots)	Detection rating (n.d.)	Communications Rating (n.d.)	($USD 2019)	Y/N	Uncertainty (+/- delta)	Uncerta ty (+/- delta)
4	1	Air Systems	P-51 Mustang	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0	1650, 360	0, 0	0, 0	2	1	$3[illegible],000.00	N	0	0
5	2		B-17 Flying Fortress	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0	400, 150	0, 0	0, 0	1	1	$3,39[illegible],000.00	N	0	0
6	3		C-47	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0	3800, 160	0, 0	0, 0	1	1	$2,173,80[illegible].00	N	0	200
7	4		B-52H Stratofortress	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0	4400, 525	0, 0	0, 0	2	2	$78,900,000.00	N		0
8	5		B-2 Spirit	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0	3450, 560	0, 0	0, 0	2	2	$3,423,000.00	N	0	0
9	6	Ground Systems	Infantry Platoon	1, 1, 1	0, 0, 0	0, 0, 0	0, 0, 0	0, 0	10, 3	0, 0	1	0	$8,876.91	N	0	0
10	7		M114 155mm Howitzer	9, 4, 1	0, 0, 0	0, 0, 0	0, 0, 0	0, 0	0, 0	0, 0	1	1	$182,581.95	N	0	0
11	8		M-4 Sherman	2, 3, 3	0, 0, 0	0, 0, 0	0, 0, 0	0, 0	150, 30	0, 0	1	1	$701,849.94	N	0	0
12	9		M8 Greyhound	1, 2, 2	0, 0, 0	0, 0, 0	0, 0, 0	0, 0	175, 55	0, 0	1	1	$359,147.56	N	0	0
13	10		Jeep Willis	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0	0, 0	150, 65	0, 0	1	1	$[illegible],575.21	N	0	70
14	11		"Deuce and a half" (supply truck)	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0	0, 0	150, 45	0, 0	1	0	$19,879.13	N	0	600
15	12		Advanced Targeting Pod	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0	0, 0	0, 0	0, 0	2	2	$1,000.00	Y	0	0
16	13		TARDEC Chassis	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0	0, 0	100, 45	0, 0	0	0	$142,404.01	Y	0	200
17	14		TARDEC Anti Air Module	2, 2, 2	0, 0, 0	0, 0, 0	0, 0, 0	0, 0	0, 0	0, 0	1	1	$25,000.00	Y	0	0
18	15		TARDEC Artillery Module	5, 2, 3	0, 0, 0	0, 0, 0	0, 0, 0	0, 0	0, 0	0, 0	1	1	$25,000.00	Y	0	0
19	16		TARDEC Personal Module	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0	0, 0	0, 0	0, 0	0	0	$20,000.00	Y	0	100
20	17		Bofors 40 mm gun (L60)	3, 2, 1	0, 0, 0	0, 0, 0	0, 0, 0	0, 0	0, 0	0, 0	0	0	$100,000.00	Y	0	0
21	18		Refuel Depot	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0	0, 0	0, 0	0, 0	0	0	$0.00	N	0	0
22	19		Resupply Depot	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0	0, 0	0, 0	0, 0	0	0	$0.00	N	0	100
23	20	Naval Systems	Allen M. Sumner Destroyer	0, 0, 0	4, 3, 3	4, 3, 3	4, 4, 4	0, 0	0, 0	3300, 20	2	1	$152,000,000.00	N	0	0
24	21		Higgins Boat (LCVP)	0, 0, 0	1, 1, 2	1, 1, 2	1, 1, 2	0, 0	0, 0	10, 9	0	1	$229,300.00	N	0	200
25	22		Landing Ship, Tank (LST)	0, 0, 0	4, 3, 3	4, 3, 3	4, 3, 3	0, 0	0, 0	10000, 12	2	1	$36,320,100.00	N	0	1000
26	23		Battleship	0, 0, 0	9, 3, 3	9, 3, 4	9, 4, 3	0, 0	0, 0	5900, 21	2	1	$100,238,000.00	N	0	0
27	24	Space Systems	Ultrahigh Frequency Follow-on (UFO) Communication Satellite	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0	0, 0	0, 0	0, 0	2	2	$382,000,000.00	N	0	0
28	25		Wideband Global Satellite Communication Satellite (WGS)	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0	0, 0	0, 0	0, 0	2	2	$300,000,000.00	N	0	0
	26	Human	General Personnel	0, 0, 0	0, 0, 0	0, 0, 0	0, 0, 0	0, 0	0, 0	0, 0	0	0	$170.00	N	0	0

1 Main Sheet | 2 SoS Capabilities | 3 Compatibility Constraints | 4 "Must Have" Systems | 5 Conditional Must Have S' ...

Input to DSF / 2

System-Capability Indices

No.	SoS-Capability	SC1 = Attack Air - Ground	SC2 = Defend Air - Against Ground	SC3 = Mobility Air	SC4 = Communication	...
1	Air Superiority	1,2	3,4	5,6	7	...
2	Naval Superiority				7	...
3	Tactical Bombardment			5,6	7	...
4	Land Seizure			5,6	7	...
5	Land Control				7	...
6	Reconnaissance			5,6	7	...

SoS capabilities as function of System capabilities

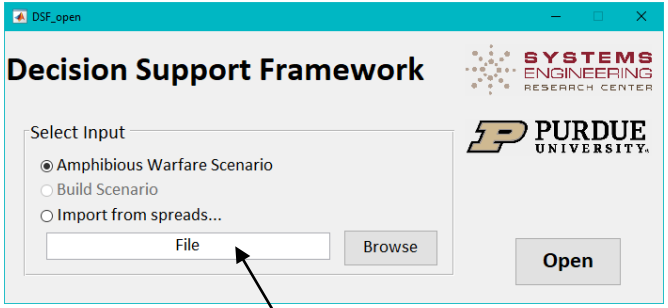
Compatibility and selection constraints

	A	B	C	D	E	G	H	I	J	K	L
1	System	Incompatible Systems				"Can Have Up To" Options			"Must Select" Options		
2	1	0	0	0	0	Start Row	End Row	Select Limit	Start Row	End Row	Select Limit
3	2	0	0	0	0	1	5	2	6	6	1
4	3	0	0	0	0	6	19	6			
5	4	0	0	0	0	20	23	6			
6	5	0	0	0	0	24	25	1			
7	6	0	0	0	0	26	26	1			
8	7	0	0	0	0						
9	8	0	0	0	0						
10	9	0	0	0	0						
11	10	0	0	0	0						
12	11	0	0	0	0						
13	12	0	0	0	0						
14	13	0	0	0	0						
15	14	0	0	0	0						
16	15	0	0	0	0						
17	16	0	0	0	0						
18	17	0	0	0	0						
19	18	0	0	0	0						
20	19	0	0	0	0						
21	20	0	0	0	0						
22	21	0	0	0	0						
23	22	0	0	0	0						
24	23	0	0	0	0						
25	24	0	0	0	0						
26	25	0	0	0	0						
27	26	0	0	0	0						

Conditionally required systems

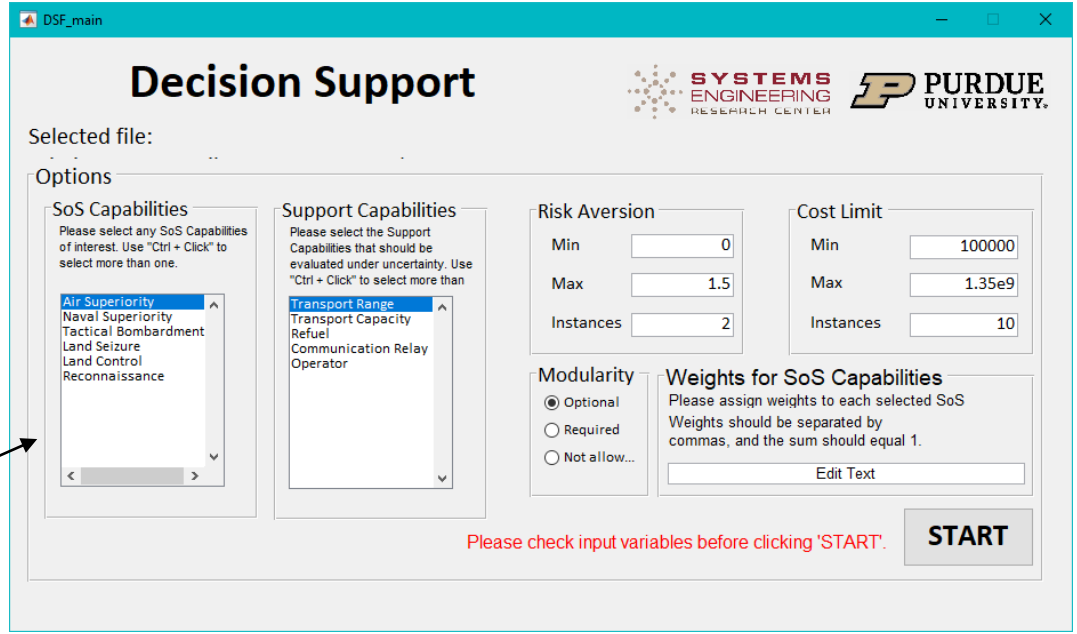
	A	B	C	D	E	F
1	System	Required Systems				
2	1	0	0	0	0	0
3	2	0	0	0	0	0
4	3	0	0	0	0	0
5	4	0	0	0	0	0
6	5	0	0	0	0	0
7	6	0	0	0	0	0
8	7	0	0	0	0	0
9	8	0	0	0	0	0
10	9	0	0	0	0	0
11	10	0	0	0	0	0
12	11	0	0	0	0	0
13	12	0	0	0	0	0
14	13	0	0	0	0	0
15	14	13	0	0	0	0
16	15	13	0	0	0	0
17	16	13	0	0	0	0
18	17	0	0	0	0	0
19	18	0	0	0	0	0
20	19	0	0	0	0	0
21	20	0	0	0	0	0
22	21	0	0	0	0	0
23	22	0	0	0	0	0
24	23	0	0	0	0	0
25	24	0	0	0	0	0
26	25	0	0	0	0	0
27	26	0	0	0	0	0

DSF GUI: opening window and main window

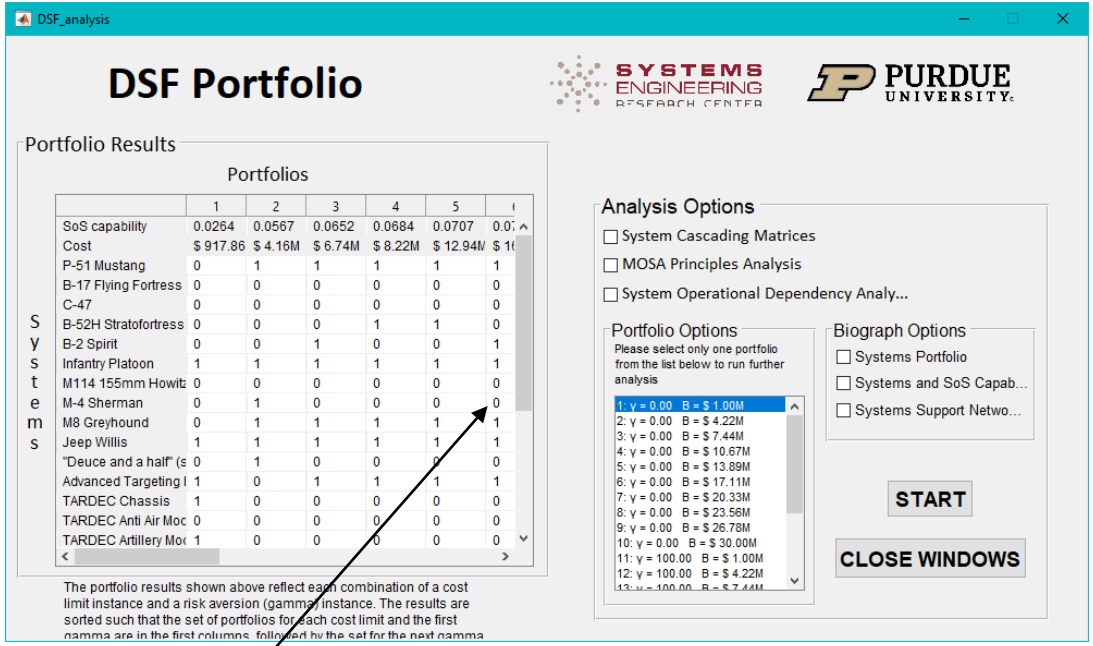


Selection of database / scenario

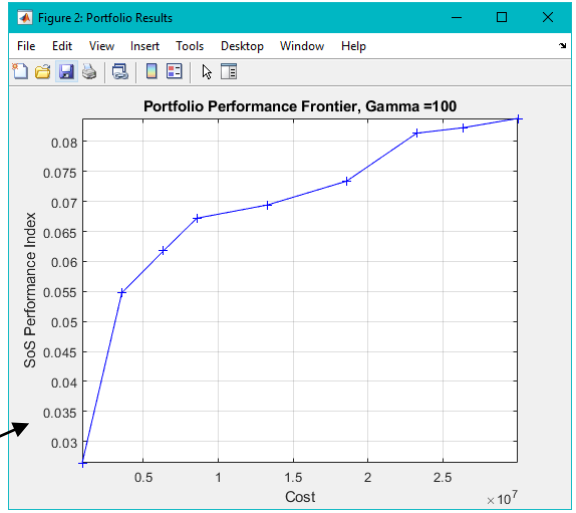
Selection of SoS capabilities for optimization, risk aversion and budget limit instances



DSF results / 1: Portfolios and Pareto fronts



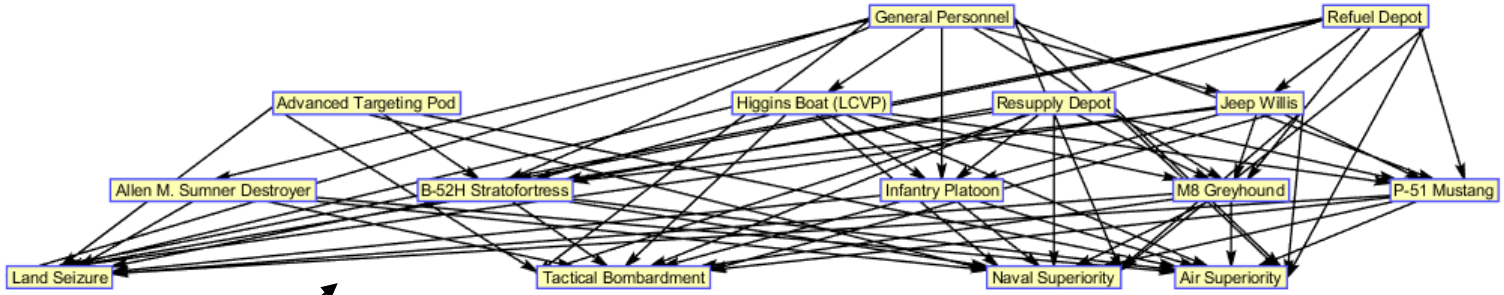
	1	2	3	4	5
SoS capability	0.0264	0.0567	0.0652	0.0684	0.0707
Cost	$ 917.86	$ 4.16M	$ 6.74M	$ 8.22M	$ 12.94M
P-51 Mustang	0	1	1	1	1
B-17 Flying Fortress	0	0	0	0	0
C-47	0	0	0	0	0
B-52H Stratofortress	0	0	0	1	1
B-2 Spirit	0	0	1	0	0
Infantry Platoon	1	1	1	1	1
M114 155mm Howitz	0	0	0	0	0
M-4 Sherman	0	1	0	0	0
M8 Greyhound	0	1	1	1	1
Jeep Willis	1	1	1	1	1
"Deuce and a half" (s	0	1	0	0	0
Advanced Targeting I	1	0	1	1	1
TARDEC Chassis	1	0	0	0	0
TARDEC Anti Air Moc	0	0	0	0	0
TARDEC Artillery Moc	1	0	0	0	0



Optimal portfolios and selection for further analysis

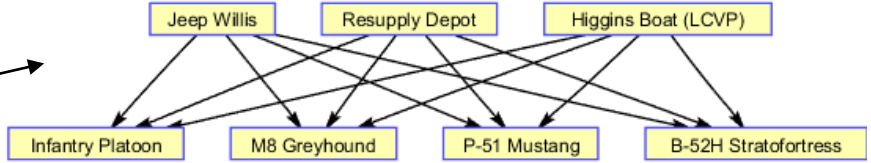
Pareto front of cost vs. performance for a given level of risk aversion

DSF results / 2: Network representations of portfolios



Systems and required support

Subset of systems that provide transport capacity



DSF results / 3: cascading matrices

Figure 3: SoS Capabilities to System Capabilities

File Edit View Insert Tools Desktop Window Help

	SC1 = Attack Air - Air	SC2 = Attack Air-Ground	SC3 = Attack Air-Sea	SC4 = Attack Ground - Air	SC5 =Atta
Air Superiority	1	1	1	0	
Naval Superiority	0	0	0	0	
Land Control	0	0	0	0	
Reconnaissance	0	0	0	0	

System capabilities to SoS capabilities

Figure 4: System Capabilities to Systems

File Edit View Insert Tools Desktop Window Help

	P-51 Mustang	B-52H Stratofortress	Infantry Platoon	M8 Greyhc
SC1 = Attack Air - Air	1	1	0	
SC2 = Attack Air-Ground	1	1	0	
SC3 = Attack Air-Sea	1	1	0	
SC4 = Attack Ground - Air	0	0	1	
SC5 =Attack Ground - Ground	0	0	1	
SC6 = Attack Ground - Sea	0	0	1	
SC7 = Attack Sea -Air	0	0	0	
SC8 = Attack Sea- Ground	0	0	0	
SC9 = Attack Sea - Sea	0	0	0	
SC10 = Defend Air - Against Air	1	1	0	
SC11 = Defend Air - Against Ground	1	1	1	
SC12 = Defend Air - Against Sea	1	1	1	
SC13 = Defend Ground - Against Air	0	0	1	

System capabilities to systems

Figure 5: Systems to SoS Capabilites

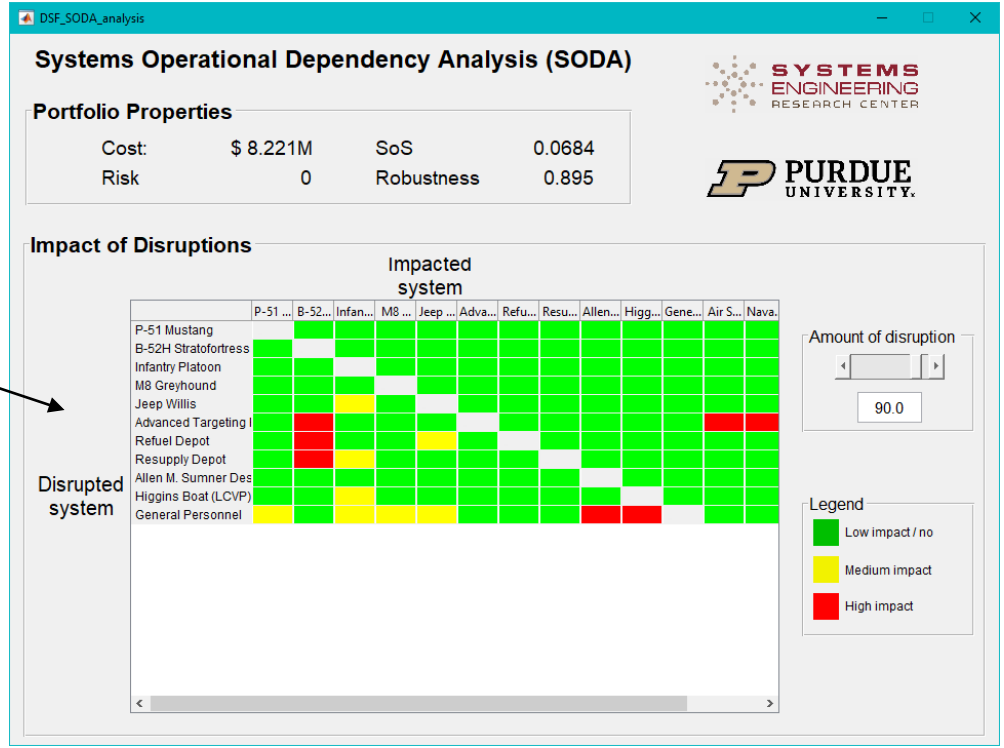
File Edit View Insert Tools Desktop Window Help

	Air Superiority	Naval Superiority	Land Control	Reconnaissance
P-51 Mustang	1	1	1	1
B-52H Stratofortress	1	1	1	1
Infantry Platoon	1	1	1	1
M8 Greyhound	1	1	1	1
Jeep Willis	1	1	1	1
Advanced Targeting Pod	1	1	1	1
Refuel Depot	0	0	0	0
Resupply Depot	0	0	0	0
Allen M. Sumner Destroyer	1	1	1	1
Higgins Boat (LCVP)	1	1	1	1
General Personnel	0	0	0	0

Systems to SoS capabilities

DSF results / 4: SODA analysis of criticalities

Systems Operational Dependency Analysis (SODA) Disruption Impact Matrix (DIM). Impact of disruptions of various systems on other systems and SoS capabilities



DSF results / 5: analysis of applicable MOSA principles

DSF_MOSA_analysis

MOSA Principles

SYSTEMS ENGINEERING RESEARCH CENTER

PURDUE UNIVERSITY

Number of programs that can benefit from each MOSA principle

	r Of Benefited Systems
Establish an enabling environment	3
Employ modular design	2
Designate key interfaces	5
Use open standards	2
Certify Conformance	0

View Graphical Representation

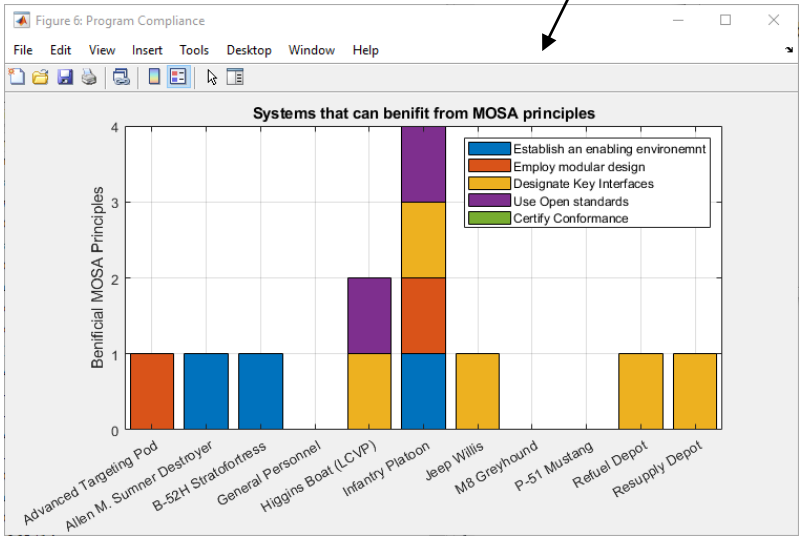
Systems that can benefit from MOSA principles

	Establish an enabling environment	Employ modular design	Designate key interfaces	Use open standards	Certify confo
1	0	0	0	0	
2	1	0	0	0	
3	1	1	1	1	
4	0	0	0	0	
5	0	0	1	0	
6	0	1	0	0	
7	0	0	1	0	
8	0	0	1	0	
9	1	0	0	0	

View Graphical Representation

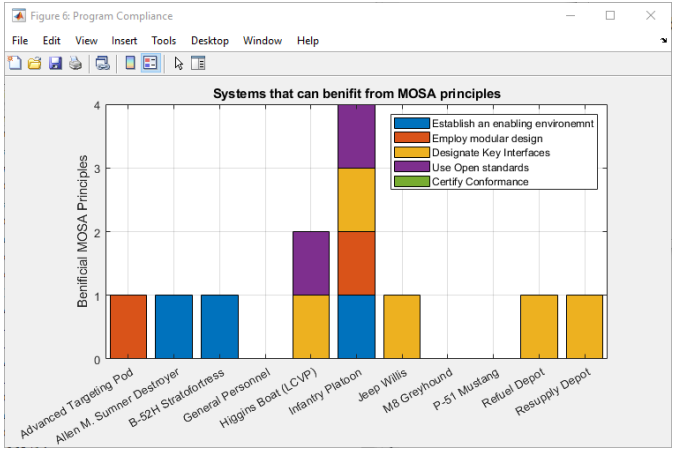
Systems and corresponding benefit from MOSA principles

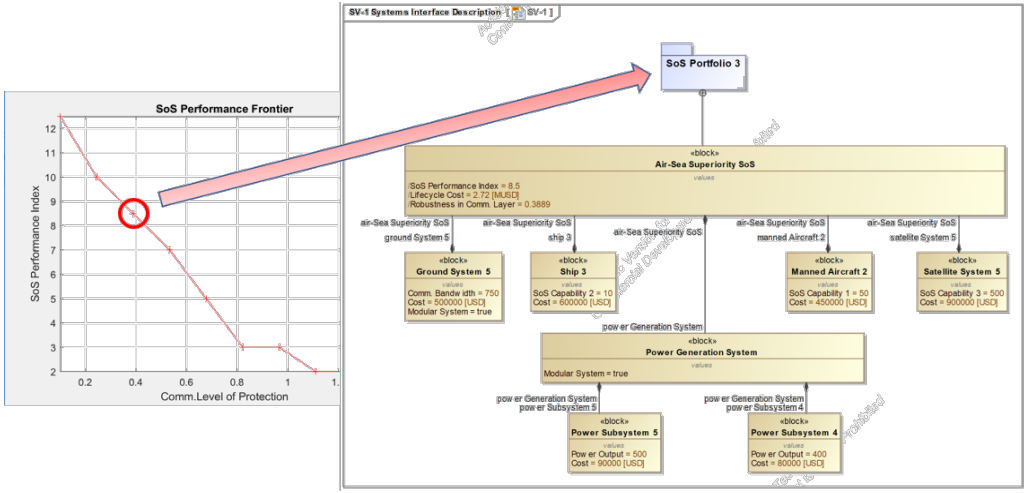
Graphical representation of systems and MOSA principles from which they can benefit



Comments on modularity in DSF

- Modularity currently from database
  - Includes lessons learned from PM guidance document
  - Includes constraints about support systems
  - Includes cost and performance
- To be added: further external information (managerial requirements, cost of modularity), internal analysis (for example, number of feasible architecture that share part of the same modular option)





Conclusions

MOSA research highlighted needs:

- **Include MOSA considerations upfront**
- **Evaluate which systems / programs can benefit from MOSA**
- Tools to **assess performance** in complex scenarios and trade-off **cost and risk** under different choices for modularity

Decision Support Framework development:

- Generate portfolios, given database of systems
- Generate pareto fronts of cost vs. performance for different level of risk aversion
- Further analysis:
  - Cascading matrices for qualitative assessment
  - Systems Operational Dependency Analysis (SODA) for operational criticalities
  - MOSA analysis for systems that can benefit from application of MOSA principles
  - Graphical representation and analysis of support requirements

Transition plan

- Developing and refining DSF in other projects
- Interest from MOSWG
- Dissemination of the work to identify potential partners for further case studies