NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

DISSERTATION

OPERATIONAL MISSION ARCHITECTURE FRAMEWORK: A BLENDED ARCHITECTURE METHODOLOGY FOR ENABLING OPERATIONAL CAPABILITY

by

Thomas Irwin

September 2018

Dissertation Supervisor: Eugene P. Paulo

Approved for public release. Distribution is unlimited.

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 2018	Dissertation

4. TITLE AND SUBTITLE
OPERATIONAL MISSION ARCHITECTURE FRAMEWORK: A BLENDED ARCHITECTURE METHODOLOGY FOR ENABLING OPERATIONAL CAPABILITY

5. FUNDING NUMBERS

6. AUTHOR(S) Thomas Irwin

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
N/A

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release. Distribution is unlimited.

12b. DISTRIBUTION CODE
A

13. ABSTRACT (maximum 200 words)

When called upon, the Department of Defense (DoD) typically organizes and integrates mission capabilities from across the enterprise, operates as a joint force, disassembles when the mission is complete, and prepares for the next potential mission. This dissertation presents an organizing construct and associative mapping tool that enables the systems engineering of this episodic joint operational mission capability. The Operational Mission Architecture Framework (OMAF) organizes the key elements of joint operational capability into an intuitive framework, orienting systems engineers to this critical perspective. With operational mission capability now in architecture form, enterprise architecture methodologies can then be applied directly to operational missions. The Operational Blended Architecture Map (OBAM) serves as the integrating mechanism. This blended approach allows the operational community to communicate in its own terminology with systems engineers, who, in turn, can execute enterprise-architecting activities in their own terminology, facilitated by this associative mapping matrix. OMAF/OBAM enables the desired top-down systems engineering effort for joint operational capability and Systems of Systems development. The cumulative effect of OMAF/OBAM provides the integrating function for a DoD capability development enterprise architecture. Without an enterprise approach, the DoD will continue to be challenged to deliver 21st century joint warfighting capability.

14. SUBJECT TERMS
joint, operational, mission, architecture, episodic, enterprise, capability, doctrine, knowledge-based

15. NUMBER OF PAGES
147

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release. Distribution is unlimited.

OPERATIONAL MISSION ARCHITECTURE FRAMEWORK: A BLENDED ARCHITECTURE METHODOLOGY FOR ENABLING OPERATIONAL CAPABILITY

Thomas Irwin
Civilian, Joint Staff
BSME, North Carolina State University at Raleigh, 1983
MS, Naval Postgraduate School, 2009

Submitted in partial fulfillment of the
requirements for the degree of

DOCTOR OF PHILOSOPHY IN SYSTEMS ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
September 2018

Approved by: Eugene P. Paulo
Department of
Systems Engineering
Dissertation Supervisor

Paul T. Beery
Department of
Systems Engineering

Anthony G. Pollman
Department of
Systems Engineering

Wayne Porter
Department of
Defense Analysis

Steve Gillespie
Department of
Systems Engineering

Approved by: Ronald E. Giachetti,
Chair, Department of Systems Engineering

Douglas Moses, Vice Provost of Academic Affairs

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

When called upon, the Department of Defense (DoD) typically organizes and integrates mission capabilities from across the enterprise, operates as a joint force, disassembles when the mission is complete, and prepares for the next potential mission. This dissertation presents an organizing construct and associative mapping tool that enables the systems engineering of this episodic joint operational mission capability. The Operational Mission Architecture Framework (OMAF) organizes the key elements of joint operational capability into an intuitive framework, orienting systems engineers to this critical perspective. With operational mission capability now in architecture form, enterprise architecture methodologies can then be applied directly to operational missions. The Operational Blended Architecture Map (OBAM) serves as the integrating mechanism. This blended approach allows the operational community to communicate in its own terminology with systems engineers, who, in turn, can execute enterprise-architecting activities in their own terminology, facilitated by this associative mapping matrix. OMAF/OBAM enables the desired top-down systems engineering effort for joint operational capability and Systems of Systems development. The cumulative effect of OMAF/OBAM provides the integrating function for a DoD capability development enterprise architecture. Without an enterprise approach, the DoD will continue to be challenged to deliver 21st century joint warfighting capability.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

I. INTRODUCTION....................1
- A. SUMMARY OF PROBLEM AND OVERALL CONTRIBUTION....................1
- B. MOTIVATION AND BACKGROUND....................2
- C. PROBLEM DEFINITION AND RESEARCH OBJECTIVES....................5
- D. RESEARCH APPROACH....................6
- E. KNOWLEDGE-BASED ENTERPRISE CAPABILITY....................6
- F. EPISODIC ENTERPRISE SYSTEMS ENGINEERING....................8
- G. OPERATIONAL LEVEL CAPABILITY INFLUENCE ON SOS....................9
- H. SPECIFIC CONTRIBUTIONS....................11
  - 1. Operational Mission Architecture Framework....................13
  - 2. Operational Blended Architecture Map....................14
  - 3. Provides Integrating Function for DoD Capability Development....................17
- I. CONCLUSION....................18

II. LITERATURE REVIEW....................21
- A. JOINT FORCE DEVELOPMENT....................21
  - 1. Joint Concepts....................22
  - 2. Joint Doctrine....................23
  - 3. Lessons Learned....................26
- B. ENTERPRISE ARCHITECTURE FRAMEWORK....................27
  - 1. Department of Defense Architecture Framework Version 2.0 (DODAF V2.0)....................28
  - 2. Zachman Framework....................30
- C. ENTERPRISE CAPABILITY REQUIREMENTS MANAGEMENT....................32
- D. ARCHITECTURE IN DOD CAPABILITY DEVELOPMENT....................34
- E. SYSTEMS ENGINEERING CONSIDERATIONS....................37
  - 1. Episodic Systems....................37
  - 2. Operational Systems....................38
  - 3. Episodic, Operational Systems....................42
  - 4. Mission Engineering....................46
- F. SUMMARY....................50

III. OPERATIONAL MISSION ARCHITECTURE FRAMEWORK....................53
- A. JOINT WARFIGHTING CAPABILITY....................53

1. Unified Action....54
2. Joint Command and Operational Core....55
3. Organization....59
4. Joint Warfighting Functions....61
5. Missions....63
6. Operational Context....64
7. Systems of Systems....65
B. TRANSFORMING JOINT OPERATIONAL KNOWLEDGE INTO ARCHITECTURE FORM....65
1. Organizing Construct....67
2. Framework Design....70
3. Summary....77
C. OPERATIONAL BLENDED ARCHITECTURE MAP (OBAM)....77
1. Operational Element-Enterprise Architecture Framework Association....78
2. Enterprise Architecture Framework Mapping....81
3. Summary....83
D. EPISODIC OPERATIONAL CAPABILITY DESCRIPTION AND DEVELOPMENT....83
1. Episodic Operational Systems Description....83
2. Episodic Enterprise Systems Development....85
E. ENTERPRISE CAPABILITY DEVELOPMENT SYSTEMS INTEGRATION....87
F. OPERATIONAL PLANNING APPLICATION....89
G. CONCLUSION....90

IV. OMAF/OBAM PROOF OF CONCEPT....93
A. JOINT OPERATIONAL ISSUES....94
1. Decade of War Study....94
2. Operation Unified Response....96
3. Operation United Assistance....97
4. Operation Odyssey Dawn....99
5. Summary....100
B. OMAF REPRESENTATION OF EPISODIC OPERATIONS....100
C. OBAM FACILITATION OF DODAF ARCHITECTING....102
D. SUMMARY AND CONCLUSIONS....104

V. CONCLUSION....107
A. SUMMARY....107
B. CONCLUSIONS....110

C. FUTURE RESEARCH 112

LIST OF REFERENCES 115

INITIAL DISTRIBUTION LIST 119

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF FIGURES

Figure 1. DoD Joint Operational Mission Capability. Adapted from CJCS (2013); CJCS (2017); SECDEF (2003). 3

Figure 2. Joint Force Development Life Cycle. Source: CJCS (2013). 7

Figure 3. C4ISR OV-1. Source: Vaneman (2015). 10

Figure 4. OMAF/OBAM Integration of DoD Capability Development Systems. Adapted from CJCS (2017). 12

Figure 5. Operational Mission Architecture Framework. 13

Figure 6. DoD Operational Blended Architecture Map (OBAM). 15

Figure 7. DODAF Model Viewpoint Mapping. 16

Figure 8. Joint Warfighting Capability Enterprise Architecture. Adapted from CJCS (2015b); CJCS (2013); SECDEF (2003). 18

Figure 9. Joint Force Development Life Cycle. Source: CJCS (2013). 22

Figure 10. Normalized Joint Cyberspace Operations Key Elements. Source: CJCS (2015c). 23

Figure 11. Joint Doctrine Hierarchy. Source: Rowlett (2013). 24

Figure 12. Systems Perspective of the Operational Environment. Source: CJCS (2017). 26

Figure 13. Joint Lessons Learned Process. Source: CJCS (2015a). 27

Figure 14. DODAF Viewpoints. Source: Wennergren (2009). 28

Figure 15. DODAF Data Categories. Source: Wennergren (2009). 29

Figure 16. DODAF Meta-model to Viewpoints and DoD Key Processes Mapping. Source: Wennergren (2009). 30

Figure 17. Zachman Enterprise Framework. Source: Zachman (2007). 31

Figure 18. Zachman Framework with Levels of Architecture. Source: Wennergren (2009). 32

Figure 19. DODAF Standard Interrogatives Matrix. Source: Wennergren (2009). 32

Figure 20. JCIDS Process. Source: CJCS (2015b). 33

Figure 21. Capability Mission Lattice. Source: CJCS (2015b). 34

Figure 22. Defense Acquisition Management Framework. Source: SECDEF (2003). 35

Figure 23. Requirements and Acquisition Process. Source: SECDEF (2003). 36

Figure 24. Decision Making Process. Source: Baumeister and Striffler (2015). 38

Figure 25. Systems analysis of South Sudan. Source: Robertson and Olson (2013). 39

Figure 26. USIP Guiding Principles. Source: Robertson and Olson (2013). 40

Figure 27. USAID Conflict Analysis Framework. Source: Robertson and Olson (2013). 41

Figure 28. Enterprise SoS and SAS Distinction. Source: Sitton and Reich (2015). 45

Figure 29. Foundation for New ESE Approach. Source: Sitton and Reich (2015). 46

Figure 30. Mission Engineering of Operational Mission Capability. Source: Gold (2018). 47

Figure 31. MIM ME Activities. Source: Gold (2018). 48

Figure 32. MEA Process. Source: Hernandez et al. (2017). 49

Figure 33. Levels of Warfare. Source: CJCS (2013). 54

Figure 34. Unified Action. Source: CJCS (2017). 55

Figure 35. Strategy and Operational Art Relationship. Source: CJCS (2017). 56

Figure 36. Notional Joint Combat Operation Model. Source: CJCS (2017). 58

Figure 37. Foreign Humanitarian Assistance Operation Model. Source: CJCS (2017). 58

Figure 38. Assessment Interaction. Source: CJCS (2017). 59

Figure 39. Notional JFHQ Organization. Source: CJCS (2017). 61
Figure 40. Joint Concept for Rapid Aggregation Scope. Source: CJCS (2015). 66
Figure 41. Joint Concept Relationships. Source: CJCS (2015d). 67
Figure 42. OMAF Unified Action Representation. 71
Figure 43. OMAF Operational Core Representation. 72
Figure 44. OMAF Operational Environment Representation. 73
Figure 45. OMAF Joint Functions Representation. 74
Figure 46. OMAF SoS Representation. 75
Figure 47. OMAF Operational Context Representation. 76
Figure 48. OMAF Mission Representation. 77
Figure 49. DoD Operational Blended Architecture Map. 82
Figure 50. Episodic Operational Systems Engineering Concept. Adapted from CJCS (2017). 86
Figure 51. Joint Warfighting Capability Enterprise Architecture. Adapted from CJCS (2015b); CJCS (2013); SECDEF (2003). 88
Figure 52. JCOA Studies Mission Issue Map. 101
Figure 53. DODAF Instantiation of Operational Issues. 103

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

Table 1. C2 Warfighting Function Decomposition. Source: CJCS (2017).............62

Table 2. Joint Missions. Source: CJCS (2017). 63

Table 3. Organization of DoD Operational Mission Capability. 68

Table 4. Operational Element DODAF Viewpoint Associations. 79

Table 5. JCOA Decade of War Study, Vol.1. Source: JCOA (2012). 95

Table 6. Operation Unified Response/DR. Source: JCOA (2010). 97

Table 7. Operation United Assistance/FHA. Source: JCOA (2015)........................98

Table 8. Operation Odyssey Dawn/NEO. Source: JCOA (2011). 99

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

AAW	Anti-Air Warfare
AV	All Viewpoint
AMN	Afghan Mission Network
AWG	Architecture Working Group
B2C2WG	Boards, Bureaus, Centers, Cells, and Working Groups
C2	Command and Control
C&D	Command and Decision
CDD	Capability Development Document
CIO	Chief Information Officer
CJCS	Chairman of the Joint Chiefs of Staff
CML	Capability Mission Lattice
COG	Center of Gravity
CONOP	Concept of Operations
CONPLAN	Contingency Plan
CPD	Capability Production Document
CV	Capability Viewpoint
DAS	Defense Acquisition System
DIA	Defense Intelligence Agency
DISA	Defense Information Systems Agency
DIV	Data and Information Viewpoint
DoD	Department of Defense
DODAF	Department of Defense Architecture Framework
DR	Disaster Relief
EA	Enterprise Architecture
EMS	electromagnetic spectrum
ESE	Enterprise Systems Engineering
FHA	Foreign Humanitarian Assistance
GBAD	Ground Based Air Defense
GIG	Global Information Grid
GIO	Globally Integrated Operations

HQ	Headquarters
ICD	Initial Capability Document
IE	Information Environment
IOC	Initial Operational Capability
IOSS	Integration and Operations Support System
IT	Information Technology
JCIDS	Joint Capabilities Integration and Development System
JCOA	Joint and Coalition Operational Analysis
JFD	Joint Force Development
JIWAB	Joint Irregular Warfare Analytic Baseline
JP	Joint Publication
JTF	Joint Task Force
JOC	Joint Operating Concept
LOE	Lines of Effort
LOO	Lines of Operation
LSE	Lifetime Support Engineering
MAGTF	Marine Air Ground Task Force
MDMP	Military Decision Making Process
ME	Mission Engineering
MEA	Mission Engineering and Analysis
MIM	Mission Integration Management
MPE	Mission Partner Environment
NATO	North Atlantic Treaty Organization
NDAA	National Defense Authorization Act
NEO	Non-combatant Evacuation Operation
OA	Operational Area
OE	Operational Environment
OBAM	Operational Blended Architecture Map
OEF	Operation Enduring Freedom
OMAF	Operational Mission Architecture Framework
OPLAN	Operation Plan
OV	Operational Viewpoint

PMESII	political, military, economic, social, information, and infrastructure
PO	Peace Operation
PV	Project Viewpoint
SAS	System of Arrays of Systems
SE	Systems Engineering
SECDEF	Secretary of Defense
SoI	System of Interest
SoS	Systems of Systems
SOSE&I	Systems of Systems Engineering and Integration
StdV	Standards Viewpoint
SV	System Viewpoint
SvcV	Services Viewpoint
UAV	Unmanned Aerial Vehicle
UJT	Universal Joint Task
UJTL	Universal Joint Task List
USAID	United States Agency for International Development
USIP	United States Institute of Peace

THIS PAGE INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

Benjamin Franklin, speaking at the Philadelphia convention in September 1787, stated,

> for when you assemble a number of men to have the advantage of their joint wisdom, you inevitably assemble with those men all their prejudices, their passions, their errors of opinion, their local interests, and their selfish views. From such an assembly can a perfect production be expected?

Our nation deploys, and continues to deploy, forces to operate around the world as part of a combined force conducting operations across multiple warfighting domains simultaneously. These forces are typically reactive and composed of multiple, disparate enterprises (Services, agencies, partner nations, non-governmental organizations, private industry) that are tailored to meet projected mission requirements. Contributing organizations bring elements of their organic capabilities and systems, manpower, and culture, which are then assembled into a "joint" capability that operates as a doctrinal joint force, disassembles when the mission is complete, and prepares for the next potential mission. This "episodic" Department of Defense (DoD) enterprise capability is developed and maintained (preparedness and readiness) through "a knowledge-based integrated enterprise" approach, executed under the Chairman of the Joint Chiefs of Staff (CJCS) Joint Force Development (JFD) Life Cycle (CJCS 2013).

The JFD system as a whole, which "delivers" the DoD knowledge-based component of our nation's joint warfighting capability, is not integrated with the materiel development systems. Joint operations are not systems engineered, but rather assembled from existing Service capabilities. Although our nation cannot wait for systems engineers to gain joint experience, or for joint commanders and staff members to become systems engineers, or for the DoD enterprise to modify its capability development systems, we can find common ground.

The DoD Defense Acquisition System (DAS), the Joint Capability Integration and Development System (JCIDS), and DoD Architecture Framework (DODAF) all support the development of integrated architectures. Those processes deliver physical systems but are not designed to provide traceability to the operational capability delivered by those systems. Given the specific intended applications of those processes, it is not possible to ensure that a system developed in compliance with those processes will meet the needs of the actual stakeholder when the system of interest is an episodic enterprise system (the operational mission commander in charge of accomplishing a military objective utilizing episodic, enterprise systems). This dissertation delivers common ground for capability development through a joint operational architecture framework construct, tailored to the unique challenges of the episodic nature of these enterprise operational capabilities and systems that leverage the value DoD already places on integrated architectures.

There are unique challenges associated with episodic operational systems (beyond traditional systems employed for joint operations). Specifically, we know we are never going to have to solve the exact same problem twice, but we also know that we are going to have to solve many similar problems using the same systems. Therefore, we need an approach for doing so. This dissertation presents an organizing construct and associative mapping tool that enables the systems engineering of this episodic joint operational mission capability (or episodic enterprise systems). This new class of episodic systems is characterized by their temporal, transitional, asynchronous, and multi-mission attributes that drive design.

Deployed system capabilities are defined, managed, engineered, developed, and tested to system requirements and subsequently arranged, tested, and sustained to deliver capability that meets validated requirements. Often these requirements are too broadly defined to deliver the mission-specific, episodic, warfighting capability necessary to gain and sustain an advantage in the complex 21st century operational environment. This research seeks to address this disconnect at the architectural level by:

1. Formalizing the meaning of “operational level capability” through an organizing construct.

2. Defining an architectural framework that can be applied to a broad range of enterprise capabilities, rather than specific physical systems or specific operational situations.

3. Defining an enterprise architecting associative map.

4. Providing an integrating function to create a DoD capability development enterprise architecture.

The **Operational Mission Architecture Framework (OMAF)** organizes the key elements of joint operational capability into an intuitive framework, orienting systems engineers to this critical perspective. With operational mission capability now in architecture form, enterprise architecture methodologies can then be applied directly to operational missions. The organizing construct and design of OMAF is not intended to replace any or all of the DoD capability develop systems, but rather to integrate them and enable the systems engineering of the ten Operational Elements of joint warfighting capability.

The **Operational Blended Architecture Map (OBAM)** serves as the integrating mechanism. OBAM has been developed to enable the use of DoD's enterprise architecture model (DODAF). This blended approach allows the operational community to communicate in their own terminology with systems engineers, who in turn, can execute enterprise-architecting activities in their own terminology, facilitated by this associative mapping matrix. Since joint operational capability is supported by systems and Systems of Systems (SoS) architectures developed under the JCIDS and DAS, the application of existing enterprise architecture tools and processes promotes an inclusive and efficient enterprise approach. OMAF/OBAM enables the desired top-down systems engineering effort for joint operational capability and SoS development.

The **cumulative effect of OMAF/OBAM** also provides the integrating function for a DoD capability development Enterprise Architecture. Without an enterprise approach, DoD will continue to be challenged to deliver 21st century joint warfighting capability.

Through integration of the JFD, DAS, and JCIDS processes it is possible to identify the physical systems (and the integration requirements associated with the utilization of those systems) required to deliver a specific, enterprise operational level capability and repeat that process episodically for a broad range of operational applications. The central idea is to organize the guiding principles, operational context, and warfighting systems for joint operations into a visual reference architecture framework that enables the development of episodic enterprise systems and integrates DoD capability development systems.

All three systems/cultures/communities are represented in the framework; JFD joint context and knowledge-based decision making elements; DAS materiel/system capabilities; and, JCIDS operational architectures. This blended approach provides joint operational level context for both traditional program/project systems engineering activities, and for the application of DoD systems engineering methodologies directly at the joint operational level (episodic operational capability). The OMAF is intended to leverage the diversity of thought, multi-cultural perspectives, and existing capabilities of the DoD enterprise (and cooperating partner enterprises), rather than provide a new, or yet another, capability development system.

The OMAF enables operational mission stakeholders, participants, and capability providers to attain unity of effort (CJCS 2017, I-9) for realizing operational level mission capability. A DoD enterprise architecture for developing joint warfighting capability emerges from the integrating function of OMAF. The integration of these systems at the architectural level is minimally disruptive to the enterprise, as existing authorities/processes remain in place.

Beyond the DoD, the notion of episodic capability applies to all enterprises. An ability to address unique challenges utilizing existing enterprise systems, processes, and relationships to achieve desired outcomes extends to all enterprises seeking to remain relevant in a rapidly changing 21st century technology landscape.

References

Joint Chiefs of Staff. 2013. *Joint Publication 1 Doctrine for the Armed Forces of the United States*. Washington, DC: Joint Chiefs of Staff.

Joint Chiefs of Staff. 2017. *Joint Publication 3–0, Joint Operations.* Washington, DC: Joint Chiefs of Staff.

ACKNOWLEDGMENTS

Throughout this endeavor, the support I received from family, friends, colleagues, and mentors is what won the day. I simply could not have done this without each and every one of you.

As I enter the reflective phase of this journey, my beautiful bride, Gail, was there for me in every aspect. Although "thank you" will never adequately address all you did, your unwavering support, and all you sacrificed, I will start there and spend the rest of my days knowing and showing how truly blessed I am to have you.

Lauren, Emma, and Grant, each of you kept me going with your love and support. When I was tired or in doubt, one of you would say just the right thing, and I would press on. Thank you, and I love you.

VADM Kevin Scott, thank you for the opportunity to push both myself and the joint community. You always trusted and believed in me.

Ms. Monica Shephard, both friend and mentor, thank you for all of the "What Tom meant to say" moments and for your continuous encouragement and advice. I would not be here without you.

That leaves Team Joint Miracle. Dr. Gene Paulo, your mentorship, guidance, and commitment to this journey is what led to my success. Thank you for the things you would say and also for those you did not. In both cases, the message was well crafted and received. Dr. Paul Beery, thank you for the moments of clarity you routinely delivered. You are a systems engineering beast! Dr. Wayne Porter, your expertise, joint experience, and unique perspectives were both inspiring and informing. Thank you for all the conversations and practical advice. Dr. Anthony Pollman, thank you for your time and "first principles" guidance. Dr. Steve Gillespie, thank you for your time and engagement. The future of systems engineering is in good hands with these educators leading the way.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

A. SUMMARY OF PROBLEM AND OVERALL CONTRIBUTION

The commercial sector has a history of recognizing and responding to environmental indicators and delivering new capability (i.e., six generations of I-phones in less than ten years). Technological advancements (e.g., advanced computing, big data, artificial intelligence, autonomy, robotics, miniaturization, additive manufacturing, meta-materials, directed energy, and hypersonics), primarily in response to societal desires and realized through commercial research and development, have resulted in unprecedented operational environment complexity for our warfighters (CJCS 2016).

The Department of Defense (DoD) typically organizes and assembles/integrates mission capabilities from across the enterprise, operates as a joint force, disassembles when the mission is complete, and prepares for the next potential mission. Our nation deploys forces to operate around the world as part of a combined/partnered force conducting operations across multiple warfighting domains simultaneously.

This is an extremely difficult and complex undertaking, and results in the joint force continuing to encounter operational mission capability issues, across a variety of missions. These combined/partnered forces are typically defensive and composed of multiple, disparate enterprises (Services, agencies, partner nations, non-governmental organizations, private industry), intended to meet projected mission requirements. Contributing organizations bring elements of their organic capabilities and systems, manpower, and culture which are assembled into a “combined” or into a “Joint” operational capability. Combined forces include U.S. and partner nation militaries. Joint is a general term applied to a force “composed of elements from two or more Military Departments operating under a single joint force commander.” (CJCS 2013, I-16). Furthermore, “Jointness implies cross-Service combination wherein the capability of the joint force is understood to be synergistic, with the sum greater than its parts (the capability of individual components)” (CJCS 2013, I-2).

This dissertation presents an organizing construct and associative mapping tool that enables the systems engineering of this episodic joint operational mission capability (or episodic enterprise systems). This new class of systems is characterized by their temporal, transitional, asynchronous, and multi-mission attributes that drive design. The Operational Mission Architecture Framework (OMAF) organizes the key elements of joint operational capability into an intuitive framework, orienting systems engineers to this critical perspective. With operational mission capability now in architecture form, enterprise architecture methodologies can then be applied directly to operational missions.

The Operational Blended Architecture Map (OBAM) serves as the integrating mechanism. This blended approach allows the operational community to communicate in their own terminology with systems engineers, who in turn, can execute enterprise-architecting activities in their own terminology, facilitated by this associative mapping matrix. OMAF/OBAM enables the desired top-down systems engineering effort for joint operational capability and Systems of Systems (SoS) development.

The cumulative effect of OMAF/OBAM also provides the integrating function for a DoD capability development Enterprise Architecture. Without an enterprise approach, DoD will continue to be challenged to deliver 21st century joint warfighting capability.

B. MOTIVATION AND BACKGROUND

There are similarities in the core tenets of joint force capability (sum greater than its parts) and systems engineering architectures that can be associated with realizing joint operational capability. However, systems engineering approaches and/or methodologies are not being directly applied to achieve.

The DoD enterprise utilizes a requirements oversight system, an acquisition system, and a knowledge-based development system to develop and employ global joint capability. The requirements oversight and acquisition systems are integrated at the architectural level through an authoritative enterprise architecting methodology focused on developing system(s) based capabilities. The knowledge-based development system focuses on the cognitive capability necessary for conducting joint operations/missions. Once the specified mission is complete, those participating elements of the DoD enterprise return to a readiness state within the knowledge-based capability development system and prepare for a future joint operation/mission. Although some products of the knowledge-based development system are used to inform the other two capability development systems, it is not integrated with them. Additionally, the DoD executes a variety of missions when called upon, which are not synchronized with system(s) based capability development and fielding schedules (Figure 1). Evolving social norms, adaptive adversaries, and the complex, uncertain, and rapidly changing 21st century operational environment challenge this approach to fielding joint operational mission capability.

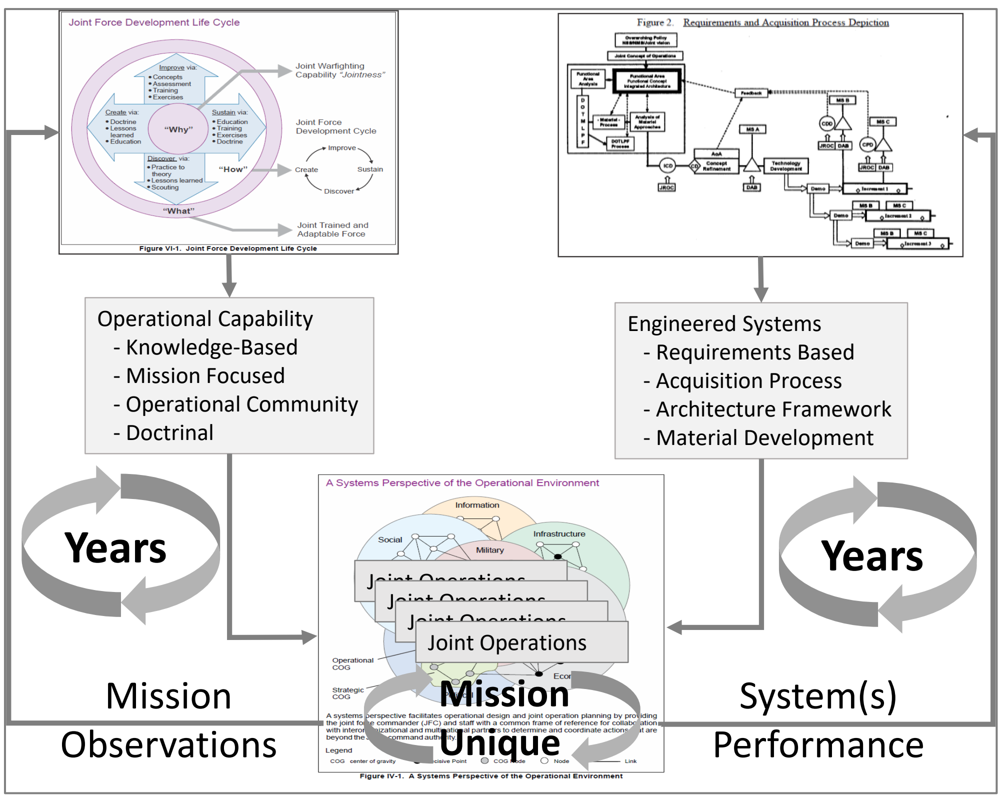

Figure 1. DoD Joint Operational Mission Capability. Adapted from CJCS (2013); CJCS (2017); SECDEF (2003).

Currently, the integration necessary to execute assigned joint operational missions is performed with knowledge-based guidance, acquired through a formal Joint Force Development (JFD) construct (CJCS 2013). Joint operational mission capability is therefore an extension of acquired knowledge, rather than being deliberately engineered and developed. This doctrinal (or ideological) influence on operational effectiveness and the systems engineering influence on materiel capability development are not deliberately aligned, resulting in architectural (structural, functional, organizational, information, process) points of contention and incompleteness.

A well-known example of this operational issue was the inability to network combined force IT systems among coalition forces in Operation Enduring Freedom (OEF), which commenced in October 2001. The solution, the Afghan Mission Network (AMN), finally reached Initial Operational Capability (IOC) in 2010. Work continues today (16 years after OEF commencement) by the combined forces community, informed by AMN, to implement an enduring framework to achieve networked operational level capability. This involves coalition partners under the U.S. Mission Partner Environment (MPE) and NATO Federated Mission Network (FMN) efforts, and is being implemented through the Joint Force Development Life Cycle.

Systems engineers capture operator's requirements primarily through the development of a Concept of Operations (CONOP) accompanied by architectural Operational Viewpoints (OV). The essence of these CONOPs and OVs, however, reside at the tactical level of warfare vice the operational level resulting in significant capabilities gaps.

> The operational level of warfare links the tactical employment of forces to national and military strategic objectives. The focus at this level is on the planning and execution of operations using operational art: the cognitive approach by commanders and staffs—supported by their skill, knowledge, and experience—to develop strategies, campaigns, and operations to organize and employ military forces by integrating ends, ways, and means. (CJCS 2017, xii)

Achieving operational mission capability is therefore a human centric (commanders and staffs) methodology with dependencies on other human centric activities (e.g., Doctrine community; Service and Joint trainers; Service and Joint exercises; Service and Joint lessons learned communities; partners), complex socio-technical systems (e.g., command posts).

When called upon, the DoD typically organizes and assembles/integrates mission capabilities from across the enterprise (i.e., Services), operates as a doctrinal joint force, disassembles when the mission is complete, and prepares for the next potential mission. This “episodic” DoD enterprise capability is developed and maintained (preparedness and readiness) through “a knowledge based integrated enterprise” approach, executed under the Joint Force Development Life Cycle (CJCS 2013).

The DoD enterprise’s ability to produce operational capability requires contributions from all three of its capability development systems. Current Enterprise Systems Engineering (ESE) and Systems of Systems Engineering (SoSE) approaches include architecture, requirements, organization, information, data, and process elements across the life cycle of a systems engineering effort. However, where episodic enterprise capability, and ultimately operational mission success, is dependent on both knowledge-based and SoS capabilities, current DoD systems engineering methodologies fail to adequately address the knowledge-based component of operational capability.

C. PROBLEM DEFINITION AND RESEARCH OBJECTIVES

This research is focused on the definition of an operational framework to enable the development and assessment of episodic enterprise systems. Specifically, this research will provide an integrating mechanism linking knowledge-based processes for realization of operational capability and requirements-based processes for the acquisition of engineered systems. Accordingly, the following research objectives are presented:

1. Definition of the unique challenges associated with the realization of episodic enterprise systems, with particular focus given to the challenges associated with the definition of such systems in a Joint Department of Defense environment.

2. Definition of an operational architecture framework uniquely suited to the development of episodic enterprise systems.

3. Definition of an architecture map that establishes a mapping between the operational architecture framework produced in satisfaction of research objective #2 and existing systems architecture frameworks.

D. RESEARCH APPROACH

This research utilizes the design method as defined in (Giachetti 2016). Specifically, this dissertation will develop a new systems engineering process for the definition and development of episodic enterprise systems. Accordingly, this dissertation is organized into three primary sections: a literature review that summarizes the motivation for the research as well as existing engineering processes; a presentation of the proposed operational architecture framework and blended architecture map; and a review of historical operations to demonstrate the utility of the proposed operational architecture framework and blended architecture map.

E. KNOWLEDGE-BASED ENTERPRISE CAPABILITY

JFD is a knowledge-based enterprise approach to developing the capability for planning and executing assigned joint operational missions. (CJCS 2013). The focus of the enterprise is on mission "planning and execution using Operational Art: the cognitive approach by commanders and staffs" (CJCS 2013, I-8). Joint concepts, joint doctrine, joint education, joint training, joint exercises, and assessments/lessons learned are the primary elements of the Joint Force Development (JFD) Life Cycle (Figure 2). JFD does not include materiel development, fielding, and sustainment, which are the responsibility of the participating organizations (CJCS 2013). Joint operational mission capability is achieved through the cumulative efforts of joint force development activities and the deployment of materiel from participating organizations in doctrinal compliance with joint operations. "The purpose of joint doctrine is to enhance the operational effectiveness of joint forces by providing fundamental principles that guide the employment of U.S. military forces toward a common objective" (CJCS 2013, I-1).

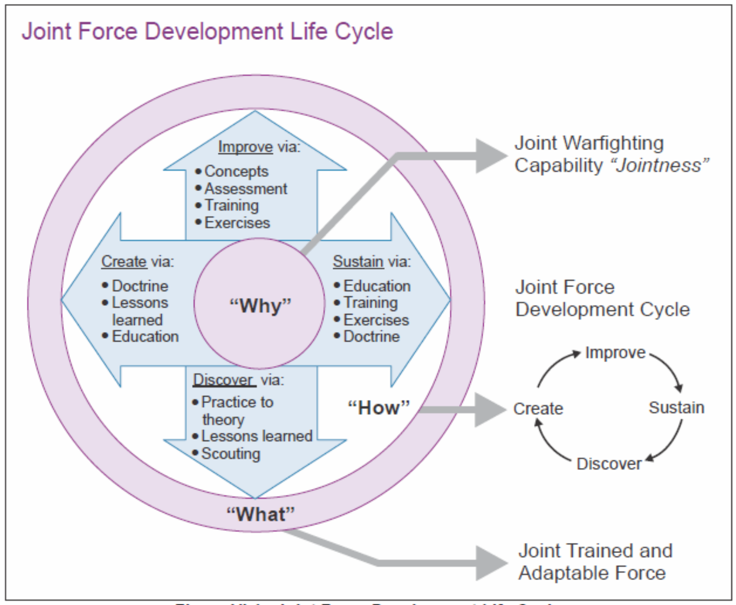

Figure 2. Joint Force Development Life Cycle. Source: CJCS (2013).

As previously discussed, this knowledge-based enterprise capability is commander centric and is intended to "organize and employ forces by integrating ends, ways, and means." (CJCS 2017, I-14). Acquiring the necessary cognitive ability is then dependent on the skills, knowledge, and experience of commanders and staffs, obtained through both Service and Joint education, assignments, training, and experience. Furthermore, the resultant cognition-based capability is sensitive to the introduction of new system(s) based capabilities.

Traditional systems engineering in the Department of Defense is a foundational element of systems, SoS, and enterprise systems capability development and is codified in DoD policy and instruction. Essentially, the warfighter gets the benefit of the engineering mindset as part of an acquisition program or system design/upgrade, both of which rely on requirements maturity and clarity. The introduction of these systems into the joint force must be institutionalized before operational benefits can by realized. By organizing the key operational level elements into an architectural framework and providing an associative mapping tool for enterprise architecting, systems engineers may better comprehend and account for this cognition-based level of war, and subsequently better support the operational force by applying systems engineering methodologies in the development of warfighting systems.

F. EPISODIC ENTERPRISE SYSTEMS ENGINEERING

As previously discussed, the DoD enterprise executes a variety of missions as a joint force when called upon, then returns to state of readiness and prepares for the next potential mission. The necessary joint warfighting capability, including the readiness to respond to mission assignments, is developed through the knowledge-based JFD Life Cycle. SoS/systems are systems engineered to requirements through JCIDS/DAS with multi-year development timelines. Neither of the enterprise's development systems are designed to address the episodic nature of joint missions. A deliberate systems engineering approach, centered on the complexities of the operation level of warfare, is necessary to address the episodic nature of joint warfighting.

This application of systems engineering at the operational level of war introduces a new class of systems: Episodic Enterprise Systems. These joint warfighting systems are necessarily developed asynchronously with enterprise capability development schedules in order to address the temporal, transitional, and multi-mission characteristics of joint operations: "an Enterprise is a complex, socio-technical system that comprises interdependent resources of people, information, and technology that must interact with each other and their environment in support of a common mission" (Giachetti 2010, 4). The DoD, in addition to being an enterprise unto itself, is also composed of large and complex organizations (i.e., Army, Navy, Air Force, Marine Corps, DISA, DIA) that design, develop, field, and sustain capability in compliance with enterprise policies and instructions, and through the application of enterprise methodologies.

DoD operational level capability is delivered through a Joint Task Force (JTF) organizing construct, enabled by SoS capability developed and sustained by multiple components of the DoD enterprise. This temporary, or episodic, mission-specific task force is established "when the scope, complexity, or other factors of a contingency or crisis require the capabilities of at least two military departments operating under a single Joint Force Commander" (CJCS 2012b, ix). The JTF operates through a set of disciplined doctrinally based decision support processes (CJCS 2013). Operational environment complexities exploited by Nation States and Violent Extremist Organizations that present transregional, transnational, and global threats, stress traditional JTF architectures and decision-support processes.

The inherently complex nature of realizing episodic DoD operational enterprise capability introduces challenges to the enterprise engineer. Operational level enterprise capability is currently not engineered, but rather doctrinally based and task-organized (i.e., assembled) for a specified purpose, independently from the core enterprise organizations. Additionally, systems or SoS are not architected or designed for the specific operational missions but rather to requirements, generally at the tactical level (i.e., "the employment, ordered arrangement, and directed actions of forces in relation to each other" [CJCS 2017, I-14]). Capabilities from across the DoD enterprise are developed through the enterprise's systems engineering policies and processes. However, due to the episodic nature and breadth of operational missions, and the dynamic nature of the operational environment—"the composite of the conditions, circumstances, and influences that affect employment of capabilities and bear on the decisions of the commander" (CJCS 2017, xiv)—multiyear system/SoS requirements may not reflect rapidly changing operational level needs. Furthermore, episodic enterprise systems engineering can be applied to a broader set of similar systems in other domains, beyond DoD operational-level enterprise systems.

G. OPERATIONAL LEVEL CAPABILITY INFLUENCE ON SOS

Conceptually, the United States will respond to 21st century military challenges with globally integrated operations (GIO) (CJCS 2012a). Key elements of this joint concept to be operationalized include global command and control, cross-domain synergy, integrated physical and information power, and partner integration (CJCS 2016). With cyberspace now included as a warfighting domain in joint doctrine (CJCS 2013), cyberspace operations, or *cyber*, must be integrated into all levels of war (strategic, operational, and tactical). At the operational level, where the focus is on commander centric cognitive decision making, missions may be episodic and supporting systems are assembled from multiple enterprises. Systems engineers must consider these dynamics in the architecture and design of capability development.

Operational concepts for SoS capability development efforts are typically documented at the tactical level of war, as seen in the DODAF Operational Viewpoint 1 (OV-1): High-Level Operational Concept Graphic for a C4ISR architecture (Figure 3). This Intelligence-function architecture must integrate with the other six functional areas; perform in compliance with authoritative operational context (i.e., Joint Concepts and Joint Doctrine); support multiple missions; account for the operational environment; and, operate within operational lines of communication, command relationships, command authorities, and interagency coordination venues.

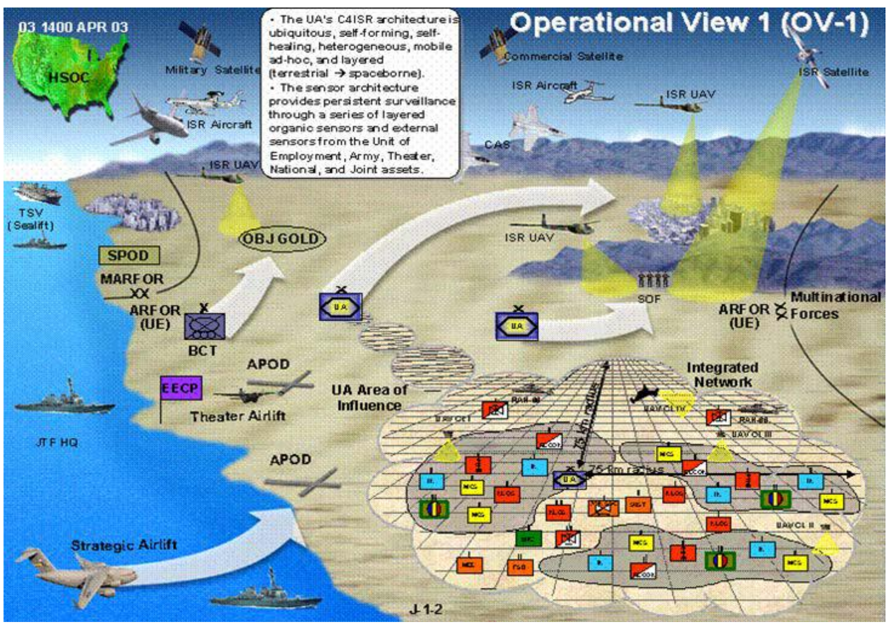

Figure 3. C4ISR OV-1. Source: Vaneman (2015).

Note that this OV-1 representation is focused primarily at the tactical implementation of the system of interest. SoS engineering approaches and activities must include the operational level in both architecture and design. Key aspects of this higher-level architecture must be considered in order to provide a more representative and complete architecture for SoS and system design activities that recognize and account for the cognitive approach to warfighting.

H. SPECIFIC CONTRIBUTIONS

This dissertation presents an organizing construct and associative mapping tool that enables the systems engineering of episodic joint operational mission capabilities. The Operational Mission Architecture Framework (OMAF) organizes the key components of joint operational capability into an intuitive framework, orienting systems engineers to this critical perspective. With the knowledge-based capability of the enterprise organized through the OMAF, the application of enterprise architecture methodologies, such as DODAF, can then be executed within both the engineering (JCIDS/DAS) and operational (JFD) domains (Figure 4). The Operational Blended Architecture Map (OBAM) serves as the integrating mechanism between the knowledge-based capability elements in OMAF and the enterprise's authoritative architecting methodology (DODAF) utilized in JCIDS/DAS material solution development.

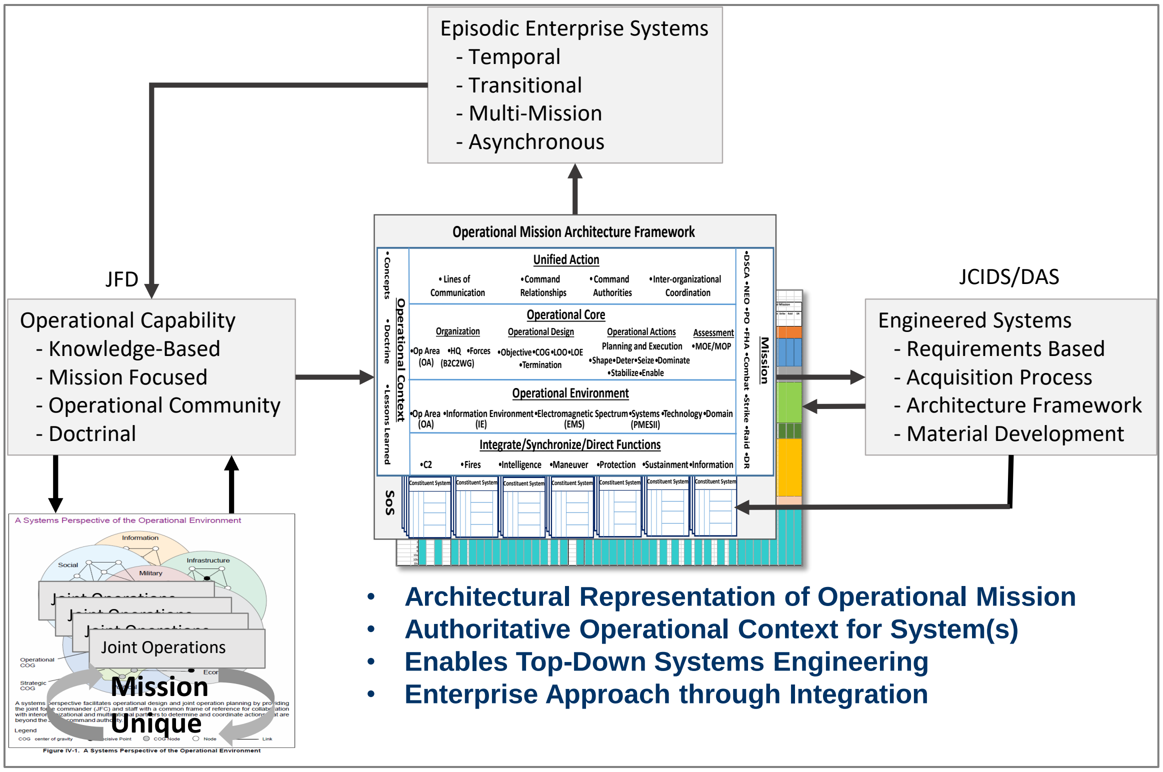

Figure 4. OMAF/OBAM Integration of DoD Capability Development Systems. Adapted from CJCS (2017).

Note that this implementation of OMAF/OBAM addresses the limitation presented in Figure 1, specifically the lack of integration between the knowledge-based development system for realizing operational capability (in this case, JFD) and the requirements oversight and acquisition systems (in this case, JCIDS/DAS). This blended approach allows the operational community to communicate, using their own terminology, with systems engineers. Systems engineers can, in turn, execute enterprise-architecting activities in their own terminology, facilitated by the associative mapping matrix. This promotes a more effective and efficient dialogue between mission operators and systems engineers than those centered on review and adjudication of engineering and architecture products. Together, they deliver an intuitive approach for both systems engineers and enterprise stakeholders to converge and achieve operational success for a mission-focused enterprise.

1. Operational Mission Architecture Framework

OMAF organizes the key components of DoD's JFD Life Cycle into a common reference architecture, composed of ten Operational Elements (Unified Action, Organization, Operational Design, Operational Actions, Assessment, Operational Environment, Functions, Operational Context, SoS, and Mission), for mission stakeholders and systems engineers to achieve unity of effort for realizing joint operational capability (Figure 5). The organizing construct provides a visual reference that orients stakeholders to the foundational components of joint operations, as defined in joint doctrine (CJCS 2013): achieving Unified Action; executing Operational Core functions; scoping the Operational Environment; and, integrating, synchronizing, and directing mission essential operations.

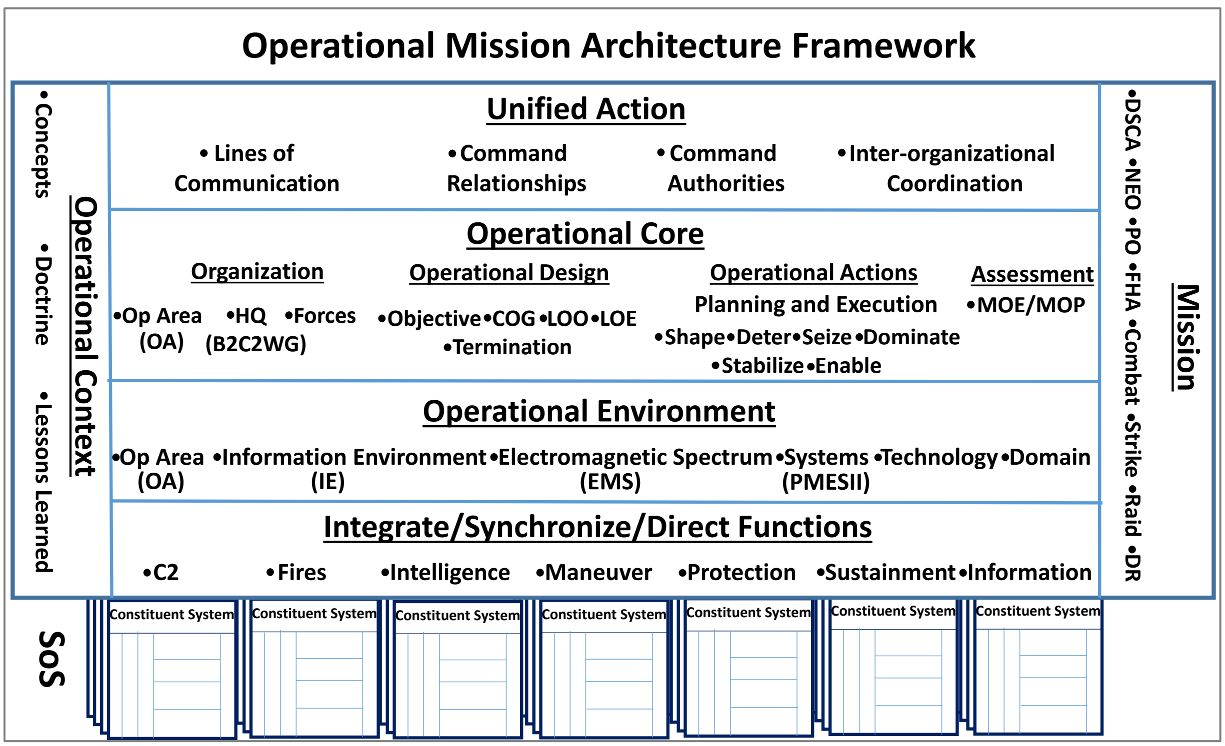

Figure 5. Operational Mission Architecture Framework.

OMAF utilizes existing integrated architecture products, created within the DAS and JCIDS constructs. Operational context is defined specifically, using authoritative doctrine and informed by lessons learned from previous operations, in terms of Unified Action, Operational Core, Operational Environment, and Operational Functionality. This provides an additional structural perspective regarding the operation of SoS (as well as their constituent subsystems) in support of broader operational mission objectives that would not be possible using traditional SE or SoS processes. Systems engineers are now able to develop solutions, using a preferred top-down approach, for the full range of operational mission types.

Rapid technology advancements and access, and adaptive adversaries increasingly challenge our ability to deliver relevant operational mission capability through traditional doctrinal thinking and legacy industrial-era mindsets. The proposed OMAF explored in this research is intended to provide an enabling framing construct and blended approach that leverages cultural strengths, accepts operational complexity and uncertainty, and bridges communities to achieve unity of effort toward a more adaptive and innovative enterprise response to 21st century operational challenges.

2. Operational Blended Architecture Map

The organizing construct and design of OMAF is not intended to replace any of the DoD capability develop systems, but rather to integrate them and enable the systems engineering of the ten Operational Elements of joint warfighting capability. An associative mapping tool, the Operational Blended Architecture Map (OBAM), has been developed to enable the use of DoD's enterprise architecture model (Figure 6). The mapping of DODAF to OMAF promotes a blended approach to architecting where systems engineers can communicate with the warfighter in doctrinally consistent terms while generating architecture viewpoints. Since joint operational capability is supported by systems and SoS architectures developed under the JCIDS and DAS, the application of existing enterprise architecture tools and processes promotes an inclusive and efficient enterprise approach.

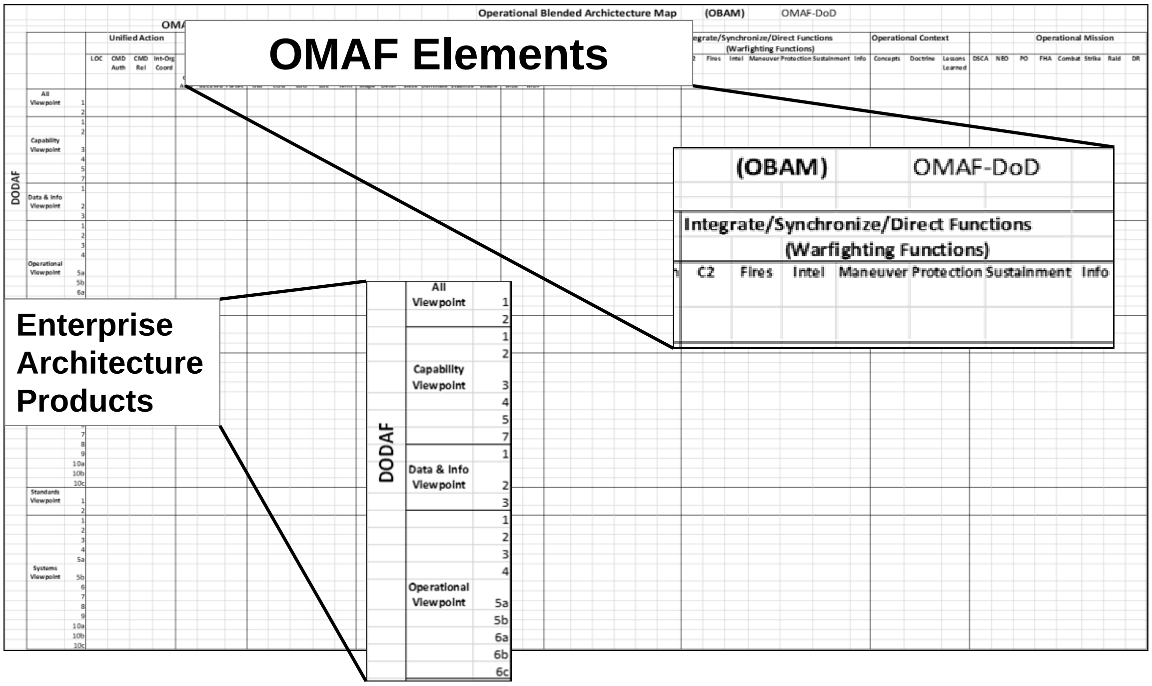

Figure 6. DoD Operational Blended Architecture Map (OBAM).

The mapping of the DODAF model viewpoints to the OMAF Operational Elements enables a precise architecting effort by the systems engineer and facilitates the desired blended approach for the DoD enterprise (Figure 7). The color coding is consistent with the DODAF model color codes (Wennergren 2009, 9). The mapping was conducted by decomposing OMAF Operational Elements in terms of the standard interrogatives (who, what, when, where, why, and how), and subsequently associating them with the applicable DODAF model viewpoints.

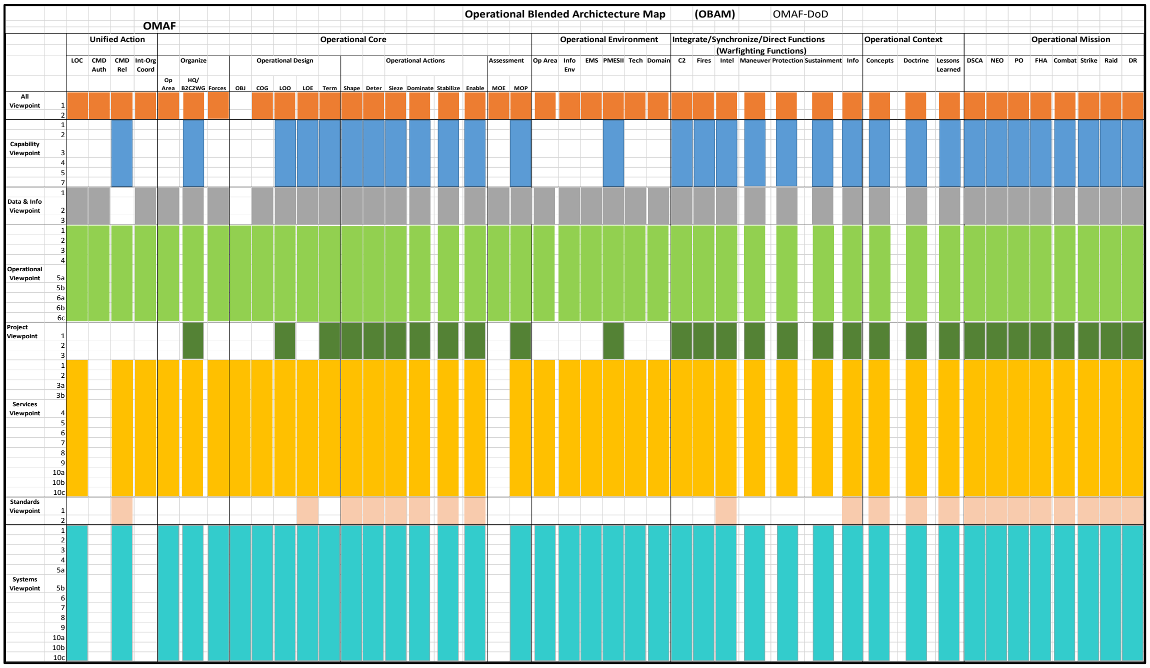

Figure 7. DODAF Model Viewpoint Mapping.

For example, the purpose of the OMAF Organize HQ operational sub-element is to prepare and arrange the command installation (CJCS 2017). Recognizing that the command installation has a geographic location (where), personnel (who), mission (what, when), and functions/processes (how), the standard interrogatives are who, what, where, when, and how for that element. The applicable DODAF Viewpoints for this set of standard interrogatives are therefore: All Viewpoint; Capability Viewpoint; Project Viewpoint; Operational Viewpoint; Systems Viewpoint; Services Viewpoint; and, Data & Information Viewpoint.

A deeper look at the Project Viewpoint, since the applicability of this particular viewpoint to headquarters (HQ) organization may not be intuitive, may have some value. The three Project Viewpoints (PV) in DODAF describe "the dependency relationships between organizations and projects as well as the organizational structures needed to manage a portfolio of projects; a timeline for programs or projects citing key milestones and interdependencies; and, a mapping of programs and projects to capabilities" (Wennergren 2009, 177). Since the PV is the architecture model that addresses organizational structures, it is appropriate (at an architectural level) to utilize the PV model.

Furthermore, an operational mission has a beginning, an objective(s), a desired end-state, and defined phases that resemble a life cycle, essentially the same elements of a project but in a different context, thereby reinforcing the assertion that the PV model is appropriate.

Stepping back, the mission-level organizational relationships in OMAF are sub-elements of Unified Action, "a comprehensive approach that focuses on coordination and cooperation between the U.S. military and other inter-organizational participants to achieve common objectives" (CJCS 2017, x). Operational timelines are elements of Operational Design and Operational Phasing. The complete mapping of the DODAF/OMAF elements through OBAM can facilitate a more informed dialogue and clarify critical context that affects architecture and design of supporting SoS and system capabilities. Through this blended approach, OBAM enables a comprehensive cross-community effort, or "Unified Action," for realizing 21st century operational level capability.

3. Provides Integrating Function for DoD Capability Development

A DoD-enterprise architecture for developing joint warfighting capability emerges from the integrating function of OMAF (Figure 8). The integration of these systems at the architectural level is minimally disruptive to the enterprise, as existing authorities/processes remain in place.

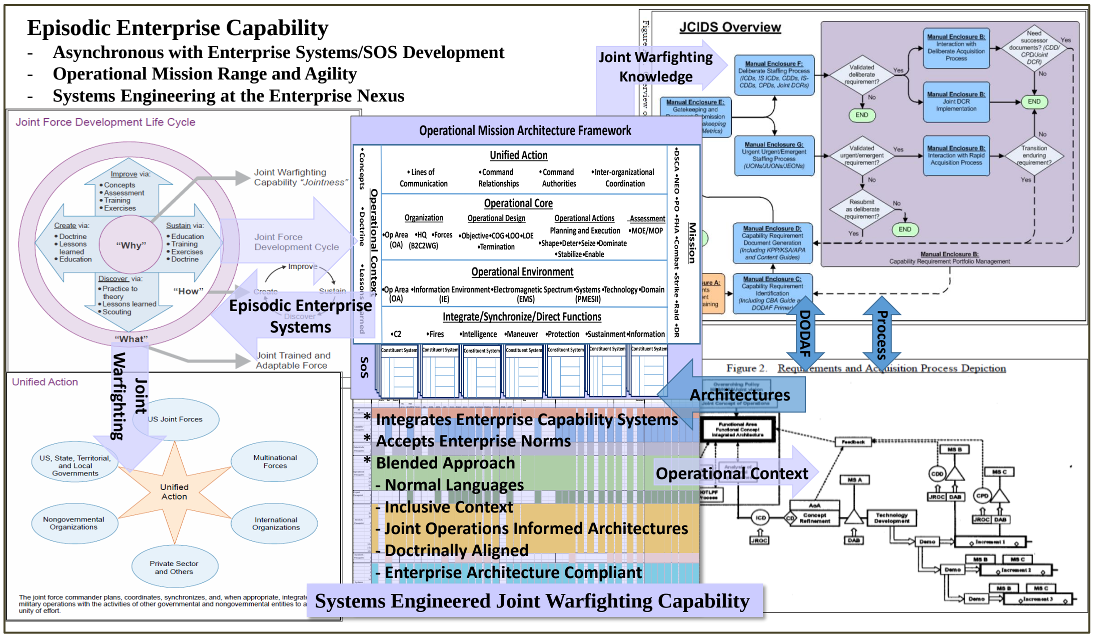

Figure 8. Joint Warfighting Capability Enterprise Architecture. Adapted from CJCS (2015b); CJCS (2013); SECDEF (2003).

I. CONCLUSION

This dissertation proposes an operational level architecture framework and an enterprise approach to develop and deliver joint warfighting capability. Furthermore, it is intended to provide the structure and organization to engineer directly at the operational level, (accepting the inherent complexity at that level), and seeks to provide missing context for traditional enterprise systems/SoS engineering endeavors. All three lines of effort are needed to deliver relevant 21st century operational mission capability.

The pace of change of the operational environment, commercial technology advances, emergence of the cyberspace domain, and resurgent adversaries, place unprecedented demands on our warfighters. The fielding of time-sensitive capability that supports the cognition-based approach of commanders and staffs requires a more inclusive, adaptive, and agile approach to developing warfighting capability. The timelines and tactical level focus of the traditional reductionist industrial era approach are no longer sufficient.

A comprehensive development effort, inclusive of systems engineering capabilities (i.e., architecting, modeling, design, and analysis), is required to better integrate the joint force, provide timely solutions to unique operational challenges, and influence supporting system(s) development by the Services and partners. The episodic time-sensitive nature of joint operational capability and the complexity of the operational environment typically require an enterprise approach to deploy the breadth of capabilities necessary to achieve operational mission success.

Traditional systems engineering in the Department of Defense is a foundational element of systems, Systems of Systems, and enterprise systems capability development and is codified in DoD policy and instruction. Essentially, the warfighter gets the benefit of the engineering mindset as part of an acquisition program or system design/upgrade, both of which rely on requirements maturity and clarity and introduce changes that must be institutionalized before operational benefits can by realized.

The OMAF organizing construct and the OBAM blended approach delivered in this research provide an architectural framework intended to enable cross-domain dialogue and to address vital elements of the operational perspective (relationships, interdependencies, and complexities) through systems engineering. Bringing enterprise process owners, commanders, operators, and system engineers into better alignment is critical for successful SoS architecting and design activities that deliver relevant 21st century warfighting capability.

THIS PAGE INTENTIONALLY LEFT BLANK

II. LITERATURE REVIEW

The intent of this chapter is to orient the reader to the three capability development systems of the United States Armed Forces, as well as the enterprise architecting and systems engineering applications for developing warfighting capability: Joint Force Development (JFD) Life Cycle; Joint Capabilities Integration and Development System (JCIDS); Defense Acquisition System (DAS); and, Department of Defense Architecture Framework (DODAF). This dissertation offers an enabling framework for both the warfighting and systems engineering communities (a blended approach) to collectively develop operational level capability with a common methodological context and architecture.

Specifically, fundamental principles and doctrinal foundations, levels of warfare, and JFD Life Cycle will be outlined to provide insight into DoD's knowledge-based approach to joint warfighting capability. With joint operational capability being formed from the DoD enterprise, as well as other agencies and partner nations, the application of enterprise architecting will be reviewed. Also, the application of systems engineering, to include mission engineering (Gold 2018), directly at the operational level will be explored.

A. JOINT FORCE DEVELOPMENT

Developing the joint force is accomplished through a continuous systematic effort that integrates capabilities developed by the Services and prepares individuals and teams to execute assigned missions (CJCS 2013). The joint force development process is closed looped and is designed to both improve and sustain joint warfighting capability (Figure 9). Rather than being a requirements-based process, joint force development is a knowledge-based enterprise where both preparedness of participants and integration of enterprise capabilities are critical to mission success. Additionally, the continuous nature of the Joint Force Development Life Cycle enables the DoD enterprise to form episodic, event-driven/on-demand operational capability supported by individual Service capabilities. Three subordinate processes provide operational context for planning and executing joint operations, as well as for SoS development: joint concepts; joint doctrine; and joint lessons learned.

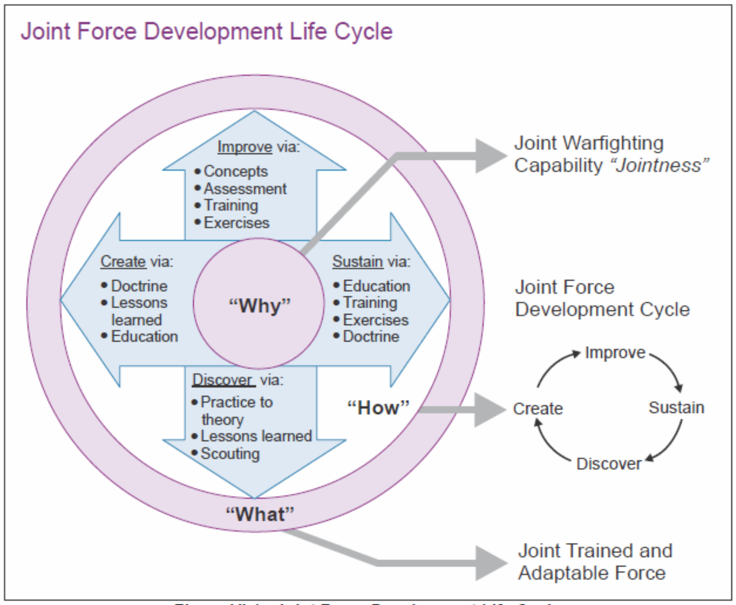

Figure 9. Joint Force Development Life Cycle. Source: CJCS (2013).

1. Joint Concepts

> Joint concepts examine military problems and propose solutions describing how the joint force, using military art and science, may operate to achieve strategic goals within the context of the anticipated future security environment. Joint concepts lead to military capabilities, both non-materiel and materiel, that significantly improve the ability of the joint force to overcome future challenges.(CJCS 2013, VI-9)

The primary purpose of joint concepts is to provide the joint enterprise a vision for conducting operations. The Capstone Concept for Joint Operations: Joint Force 2020 (CCJO: 2020) for example, introduces the vision of Globally Integrated Operations (GIO) in response to disruptive technologies. The document also states that 80% of Joint Force 2020 is already programmed/under contract (CJCS 2012a). Together, the GIO vision and the constraint of 20% availability of forces provide critical architecture and design context for operators and capability developers alike.

Another joint concept, the Joint Concept for Cyberspace, nests under the CCJO: 2020 and provides additional insight into how joint concepts influence architecture and design. The concept's central idea is to normalize cyberspace operations. (CJCS 2015c). The word "normalize" may have connotations, or at the very least considerations, at both the operational and SoS levels, to include governance, business and technical processes, lexicon, interoperability and integration, command and control, coordination, architecture, and design (Figure 10).

(U) Key Elements of
Normalized Joint Cyberspace Operations

- (U) Integrate CO into the intelligence, planning, and targeting processes and operations
- (U) CO-ready joint force
- (U) Agile, flexible, reliable, and rapidly deployable common network architecture
- (U) Synchronized situational awareness of cyberspace and the other domains
- (U) Responsive CO approval process
- (U) Partnerships with other agencies and governments
- (U) Command and control
- (U) Rapid capability development

Figure 10. Normalized Joint Cyberspace Operations Key Elements. Source: CJCS (2015c).

2. Joint Doctrine

Fundamental principles and authoritative guidance for employment of joint forces is provided in joint doctrine. As such, systems engineers must architect and design capabilities that ensure alignment with authoritative guidance. To reinforce this assertion, Joint Publication 1, Doctrine for the Armed Forces of the United States authoritatively states that

> This publication is the capstone joint doctrine publication and provides doctrine for unified action by the Armed Forces of the United States. It specifies the authorized command relationships and authority that military commanders can use, provides guidance for the exercise of that military authority, provides fundamental principles and guidance for command and

control, prescribes guidance for organizing and developing joint forces, and describes policy for selected joint activities. It also provides the doctrinal basis for interagency coordination and for U.S. military involvement in multiagency and multinational operations. (CJCS 2013, i)

Joint Doctrine is comprehensive, with publications spanning levels of war, joint operations, and joint functions. This collection of enterprise knowledge is extensive and evolves through doctrinal publication updates that are intended to keep pace with approved joint concepts, inputs from the joint force, and lessons learned from joint operations and joint exercises. Both the hierarchy and fluidity of joint doctrine can be seen in Figure 11, with forty one percent of the publications being modernized.

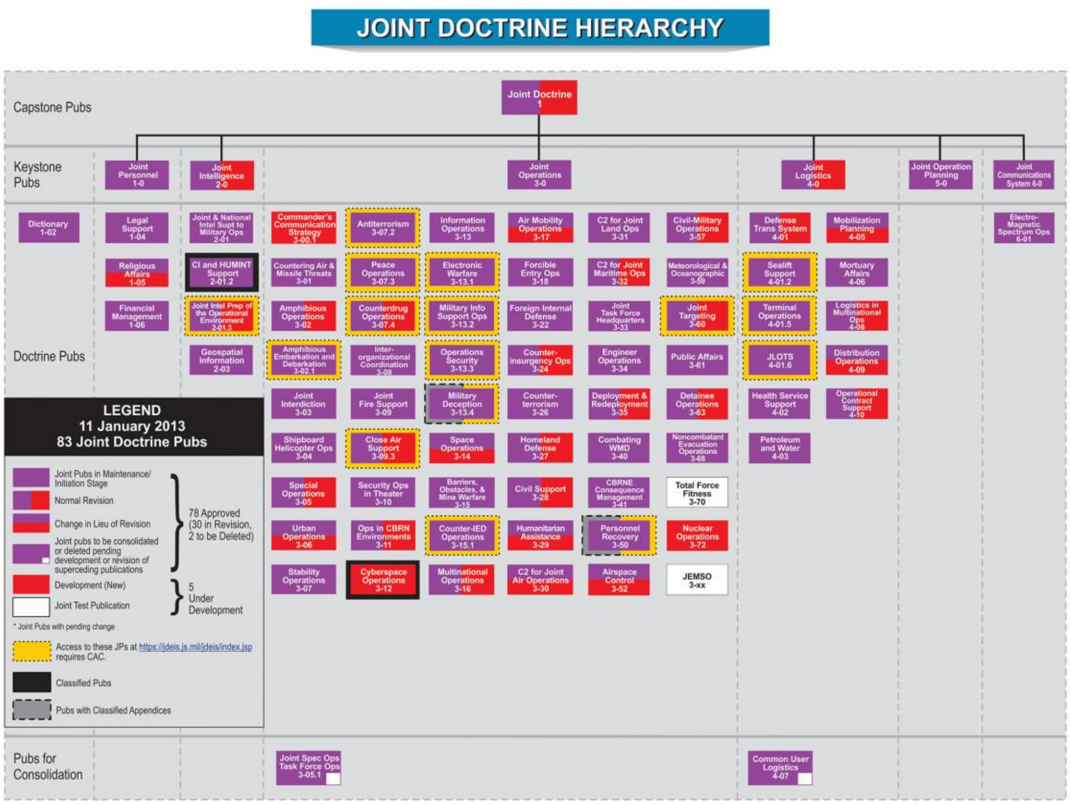

Figure 11. Joint Doctrine Hierarchy. Source: Rowlett (2013).

At the operational level, authoritative guidance is promulgated through Joint Publication 3–0: Joint Operations, and is even more direct regarding its authoritative nature: “The guidance in this publication is authoritative; as such, this doctrine will be followed except when, in the judgment of the commander, exceptional circumstances dictate otherwise” (CJCS 2017, i). Operational Art, the cognition-based capability previously discussed, is supported by Operational Design: “the conception and construction of the framework that underpins a campaign or major operation plan and its subsequent execution” (CJCS 2017, xii). This statement indicates that this higher-level design component for joint operations should indeed be considered in the design of supporting SoS. For example, a systems perspective of the operational environment, Figure 12, identifies the interconnected components that influence both operational design and SoS capabilities architecture, design, and testing. There will be a deeper look at operational design in Section C. The organizing construct in OMAF includes these capstone/keystone elements and provides operational and engineering perspectives not explicitly covered in the DODAF.

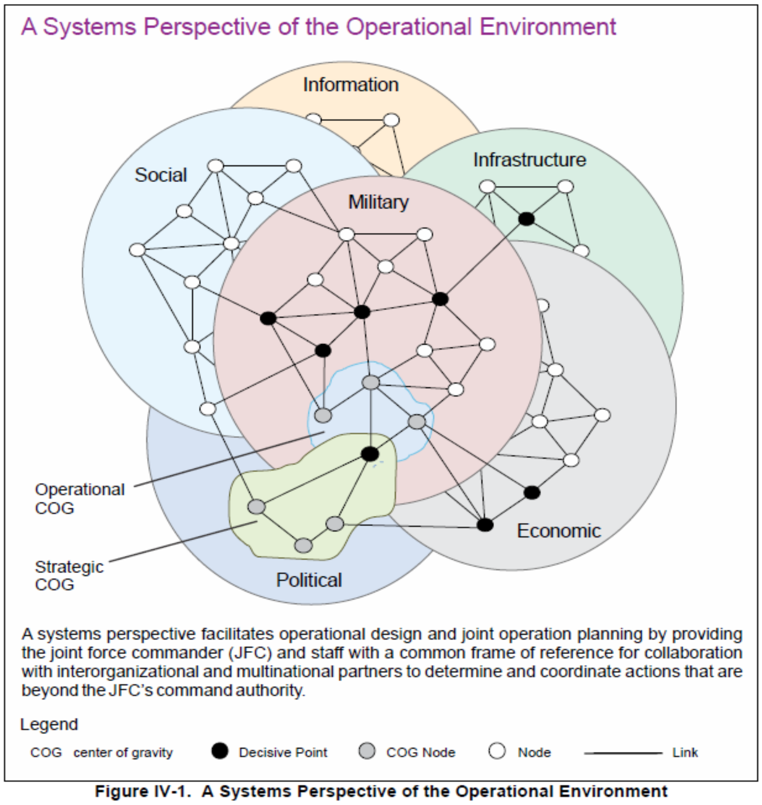

Figure 12. Systems Perspective of the Operational Environment.
Source: CJCS (2017).

The operational environment is influenced by the strategic environment, which is continuously changing. Partnerships/alliances and threats emerge, disaggregate, and remerge in an unpredictable manner. Additionally, the DoD enterprise will organize into a mission specific JTF that will be dissolved once mission objectives have been achieved (CJCS 2017, I-3). The episodic and uncertain nature of the environment and the enterprise capability employed in the operational environment should influence the systems engineering of enterprise capabilities, to include the application of systems engineering directly at the operational level.

3. Lessons Learned

The third component of joint force development that contributes to operational context for systems engineers is the lesson-learned process. This process (Figure 13) includes observing joint operations, conducting analysis, and implementing necessary changes across the Joint Force Development Life Cycle and capability development.

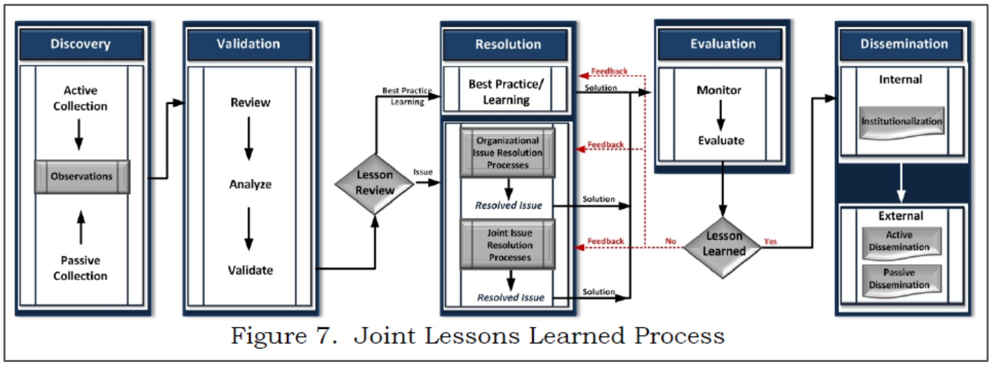

Figure 7. Joint Lessons Learned Process

Figure 13. Joint Lessons Learned Process. Source: CJCS (2015a).

The focus of lessons learned, as stated in JP-1, is

> the conduct of joint operations, as well as the execution of each part of the joint force development process, in order to continuously identify and assess the strengths and weaknesses of joint doctrine, joint education, and joint training as well as strategy, policy, materiel, and supporting military systems. (CJCS 2013, VI-8)

The construct of lessons learned is doctrinally mandated, or authoritative, and therefore must be considered by systems engineers. Due to the breadth of lessons learned (operations, policy, materiel, doctrine, etc.), this component of joint force development should be considered at the architectural level of a capability development effort and continued throughout the systems engineering processes.

B. ENTERPRISE ARCHITECTURE FRAMEWORK

Engaging the collective brains of the enterprise's cognition-based decision makers/stakeholders and the rational/analytic systems engineers to deliver 21st century operational level capability, begins with defining an operational framework, at the architectural level. Maier and Rechtin (2009) point out that frameworks at the architectural level are the primary vehicle for standardization and serve much the same purpose as blue-print standards. Furthermore, Maier and Rechtin emphasize that an architecture framework does not specify information at the detailed design level but rather contains information that is needed to represent the purposes of the user. A review of predominate architecture frameworks for system(s) development and interoperability follows, with an excursion into decision-making frameworks. The intent is to explore how systems engineers can address the cognitive art elements of OMAF in architecture.

1. Department of Defense Architecture Framework Version 2.0 (DODAF V2.0)

The DoD mandates, through policy and instruction, the use of DODAF V2.0 for Joint Capability Development. This version of the framework acknowledges the distinction between services and systems and emphasizes the purpose, scope, and information requirements of the architecture (Figure 14). While other frameworks and/or approaches can influence DoD architects/systems engineers, DODAF V2.0 is the approved framework.

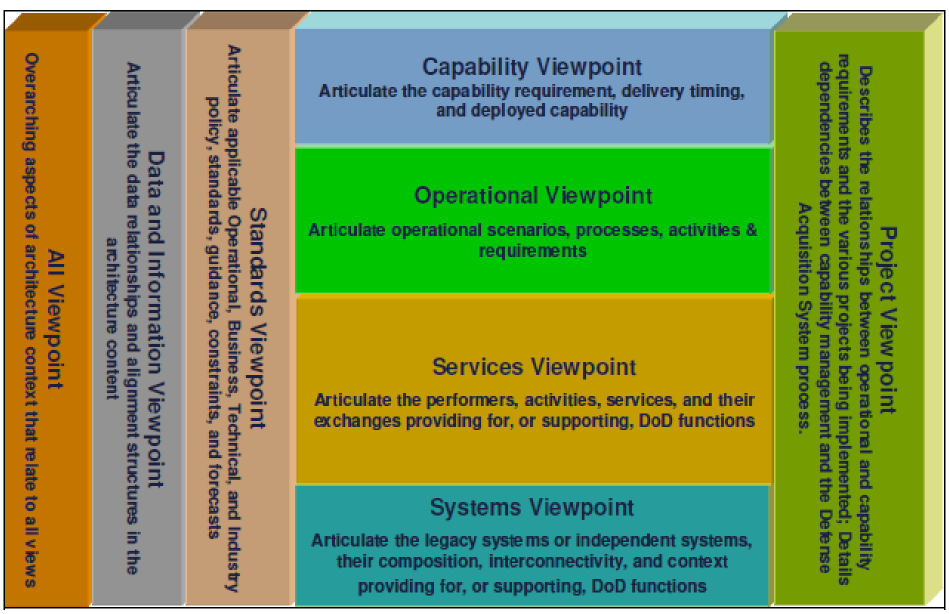

Figure 3-1: DoDAF Viewpoints

Figure 14. DODAF Viewpoints. Source: Wennergren (2009).

This version of the DoD architecture framework, with fifty-two models/viewpoints, serves as the enterprise framework and conceptual data model. Wennergren (2009) explains that it “focuses on architectural data and information required by key DoD decision-makers, rather than on developing individual products” (2). Additionally, there are twelve categories of data that architectures are to be built upon, Figure 15, as well as guidebooks for managers, architects, and developers. Management and modernization of DODAF V2.0 will be accomplished through incremental changes with oversight from the DoDAF Core Management Group, within the context of a federated enterprise architecture, which promotes integration and interoperability. The standardized structure, categorization of data, and guidebooks promote consistency across the DoD enterprise.

As discussed previously, the primary audience for DODAF V2.0 data and information are DoD decision makers. However, while DoD capability developers are mandated to use DODAF V2.0, operational decision makers, both commanders and staff, are expected to be doctrinally compliant. The mandated architecture data categories in Figure 13 are not consistent with the doctrinal language at the operational level. This disconnect in language (and context) impacts the relationship between operational decision makers, architects, and engineers and is further exacerbated by the episodic/time sensitive and fluid nature of operational level employment.

- Performers
- Resource Flows
- Information and Data
- Activities
- Training/Skill/Education
- Capability
- Services
- Projects
- Goals
- Rules
- Measures
- Locations

Figure 15. DODAF Data Categories. Source: Wennergren (2009).

The implementing guidance for DODAF V2.0 also aligns the data categories, or meta-model data groups, and “DoD Key Processes” (Figure 16). Both JCIDS and DAS are identified. However, JFD, the processes that develops the cognition-based element of the joint force, is not included.

Table 3.3-1: DoDAF Meta-model Groups Mapping to Viewpoints and DoD Key Processes

Metamodel Data Groups	Viewpoints AV, CV, DIV, OV, PV, StdV, SvcV, SV	DoD Key Proceses JCIDS, DAS, PPBE, System Engineering, Operations, Portfolio Management (IT and Capability)
Performer	CV, OV, PV, StdV, SvcV, SV	J, D, P, S, O, C
Activity	OV	J, O, C
Resource Flow	OV, SvcV, SV	J, S, O
Data and Information	AV, DIV	J, D, P, S, O, C
Capability	CV, PV, SV, SvcV	J, D, P, S, O, C
Services	CV, StdV, SV	P, S, C
Project	AV, CV, PV, SvcV, SV	D, P, S, C
Training / Skill / Education	OV, SV, SvcV, StdV	J, S, O
Goals	CV, PV	J, D, P, O, C
Rules	OV, StdV, SvcV, SV	J, D, S, O
Measures	SvcV, SV	J, D, S, O, C
Location	SvcV, SV	P, S, O

Figure 16. DODAF Meta-model to Viewpoints and DoD Key Processes Mapping. Source: Wennergren (2009).

Subsequent sections of this dissertation will describe OBAM's associative mapping of authoritative, doctrinally based, operational architecture and mandated DODAF V2.0 architecture viewpoints. It will then be possible to explore whether DoD cognition-based, operational decision makers' needs can readily be included in DODAF V2.0 compliant architecting activities.

2. Zachman Framework

One of the most widely adopted frameworks for enterprise architecture development is the Zachman Framework (Sowa and Zachman 1992). The two-dimensional matrix is organized so that each cell uniquely represents a relationship and entity of the enterprise (Figure 17).

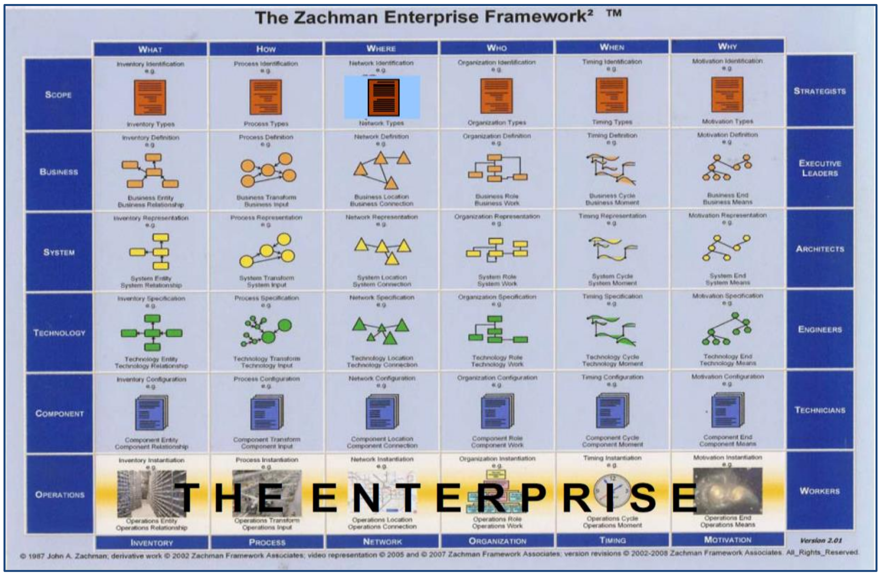

Figure 17. Zachman Enterprise Framework. Source: Zachman (2007).

Enterprise integration relationships are captured horizontally (rows) across the standard interrogatives (what, how, where, who, when, and why), and enterprise transformation relationships are identified vertically (columns). The resultant enterprise operational capability is identified along the bottom row, as enterprise instantiations. The Zachman Framework captures the fundamentals of an enterprise architecture (i.e., standard interrogatives for the unique roles of the enterprise members) for solution development.

The DoD enterprise has tried to take advantage of this approach and mapped enterprise architecture levels to the Zachman Framework (Figure 18) for DODAF V2.0. Furthermore, DODAF viewpoints are mapped to the standard interrogatives (Figure 19). These mappings should foster an enterprise perspective for the DoD architect. However, generically mapping two enterprise frameworks omits critical enterprise-specific context and values that can affect solution architecture and design. For example, the DoD Enterprise's values and principles are documented in a structured series of authoritative documents, called Joint Doctrine (CJCS 2013). Both architecture and design for enterprise endeavors must reflect these principles, which are not deliberately addressed in either enterprise framework.

Table 1.2-3: Zachman Framework with Levels of Architecture

Strategic Architectures apply to entire Department | Capability Architectures specific to CPM & Component Tiers | Solution Architecture: Materiel/Non-materiel | DoD EA { Strategic, Capability }

	Layer	What (Data)	How (Function)	Where (Network)	Who (People)	When (Time)	Why (Motivation)
1	Scope Context Boundary (Planner)	List of things important to the business	List of processes the business performs	List of locations in which the business operates	List of organizations important to the business	List of events significant to the business	List of business goals/ strategies
2	Business Model Concepts (Owner)	e.g., Semantic or Entity-relationship Model	e.g., Business Process Model	e.g., Business Logistics System	e.g., Work Flow Model	e.g., Master Schedule	e.g., Business Plan
3	System Model Logic (Designer)	e.g., Logical Data Model	e.g., Application Architecture	e.g., Distributed System Architecture	e.g., Human Interface Architecture	e.g., Processing Structure	e.g., Business Rule Model
4	Technology Model Physics (Builder)	e.g., Physical Data Model	e.g., System Design	e.g., Technology Architecture	e.g., Presentation Architecture	e.g., Control Structure	e.g., Rule Design
5	Component Configuration (Implementer)	e.g., Data Definition	e.g., Program	e.g., Network Architecture	e.g., Security Architecture	e.g., Timing Definition	e.g., Rule Specification
6	Functioning Enterprise Instances (Worker)	e.g., Data	e.g., Function	e.g., Network	e.g., Organization	e.g., Schedule	e.g., Strategy

Figure 18. Zachman Framework with Levels of Architecture. Source: Wennergren (2009).

Table 1.2.1-1: Standard Interrogatives Matrix

	What (Date)	How (Function)	Where (Network)	Who (People)	When (Time)	Why (Motivation)
Viewpoint	AV, DIV	OV, SV, SvcV	OV, SV, SvcV	OV	CV, OV, PV, SV, SvcV	AV, CV, OV, StdV, SV, SvcV
DoDAF-described Models	AV-2, DIV-1, DIV-2, DIV-3	OV-5a, OV-5b, OV-6a, b, c, SV-4, SV-10a, b, c, SvcV-10a, b, c	OV-2, SV-2, SvcV-2	OV-2, OV-4	CV-2, CV-4, OV-6c, PV-2, SV-8, SvcV-8, Sv-10c, SvcV-10c	AV-1, CV-1, OV-6a, StdV-1, StdV-2, SV-10a, SvcV-10a
Meta-model group	Information and Data, Project	Activity, Capability, Service, Measures	Location	Performer	All	Rules, Goals

Figure 19. DODAF Standard Interrogatives Matrix. Source: Wennergren (2009).

C. ENTERPRISE CAPABILITY REQUIREMENTS MANAGEMENT

The DoD enterprise manages and prioritizes capability requirements through JCIDS (CJCS 2015b). Essentially, the “system” is composed of capability portfolios and capability requirements documents for the Joint Force. Requirements validation, and interaction with the acquisition system, are guided by JCIDS processes (Figure 20). Enterprise architecture products are generated early in the requirements process and included in subsequent capability documents, which are passed to the acquisition system for solution development. Prior to entering the JCIDS process, a Capability Gap Assessment (CGA) or a similar study to assess requirements, gaps, and risks must be completed. The JFD Lessons Learned program is recognized as a source for both requirements and gap identification.

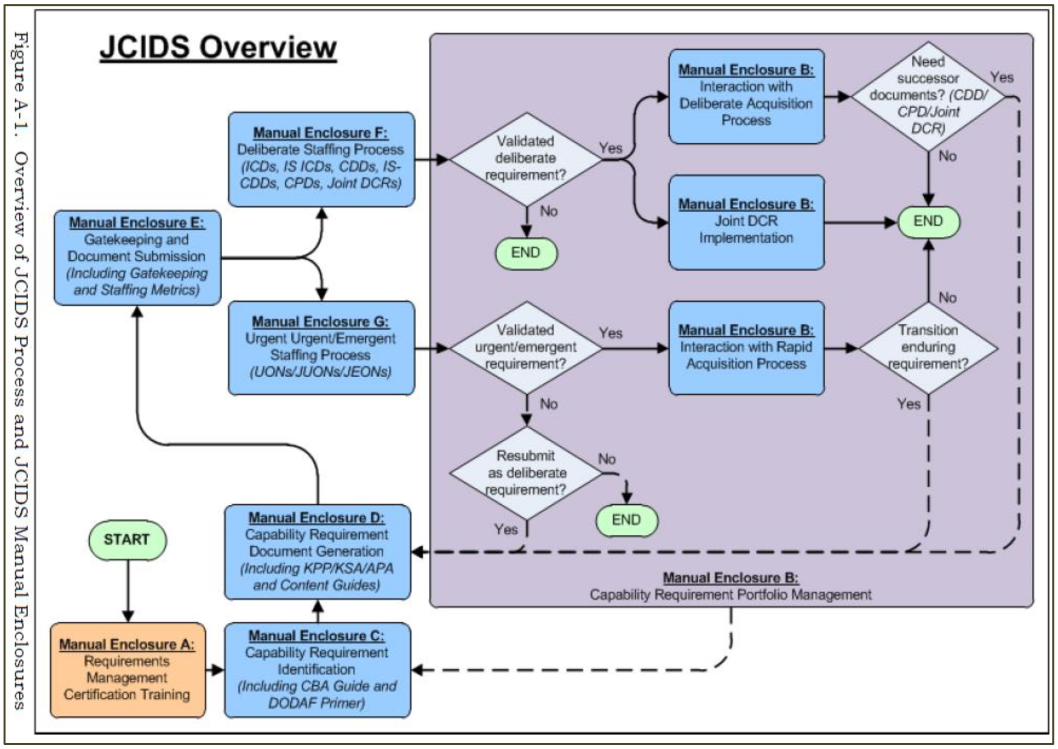

Figure 20. JCIDS Process. Source: CJCS (2015b).

The organizing construct for integration and management of the multiple factors associated with identification, assessment, and validation of requirements can be seen in Figure 21. System solutions and architectures are organized by warfighting domains (land, air, sea, space, and cyber). Capability Requirements are managed as a portfolio that include the operational architectures. This construct also includes alignment of capability requirements, strategy, operations, and missions to threats through the application of Universal Joint Tasks (UJTs). A "list" of these actionable, commonly understood tasks for DoD is maintained through the UJTL Program (CJCS 2014).

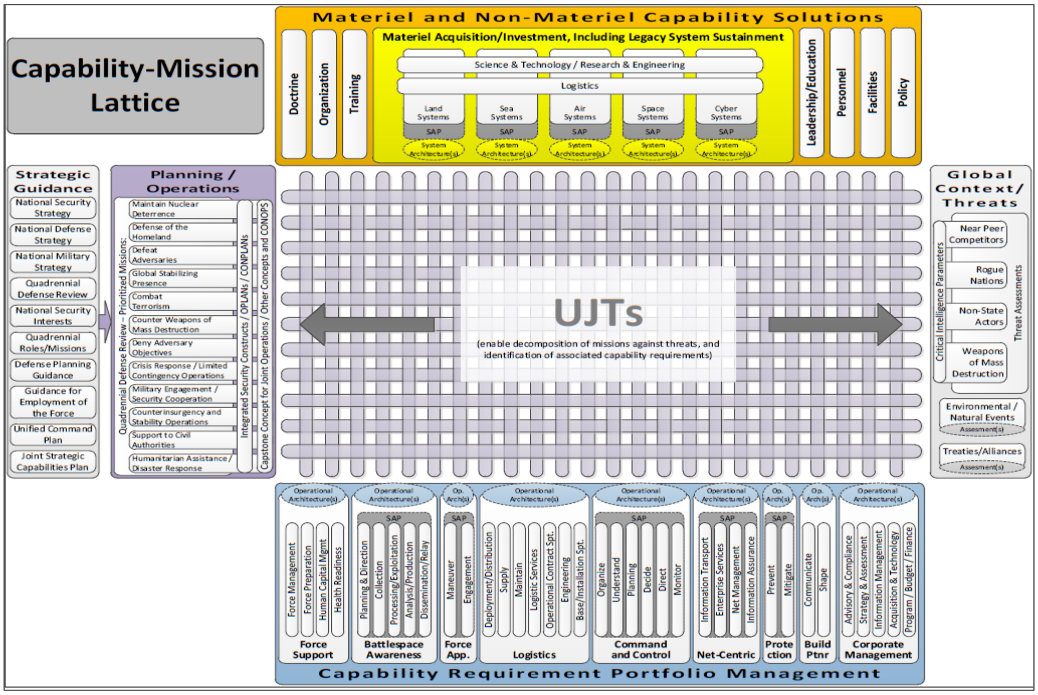

Figure 21. Capability Mission Lattice. Source: CJCS (2015b).

Through both the JCIDS process and the Capability Mission Lattice (CML) management construct, capability requirements are identified, documented, decomposed, and allocated for solution development. This is consistent with traditional systems engineering activities. However, the key components of JFD are not considered comprehensively, but rather are fragmented. Doctrine is allocated to the solution element of the CML when it should be considered together with Joint Concepts and Lessons Learned. With this partitioning, operational context is now incomplete and the cognitive approach to warfighting is not holistically considered at the operational level.

D. ARCHITECTURE IN DOD CAPABILITY DEVELOPMENT

Through the Defense Acquisition System (DAS), materiel solution-based capabilities are developed, fielded, and sustained for the DoD (SECDEF 2003). The system includes an acquisition management framework, as well as a requirements management process, and utilizes integrated architectures to integrate requirements and acquisition. The management framework, Figure 22, includes milestone decisions to assess readiness to move through the development phases. Requirements documents, generated through JCIDS, are required for Milestones A, B, and C.

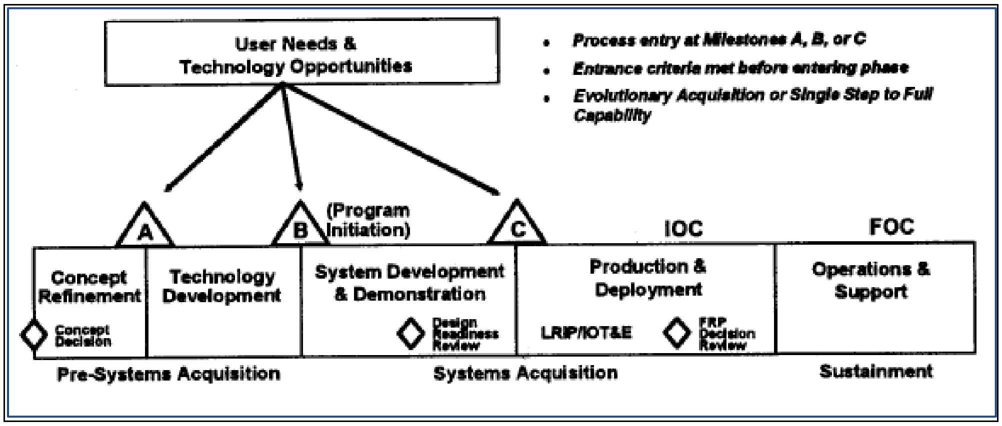

Figure 22. Defense Acquisition Management Framework.
Source: SECDEF (2003).

The process relationships, Figure 23, between requirements and acquisition are intended to achieve balance between requirements, capability, and resources. Requirements definition and technology maturation are considered throughout the process to promote a disciplined approach toward affordable systems and production. An Initial Capability Document (ICD) supports a concept decision to begin concept refinement and the Milestone A decision to move forward with technology development. The Capability Development Document (CDD) is required for a decision to begin system development at Milestone B. Lastly, a Milestone C production decision is informed by a Capability Production Document (CPD). The requirements documents (ICD, CDD, and CPD) are produced through the JCIDS process. These documents therefore also provide requirements and acquisition process integration points. Requirements are then informed by the solution development effort, and the solution development effort is then informed by requirements as the effort progresses.

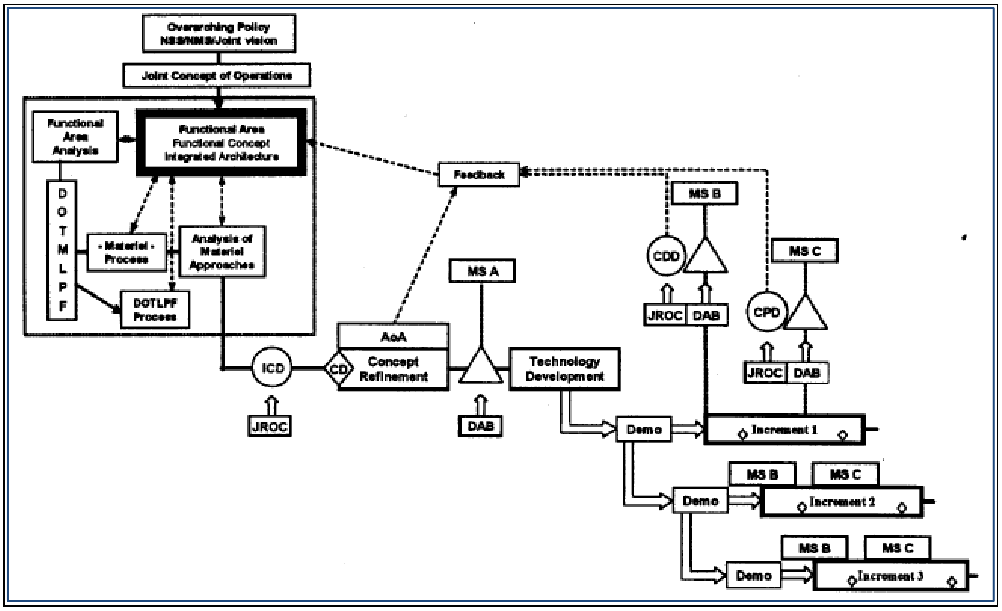

Figure 23. Requirements and Acquisition Process. Source: SECDEF (2003).

Integrated architectures, developed in compliance with DODAF, drive the development of plans that guide capability assessments, systems development, and investment decisions (SECDEF 2003). Both the requirements community and the acquisition/technical communities work collaboratively to develop the architecture products. The foundation for all integrated architectures, for all acquisition programs, is the Global Information Grid Integrated Architecture. The DoD Chief Information Officer (CIO) is responsible for its development (SECDEF 2003). This approach implies that interoperability and integration with the Global Information Grid (GIG), or information technology (IT), is the primary objective of the architecture effort. Furthermore, it implies that integrated architecting is an IT effort rather than a comprehensive capability architecting effort.

This skewing of the architecting effort toward IT during material development, and the fragmenting of the JFD components during requirements definition further obscure the operational context and JFD knowledge based capabilities necessary for operational capability.

E. SYSTEMS ENGINEERING CONSIDERATIONS

In order to contextualize OMAF within the existing systems engineering literature three areas must be reviewed: episodic systems, operational systems, and episodic operational systems. Note that these are not generally used terms in the systems engineering literatures, accordingly the relevant literature spans a number of distinct fields, specifically enterprise systems engineering, system of systems engineering, and systems architecting.

1. Episodic Systems

There are a number of approaches for developing enterprise capabilities. For example, existing enterprises may undertake strategy-initiated, subsystem level, or continuous improvement efforts (Giachetti 2010). Similarly, the DoD as an enterprise achieves alignment to strategy through the JCIDS process, subsystem development is executed through the DAS, and continuous improvement through the JFD Life Cycle (i.e., lessons learned, and training). The DoD enterprise also requires episodic capability: specific to a particular mission, limited in duration, and occurs at irregular intervals (*Merriam-Webster* 2018).

Relevant to this research and the episodic nature of DoD missions, Baumeister and Striffler (2015) explored systems development for episodic decision support capability. Knowledge-driven Decision Support Systems (DSS), which use problem-solving capabilities to derive courses of action for specified problems, loosely correlates with the knowledge-based approach to joint operations. The Knowledge Base and new/updated data available components of the decision-making process model in Figure 24 can be associated with the Joint Doctrine and Joint Lessons Learned elements of JFD, respectively.

Note that OMAF/OBAM are focused on definition of a framework to support enterprise level decisions and capabilities, while Baumeister and Striffler present an approach for the capture and reuse of data to support specific capabilities, accordingly the two efforts could be used simultaneously. They identify and discuss engineering challenges. Their recognition that aspects of the knowledge domain are not clearly understood by the technical community and that decisions are based more on "*past* *experience, evidence, and intuition*" certainly resonates with the motivation for this research (Baumeister and Striffler 2015, 46).

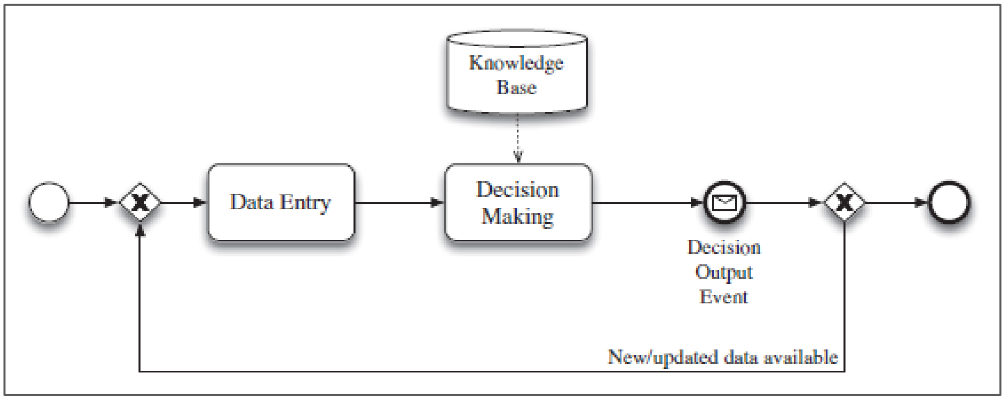

Figure 24. Decision Making Process. Source: Baumeister and Striffler (2015).

The engineering of capability for joint operations first needs to be organized at the architectural level due to scope (multi-mission/domain) and complexity (operational environment), before process modeling is undertaken. Engineering activities, like process modeling, can then be executed without losing mission-critical context.

2. Operational Systems

The application of systems engineering directly to operations (vice the systems that enable operations) has been recently explored and is both extremely relevant to this research and encouraging to this researcher. The National Academy for Engineering and the United States Institute of Peace (USIP) conducted a workshop to explore the concept of *operational systems engineering* in support of their peacebuilding mission (Robertson and Olson 2013). The term operational systems engineering is defined as:

> Operational systems engineering is a methodology that identifies the important components of a complex system, analyzes the relationships among those components, and creates models of the system to explore its behavior and possible ways of changing that behavior. In this way, it offers quantitative and qualitative techniques to support the design, analysis, and governance of systems of diverse scale and complexity for the delivery of products or services. (Robertson and Olson 2013, 1)

USIP has similar operational challenges as the DoD. Peacebuilding missions are also complex, with multiple relationships to manage in a conflict environment and the need for mission specific solutions. Workshop participants acknowledged that the peacebuilding community had limited ability to apply systems engineering, and that systems engineering should be included in peacebuilding efforts at all levels (from the field to management organizations). Both computational and relational modeling techniques were explored in the workshop. Building upon a DoD Joint Irregular Warfare Analytic Baseline (JIWAB) model (Wong et al. 2017), the Causal Loop Diagram in Figure 25, illustrates the value of systems maps for identifying unexpected operational behaviors (through both positive and negative feedback).

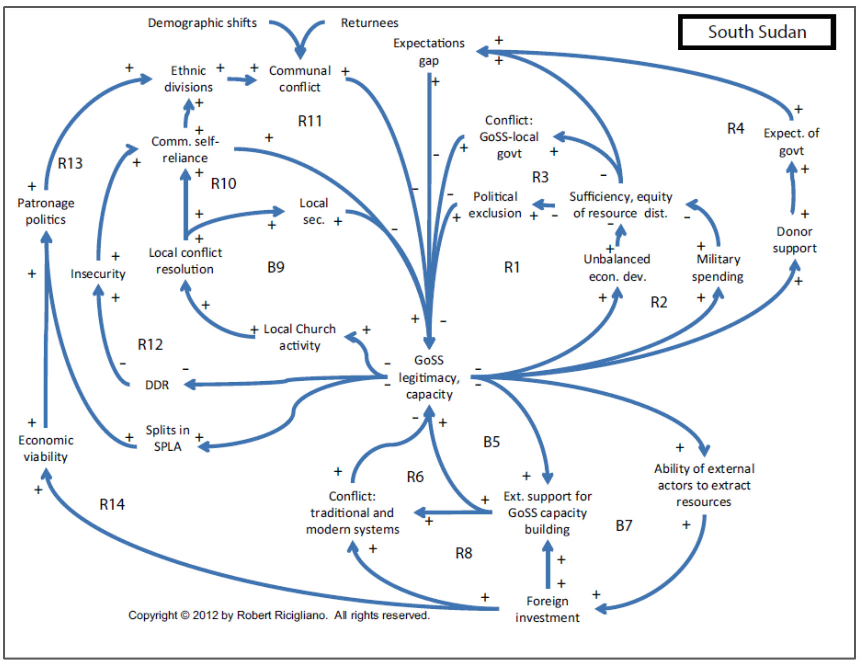

Figure 25. Systems analysis of South Sudan. Source: Robertson and Olson (2013).

Consistent with the DoD enterprise (i.e., DoD Joint Doctrine), USIP also developed guiding principles (Figure 26). Participants suggested that operational systems engineering could be applied for analysis of these guiding principles, several of which are thematically consistent with elements of DoD's Joint Doctrine. The cross-cutting principle of Unity of

Effort for USIP missions correlates with DoD's Common Operating Precept, by the same name, as characterized in Joint Doctrine (CJCS 2017). Unity of Effort for USIP missions "begins with a shared understanding of the conditions. It refers to cooperation toward common objectives over the short and long term, even when the participants are from many different organizations with diverse operating cultures" (Robertson and Olson 2013, 11–12). Interagency Unity of Effort, for DoD, is realized through unified action and "can only be achieved through close, continuous interagency and interdepartmental coordination and cooperation, which are necessary to overcome discord, inadequate structure and procedures, incompatible communications, cultural differences, and bureaucratic and personnel limitations" (CJCS 2013, II-13,14). Another consistency worth noting can be found in the cross-cutting principle/operating precept of transformation/transition. For USIP missions, "conflict transformation guides the strategy to transition from violent to peaceful means of conflict resolution" (Robertson and Olson 2013, 12), while DoD seeks to "plan for and manage operational transitions over time and space" (CJCS 2017, I-3).

Figure 26. USIP Guiding Principles. Source: Robertson and Olson (2013).

Also explored in this workshop, as part of the larger operational systems engineering topic, was the value of frameworks for enabling a systemic process for programming and mission assessment. The Conflict Assessment Framework (CAF) 2.0 (Figure 27) was developed by United States Agency for International Development (USAID) to better integrate mission analysis and response. All elements of the framework are nested within the context element.

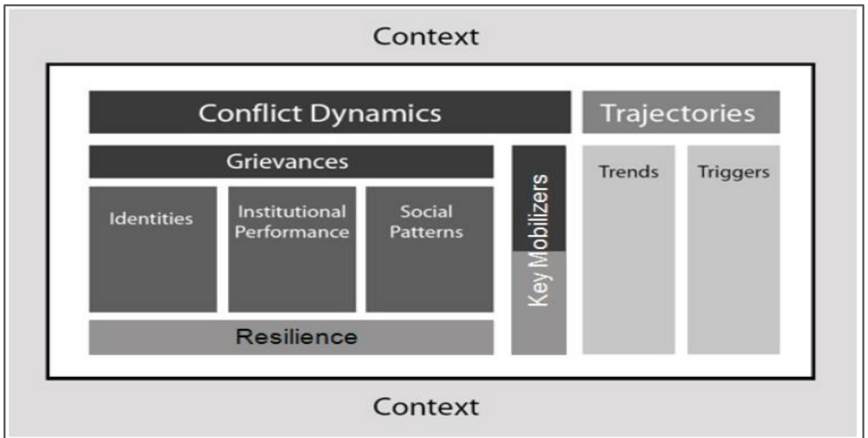

FIGURE 2-2 USAID's Conflict Analysis Framework 2.0. The framework is used to identify current conflict dynamics, possible future trajectories, and potential options for response to the crisis. SOURCE: USAID, Reiling workshop presentation.

Figure 27. USAID Conflict Analysis Framework. Source: Robertson and Olson (2013).

With both guiding principles and a mission framework available, the workshop participants acknowledged the importance of modeling to operational systems engineering, and that models become more complex when taking a systems approach. This complexity, in turn, then makes the models less useful when interacting with operations participants.

The dichotomy between systems engineering and operations is a motivating factor for this research. Additionally, the assertion that operational systems engineering can be applied across the levels (tactical/field through strategic/policy) of peacebuilding, and that "*operational systems engineering offers new and powerful ways of analyzing conflict situations and arriving at ways to address them*" (Robertson and Olson 2013, 55) is consistent with the intent of this research endeavor.

3. Episodic, Operational Systems

Enterprise capability development and the challenges of systems engineering episodic and operational systems have so far been explored. Enterprises also require a capability for episodic, operational systems that allow for the timely employment of multi-mission capabilities in challenging 21st century operational environments.

Enterprise systems (or enterprises as systems) have been researched in detail by Rouse (2006), who focuses on enterprise transformation across a three- to five-year time frame. He recognizes that developing system-based capabilities independently within the enterprise decreases the enterprise's potential to succeed, and that alternatively, through a combined systems engineering and management approach to transformation, a complete enterprise perspective can be included in the transformation effort.

Rouse further points out the challenges of applying engineering methods and tools at the enterprise level. Modeling techniques and tool selection, difficulties associated with determining the as-is and to-be states of the enterprise, overcoming the resistance to change, the lack of understanding of business processes, and transitioning knowledge and information into engineering form requires a substantial effort (Rouse 2006). Also, transforming the enterprise requires consideration of technical, behavioral, and social perspectives. The impacts to both how the enterprise does work and the social elements of the enterprise must be considered when introducing technology changes (Rouse and Baba 2006).

Rather than pursuing the above three-to-five year enterprise-wide effort to transform enterprise systems engineering, this dissertation addresses the architecture and methodology needed to engineer time-critical enterprise capability asynchronously from the larger enterprise transformation strategy. The technical, social, and behavioral perspectives of the enterprise are instantiated in architecture form to enable DoD operations.

Nightingale has conducted extensive research into ESE, focused primarily on frameworks for the transformation of enterprises (Nightingale 2009). The work is expanded to include the application of architecting to SoS-based enterprises through the field of engineering systems, which focuses on the enterprise challenges caused by the complexity of modern systems (Rhodes, Ross, and Nightingale 2009). Note that this research is focused primarily on the as-is and to-be enterprise. This can be contrasted with the goals of this intended to propose the creation of a unique mission-focused capability, enterprise systems engineering architecture.

Lankhorst's research on enterprise architecting, recognizes the ESE view of an enterprise, and categorizes the enterprise architecture drivers as internal (e.g., business-IT Alignment) and external (e.g., Clinger-Cohen Act requiring government agency IT architectures) (Lankhorst 2017). Lankhorst also explores the various architecture frameworks and methods (e.g., ArchiMate) to include DODAF, for developing enterprise architectures. The approach however, does not adequately address the application of enterprise architecture tools as part of a larger systems engineering methodology to realize unique mission-focused capability asynchronously from the larger enterprise.

Rebovich (2005) views government enterprises as "nested" with virtual boundaries that depend on the participants, and offers an operational definition of the enterprise as "the set of interdependent elements (systems and resources) that a participating actor or actors either control or influence. The remainder of the elements constitutes the enterprise environment" (2–3). He further explores how to evolve the enterprise in concert with traditional systems engineering efforts. Consistent with the previously cited research on engineering enterprises, the objective is to transform (or evolve) the enterprise however it is defined. A methodology to deliver time-sensitive, asynchronous, and unique episodic enterprise capability goes beyond such evolution of systems and processes. For the DoD enterprise, operational missions are unique and time-sensitive. Although the enterprise certainly has an opportunity to learn and evolve from each mission through a formal Lessons Learned program, a systems engineering methodology and architecture to deliver episodic operational capability is still not adequately addressed.

Goranson (1990) recognizes the need for enterprise agility and proposes metrics within a three-step process that allows managers to make informed decisions: assess the threat; evaluate ability; select tools and techniques. The research looks at the benefits of a combined virtual enterprise strategy that accepts diverse perspectives as an approach to achieving agility, particularly in the manufacturing of system-based capability. Although the central idea of making metrics-informed decisions and leveraging diversity to achieve agility can broadly be applied to episodic enterprise capability, the research focuses on only the temporal aspects of enterprise transformation. The methodology delivered through this endeavor however, provides the missing reference architecture and associated architecting approach to deliver episodic enterprise systems that achieve the desired time-sensitive mission capability.

Sitton and Reich recognize this unique challenge. Their research proposes an approach to overcoming the gaps in ESE, SOS, and SE approaches to realizing modern enterprise capability (Sitton and Reich 2015). The central component of their proposed approach includes an enterprise operational architecture, which is undefined.

The authors acknowledge the value of traditional architecture frameworks as a communication tool as well as recognizing that the state of the art insufficiently addresses the complexities of systems engineering an enterprise. Building upon, as referenced by the authors, "a very comprehensive book that covers most relevant theory and methods regarding enterprise systems engineering by Giachetti [2011]," they identify a gap in addressing unsynchronized systems, particularly in governmental organizations.

The use of current Enterprise Architectures (EA) frameworks to holistically describe enterprise architectures does not sufficiently address the gap. The Zachman Framework (Sowa and Zachman 1992) provides a comprehensive view of the enterprise, but given that the intended use of Zachman's Framework is a collection of formal, detailed models to support the extended operation of an enterprise, it is ill suited to the rapidly changing, potentially dissimilar episodic systems of interest to this research. DODAF's suitability for engineering large, complex systems and its role in DoD's core capability development processes is discussed. However, the authors did not identify JFD as one of the "six core processes." The authors accurately observed that the focus is on deliverables (8 categories and 52 viewpoints) and is fairly rigid, making adoption difficult across a diverse enterprise. Lastly, the lack of traceability from operational requirements to system architectures was identified by the authors. This gap can be reduced by including JFD in the architecting effort.

The central idea for addressing the ESE and SOS gap is the characterization of the enterprise as a System of Arrays as Systems (SAS). The characteristics can be seen in Figure 28. This bundling of SOS architectures into enterprise silos correlates well with the DoD operational level perspective of SOS capabilities as warfighting functions. The Air Force enterprise example specifically identifies Command and Control (C2) Systems and Intelligence Systems silos. C2 and Intelligence are doctrinally recognized operational functions in DoD (CJCS 2017).

Table I. Distinction between SOS and Enterprise SAS

Key Factor	SOS	Enterprise SAS
Discipline	Usually one discipline and common language.	Several disciplines, each one with different language.
System level	A planned setup of building blocks (constituent systems). A new constituent system (with the same functionality of an existing building block) can be added or replaced through time.	An enterprise is composed of unsynchronized arrays of systems (silos); each silo operates independently. New system offers new capabilities (not necessarily for existing functionality), other systems can vanish through time because of local constrains.
Processes level	Several coherent processes as integrated functionality of SOS.	Many cross-enterprise processes, each process is based on a different set of systems and silos, different requirements to support different operators' decisions in different silos. Inconsistent requirements for different silos are a major complexity factor that should be handled to reach coherent Enterprise operational architectures. New planned integrated and coordinated capabilities that cross enterprise arrays may not be achieved as planned because of local system/silo constraints resulting in a crash in the coordination effort.
Project level	SOS system development is handled as a project by itself. The project has clear goals and both start and end points. New blocks or versions are handled as projects as well.	Enterprise development over time does not have clear start and end points. Its goals are strategic and not easily translated to tactical goals of each system. Improvement in cross-enterprise processes can be achieved by defining strategic goals and road maps for long term transformation.

Figure 28. Enterprise SoS and SAS Distinction. Source: Sitton and Reich (2015).

The foundation for the proposed ESE approach, Figure 29, includes an operational architecture at the core. Although the authors recognize the importance of the architecture, it remains conceptual/undefined. Other elements of the foundation loosely align with elements in JFD. For example, an Operational Process Monitoring Center is included in the approach. Operational processes in the DoD enterprise are monitored through the JFD Life Cycle and updated through both the joint doctrine and joint lessons learned processes.

Also, the concept of an Integration Test-Bed aligns with JFD joint exercises and training where integration of knowledge, systems, and partners is assessed.

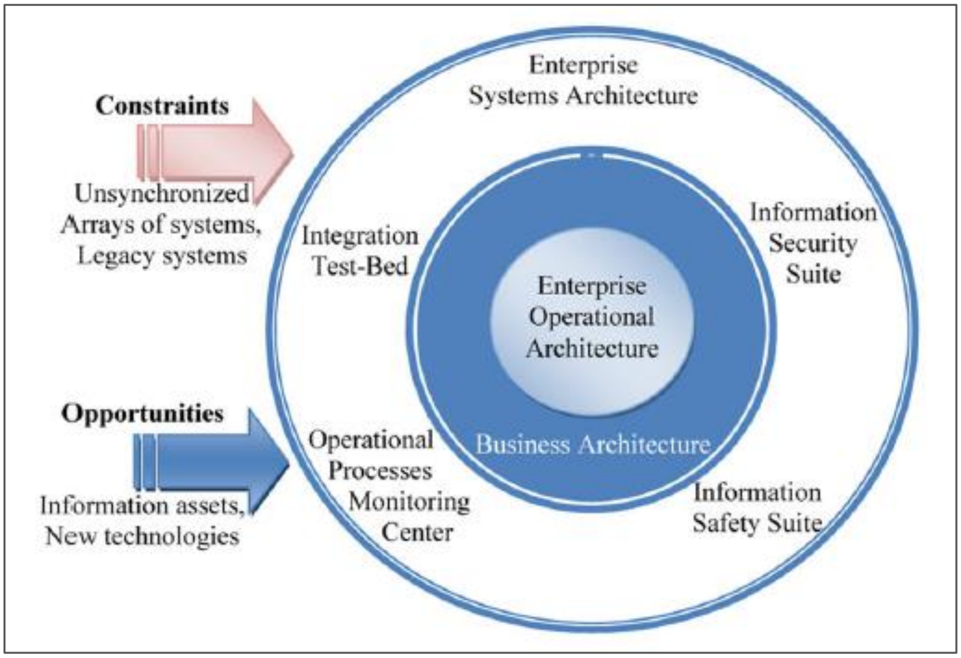

Figure 29. Foundation for New ESE Approach. Source: Sitton and Reich (2015).

Enterprise capability development occurs at different levels of the enterprise. Also, SOS operations may be unsynchronized and independent from other enterprise systems. An approach, centered on the operational architecture, to address this dynamic is proposed here. Gaps in the ESE, SOS, and SE approaches and enterprise architecture toolsets are mitigated by organizing enterprise systems into capability arrays/silos, thereby allowing enterprise operational processes to be managed as discrete engineering efforts from the array/silo engineering efforts.

4. Mission Engineering

Legislation for the DoD to establish Mission Integration Management (MIM) activities was included in the 2017 National Defense Authorization Act (NDAA). Six areas of responsibility for establishing MIM activities were identified, including research and development, systems engineering, mission driven requirements, experimentation, exercises, and Combatant Command coordination. Mission Engineering (ME), "the deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired warfighting mission effects" is the overarching engineering approach for MIM implementation (Gold 2018). Conceptually, ME seeks to integrate material solutions into a SoS architecture that supports the specific operational mission (Figure 30).

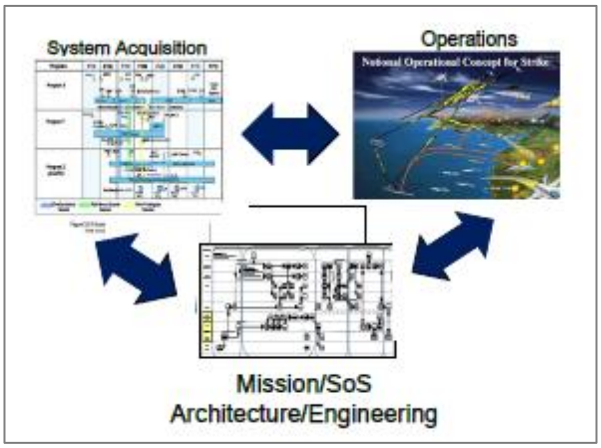

Figure 30. Mission Engineering of Operational Mission Capability.
Source: Gold (2018).

Currently, this enterprise shift from engineering systems to engineering missions requires the identification of criteria for mission outcomes and success, as well as the means of measuring mission progress. However, each operational mission is unique and typically time-sensitive, challenging the broad ME approach. Additionally, the difficulties of bridging engineering and mission effects, gaining access to critical data and information across the enterprise, addressing mission complexity, and resource shortfalls impede the implementation of ME.

Within MIM, the fielding of mission capabilities will be realized through ME activities that contribute to iterative SoS capability (Figure 31). The first two ME activities - Sponsorship and Oversight, and Mission Characterization - involve the Vice Chairman Joint Chiefs of Staff (VCJCS) and the Joint Staff (JS) to perform mission area prioritization and provide operational context, respectively. Recall that both JCIDS and JFD, which include authoritative Joint requirements, Joint Concepts, Doctrine, and Lessons Learned, are the responsibility of the JS. Mission Design & Option Analysis, Coordinated Implementation, and Fielding & Sustainment ME activities are aimed at materiel solution/SoS development and sustainment (Gold 2018).

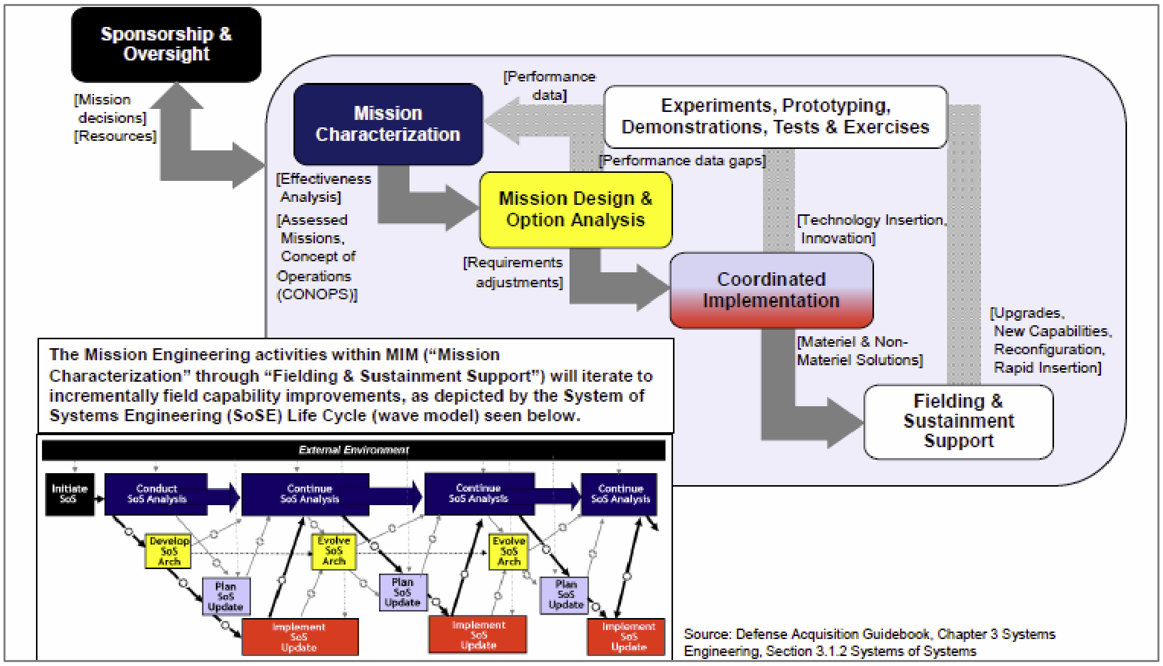

Figure 31. MIM ME Activities. Source: Gold (2018).

Also recall that joint warfighting capability is developed through the JFD Life Cycle. The proposed ME approach to partially address some components of JFD through coordination rather than inclusive systems engineering, may introduce process errors and time delays, similar to those in the current DoD materiel development approach. Additionally, note from Figure 31 that the target architecture for mission engineering is the SoS Architecture rather than the architecture of the mission, which is the SoI.

Hernandez, Karimova, and Nelson extend the ME definition to include mission and support planning, as part of a Mission Engineering and Analysis (MEA) process (A. S. Hernandez, Karimova, and Nelson 2017). This approach treats the mission (including mission and support plans) as the System of Interest (SoI) from a systems engineering perspective (Wasson 2016), and introduces a mission life cycle that spans from potential conflict to mission completion. Through the MEA process, the ME systems acquisition, integration, and operations processes are influenced through continuous mission analysis and assessment (Figure 32).

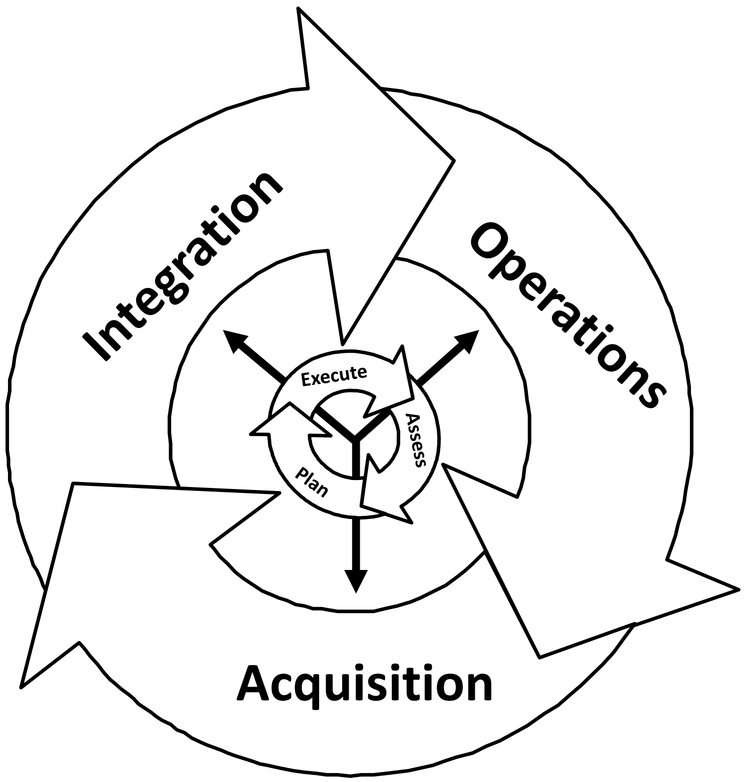

Figure 32. MEA Process. Source: Hernandez et al. (2017).

In a notional application of MEA, Hernandez, Karimova, and Nelson explore the integration of the Military Decision Making Process (MDMP) framework (Department of the Army 2012) for mission planning with the traditional SE VEE Model (Blanchard and Fabrycky 2011). Analysis and assessment SE activities were identified and applied to each of the seven steps in the MDMP framework. This approach promotes the development of viable mission capability solutions utilizing both processes and languages that are familiar to the participating operational and SE communities.

Through the MEA approach, Hernandez, Hatch, Pollman, and Upton, explore the application of scenario based analysis, modeling and simulation, and experimentation to support the integration and operation phases of MEA (Hernandez et al. 2018). The MEA integration phase focuses on the analysis of the executing organization's interactions with supporting systems and the operational environment. The importance of including doctrinal and operational authoritative guidance in integration activities is acknowledged, leading to the desired comprehensive analysis of the SoI. The MEA operations phase considers all three levels of warfare. Consistent with this research, the authors propose focusing on the operational level (referred to as military operations).

Executing MEA integration and operation phases requires continuous component-system integration. However, the process exchanges and analysis tools to support continuous analysis for MEA are not developed. To address this tool shortfall, the Integration and Operations Support System (IOSS) analytic support tool is being developed. The IOSS incorporates wargaming techniques, operations analysis, simulation, and experimentation and delivers analytically rigorous results to support decision making across MEA phases.

Both ME and MEA, as the proposed engineering implementation of MIM, provide an opportunity for the application of SE to operations/missions. However, although the ME literature discusses mission capability, the processes target the SoS architecture, rather than the mission (or operations) architecture necessary for a top-down SE approach. MEA advances the ME concept to include continuous analysis and mission planning. The importance of both the executing organization and the supporting systems interaction with the operational environment is also considered in MEA, moving implementation of the ME concept closer to the necessary comprehensive approach for delivering operational mission capability.

F. SUMMARY

As an enterprise, the DoD has three primary systems for developing joint capability: JCIDS; DAS; and, JFD. A review of these enterprise systems revealed that JFD, which produces knowledge-based capability, is not holistically included in material solution development. As a result, joint context, which should influence system design and operations, is not sufficiently included in SOS or system development activities. Conversely, episodic operational capability is developed through the JFD knowledge-based system. ESE, SOS, and SE approaches are therefore not contributing holistically to the fielding of operational capability that is unsynchronized with materiel solutions development.

The proposed ME concept for implementing congressionally directed MIM, is essentially an attempt to apply systems engineering at the mission level. Since MIM is looking toward the VCJCS and JS to provide operational context and mission based inputs, the effort therefore goes beyond the tactical level of warfare and includes the operational level. However, the target architecture is still the SoS architecture rather than the operational mission architecture.

MEA indeed advances the ME concept toward the systems engineering of operational mission capability by including the analysis of interactions between organizations, supporting systems, and the operational environment as SE activities. MEA's recognition that mission planning must be included in the mission SoI addresses an operational level element. Also, the inclusion of doctrine and other authoritative guidance in integration analysis advances the ME concept. However, the remaining elements of an operational mission are not included in MEA. Additionally, the MEA effort does not address the need for an architecture at the operational level to support the preferred top-down SE approach.

The DoD enterprise requires both materiel development solutions, i.e., technology, and episodic capabilities to operate in the complex 21st century operating environment. Current systems engineering approaches, including ME, are simply inadequate for developing DoD enterprise operational mission capability.

Through a broader lens, organizations are increasingly turning toward technology to gain a competitive advantage. This review confirmed that capability development needs do not always fit neatly into traditional ESE, SOS, and SE approaches. This literature search did find a few instances of the systems engineering community venturing into the application of our craft for realizing operational mission capability. The need to increase collaboration and interaction between operational and technical organizations, the value of operational frameworks and guiding principles, and the challenges with applying ESE, SE, or SoSE directly to operational systems were consistent. However, the operational frameworks and architecting enablers to engineer and deliver this capability were not developed beyond a conceptual level in any of the literature reviewed, indicating the value of the architecture framework and enterprise approach developed through this research to enable the systems engineering of episodic operational capability.

III. OPERATIONAL MISSION ARCHITECTURE FRAMEWORK

The focus of this chapter is presentation of the Operational Mission Architecture Framework (OMAF) and a description of the applicability of OMAF as an enable of episodic operational capability. Given that OMAF is intended to support realization of Joint Warfighting Capability, an overview of the elements of Joint Warfighting Capability is presented. Specifically, the key elements of Joint Warfighting Capability are discussed: Unified Action, Operational Core, Organization, Warfighting Functions, Missions, Operational Context, and Systems of Systems.

Although the above key elements are expressed in the natural language of the DoD enterprise, the purpose of architectures in the systems engineering process is not specific to DoD capability development. Furthermore, episodic and mission-capabilities are interchangeable and apply beyond the DoD, and are generalizable to any enterprise natural language and interrogatives.

A. JOINT WARFIGHTING CAPABILITY

> Often called the "linchpin" of the joint doctrine publication hierarchy, the overarching constructs and principles contained in this publication provide a common perspective from which to plan and execute joint operations independently or in cooperation with our multinational partners, other U.S. Government departments and agencies, and international and nongovernmental organizations. (CJCS 2017)

The DoD recognizes three levels of warfare: strategic; operational; and, tactical (Figure 33). Strategy is linked to tactics through the operational level, where the concentration is on the planning, execution, and assessment of joint operations. There are no firm boundaries between warfare levels; however, they provide perspective for operations arrangement, resource allocation, and task assignment. JP 3, Joint Operations, is the keystone authoritative document, in a series of joint operations publications (JP 3–01 through JP 3–72).

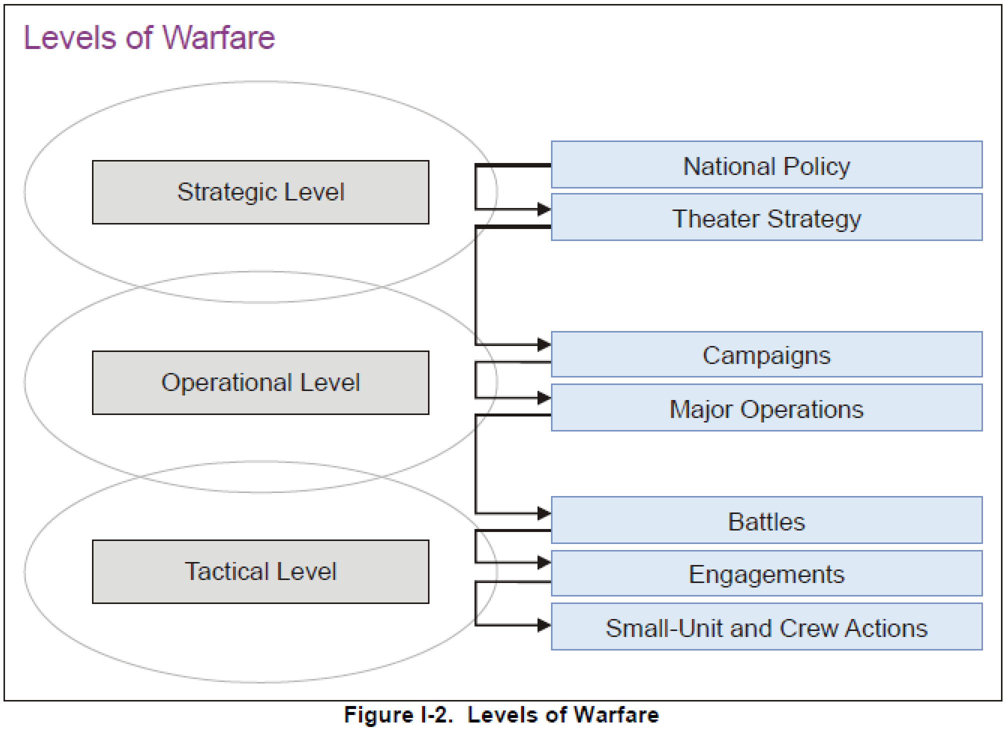

Figure 33. Levels of Warfare. Source: CJCS (2013).

Considering the breadth and depth of this body of enterprise knowledge and the in-stride knowledge gained through the JFD Joint Lessons learned program in systems engineering activities is critical. Independent of specific mission types (i.e. Disaster Relief, Humanitarian Assistance, or Combat) JP 3 describes the foundational constructs for joint operations.

1. Unified Action

Operating as a cohesive joint force involves more than interoperable and integrated systems and processes. At the operational level of war, the concept of Unified Action includes synchronization, coordination, and integration with participating organizations, both governmental and nongovernmental (Figure 34).

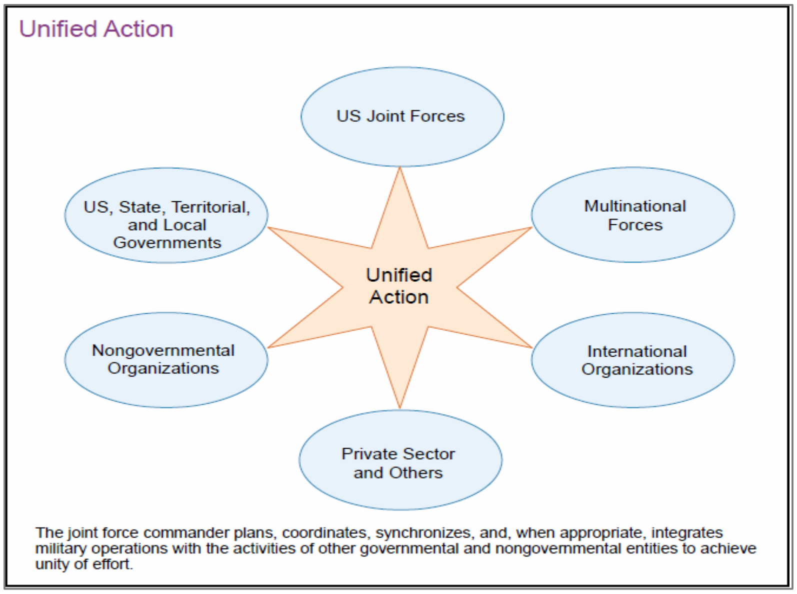

Figure 34. Unified Action. Source: CJCS (2017).

Achieving Unified Action in an operational area (OA) involves cultivating relationships within authorities and responsibilities to synchronize and integrate activities. Unified Action leads to Unity of Effort. If not realized, the resultant loss of life and instability can place the mission at increased risk. Enablers for Unified Action include:

- Designated authorizations for command of a joint force.
- Relationships derived from designated authorizations.
- Information and supply connections for C2 and relationship management.
- Coordination with partners to achieve objectives

Achieving Unified Action and subsequently Unity of Effort, has relationships and interdependencies that reach in, through, and across SoS/systems architecture and design.

2. Joint Command and Operational Core

Command extends beyond the rote exercise of designated authorities and includes leadership ability. JP-3 refers to this more comprehensive view as the art of command where the ability to organize, plan, design, execute, and assess are central to effective command. This cognitive approach, or operational art, extends beyond the commander and includes the staff (Figure 35). From an enterprise perspective, operational art performs the higher-level function of relating strategic objectives to tactical objectives/actions.

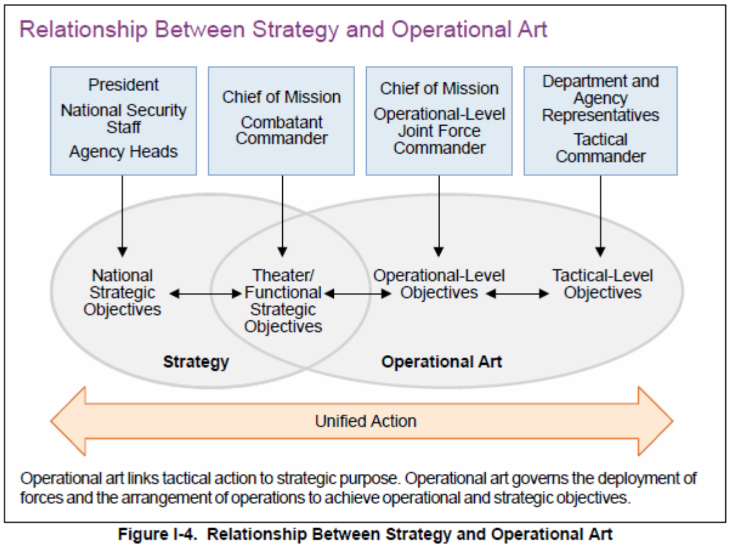

Figure 35. Strategy and Operational Art Relationship. Source: CJCS (2017).

Systems engineers must recognize that command, as well as the control of forces, encompasses both cognitive abilities gained from JFD and enabling SoS/systems capabilities when architecting and designing both episodic and enterprise systems/capabilities.

> Identifying critical objectives will depend more on judgment than on calculation, because framing objectives to achieve broad and enduring results is more art than science. (CJCS 2017, II-5)

The underlying framework of a joint operation, first visualized through operational art, is conceived and constructed through operational design. This creative process encompasses both the planning and execution activities of an operation. The framework elements include:

- Determining objectives in order to gain an advantage.
- Identification of focal points or centers of Gravity (COG)

- Provide time and space orientation, or line of operation (LOO)
- Align intent, cause and effect through line of effort (LOE)
- Determine criteria for termination.

The primary purpose of operational design is to "distill clarity from complexity for decisive action" (Reilly 2012, 1). Consistent with any design process, the characteristics and dynamics of the operational environment must also be considered. Specific operating areas, friendly and adversary systems, technologies, information, and operating domains can all influence design.

The DoD enterprise uses a common model for both planning and executing joint operations (Figure 36). This construct includes six groups (also referred to as phases) of typical mission activities. Shaping activities involve the setting of conditions for successful mission execution. Preventing undesirable adversary actions is accomplished through deterring activities. Seizing the initiative is intended to end the crisis as early as possible. Controlling the OE or discouraging the adversary from continuing undesirable actions is accomplished through dominate activities. Stabilize activities seek to provide a secure environment and restore local stability. Lastly, assisting civil authorities to regain governance abilities is accomplished through enabling activities (CJCS 2017).

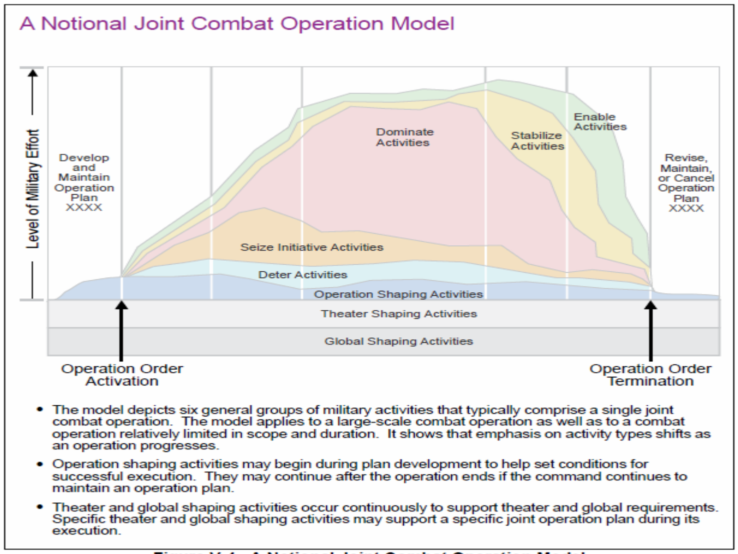

Figure V-4. A Notional Joint Combat Operation Model

Figure 36. Notional Joint Combat Operation Model. Source: CJCS (2017).

Although aligned to combat operations, the model also doctrinally applies to non-combat missions, Figure 37, allowing the transfer of skills, tools, and systems across mission types.

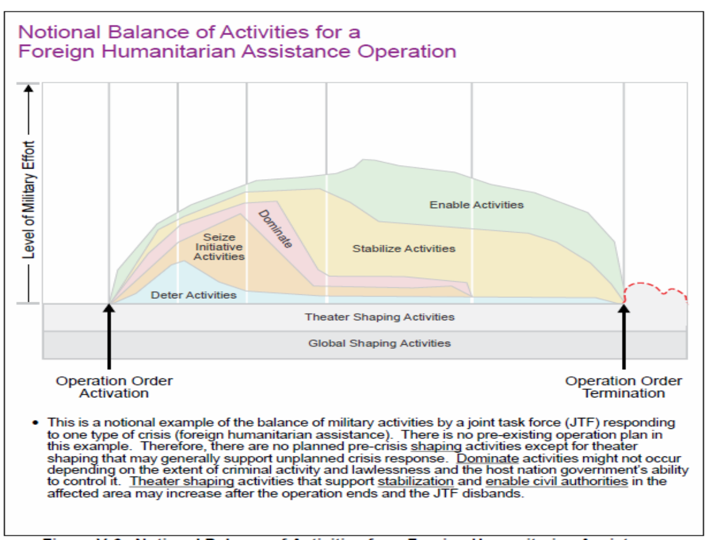

Figure V-6. Notional Balance of Activities for a Foreign Humanitarian Assistance Operation

Figure 37. Foreign Humanitarian Assistance Operation Model. Source: CJCS (2017).

Measuring the effectiveness of joint force capabilities is accomplished through the continuous process of assessment. The completion of tasks, creation of effects/conditions, and achievement of objectives are assessed throughout both mission planning and execution. The assessment of operations is complex and involves operational environment (OE) observations, partner coordination, and timely reporting to support the commander's decision-making. Additionally, assessments at the operational level of war are linked to both strategic and tactical assessments (Figure 38). Assessment design must include these requirements.

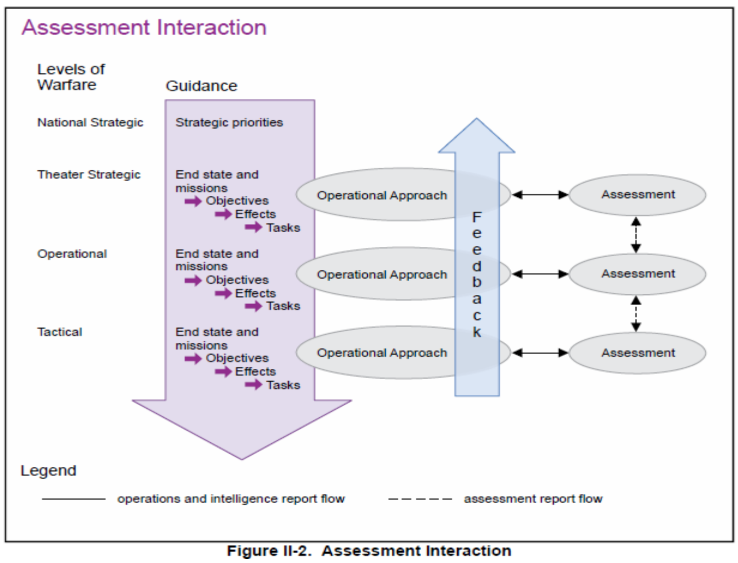

Figure 38. Assessment Interaction. Source: CJCS (2017).

3. Organization

There are three primary organizational areas of consideration for joint operations: the joint force, the headquarters, and the operational area (OA). Additionally, the geographic OA may span warfighting domains (land, air, sea, space, and cyberspace). Other physical factors including terrain, population, supporting infrastructure locations, etc., may impact organizing decisions.

The greater OE may affect organization approach/decisions. It is therefore critical to understand the composition and dynamics of the greater OE, beyond the area(s) where the joint force will be operating. In addition to the physical objects and attributes, the information environment (IE) in which "individuals, organizations, and systems operate/interact to collect, process, disseminate, and act on information" must also be resourced and organized (CJCS 2017, IV-1). Information must also be protected which may affect physical and functional organization.

The rapid development and accessibility of wireless commercial technologies, and the DoD's dependence on wireless capabilities places an importance on the electromagnetic spectrum (EMS) element of the OE. Organized and integrated EMS operations that ensure access to the spectrum are necessary for joint operations.

Taking a systems view of the operational environment is both doctrinal for the joint force and natural for the systems engineer. Through the systems view, the OE is considered to be composed of interacting political, military, economic, social, information, and infrastructure (PMESII) systems. The intended use and interactions of these systems can affect the planning, organizing, and conduct of joint operations and should therefore influence systems engineering efforts.

Organizing the joint forces for an operational mission is influenced by both the operational approach and command principles, and can be established either geographically or functionally. Interdependence and interoperability between participating organizations/systems must be understood and considered when organizing forces. The Joint Task Force (JTF) is the organizing construct chosen to execute missions with specific objectives and is subsequently dissolved once objectives are achieved, generating a requirement for episodic capability.

Joint force headquarters (HQ) basing and organizing is influenced by mission objectives, the OE/OA, operational phase and transitions. Also, the Standing up the command headquarters includes a readiness component that requires training and exercising, supported by multiple elements of the JFD Life Cycle. Within the HQ structure, Figure 39, the systems engineering center of gravity is the cross-functional staff organization.

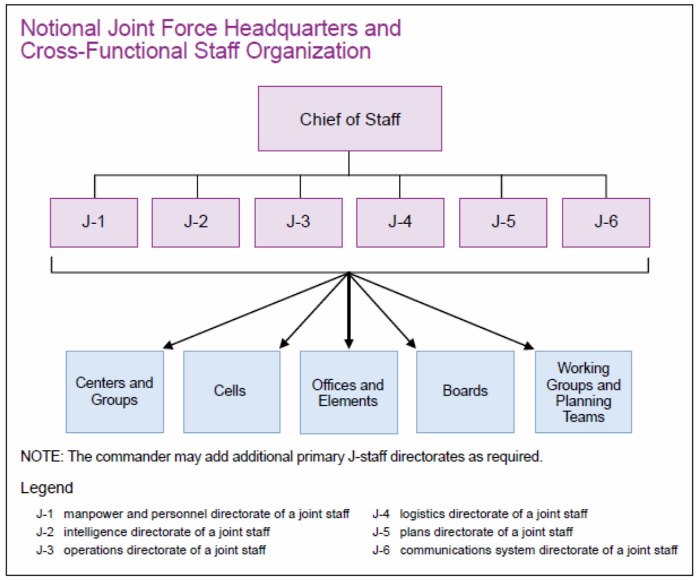

Figure IV-2. Notional Joint Force Headquarters and Cross-Functional Staff Organization

Figure 39. Notional JFHQ Organization. Source: CJCS (2017).

Through this Boards, Bureaus, Centers, Cells, and Working Groups (B2C2WGs) structure, data and information are organized and analyzed to support the command's decision-making and exercise of authority. For example, joint targeting coordination boards (JTCBs) are formed to perform an integrating and/or commander's review function in support of the joint targeting process. Data, information, process, organization, relationship, communication dependencies/ relationships extend to the SoS joint fires capabilities employed in the OA/OE. The emergence of the cyber domain and the integration of lethal and non-lethal actions (Joint Staff 2016) affect staff efforts, including the targeting process, and can influence architecture and design of the joint fires functions and SoS capabilities.

4. Joint Warfighting Functions

Related capabilities and activities are grouped together into functions for the purpose of supporting the integration, synchronization, and direction of the joint operation. Integration of these seven warfighting functions (C2, intelligence, fires, movement and maneuver, protection, sustainment, and information) is critical to mission success. A subset of these functions can be tailored as the mission requires. However, C2 and intelligence functions are applicable to all missions.

A more detailed look at the C2 function, from the joint operational perspective, can identify requirements for C2 SoS/system architecture and design that may not be obvious to the systems engineer. Through the C2 function, the commander exercises authority and direction. Decomposing the C2 function, Table 1, provides additional insight into supporting SoS/system functionality and interoperability/integration challenges that extend across warfighting functions, organizations, and systems. Task 8 for example, requires coordination and integration with the Information function, LOC, Command Relationships, Inter-organizational Coordination, and B2C2WG. This task can be affected by the OE/OA and spans multiple warfighting domains.

Table 1. C2 Warfighting Function Decomposition.
Source: CJCS (2017).

Task Number	Task Description
1	Establish, organize, and operate a joint force HQ
2	Command subordinate forces
3	Prepare, modify, and publish plans, orders, and guidance
4	Establish command authorities among subordinate commanders
5	Assign tasks, prescribe task performance standards, and designate OAs
6	Prioritize and allocate resources
7	Manage risk
8	Communicate and maintain the status of information across the staff, joint force, and with the public as appropriate
9	Assess progress toward accomplishing tasks, creating conditions, and achieving objectives
10	Coordinate and control the employment of joint lethal and nonlethal capabilities
11	Coordinate, synchronize, and when appropriate, integrate joint operations with the operations and activities of other participants
12	Ensure the flow of information and reports to higher authority

Similar to the systems view of the OE previously discussed (PMESII Figure 10), the C2 function is also viewed as a system, bringing an additional perspective and additional expectations for systems engineers that may not be reflected in approved SoS/system requirements through the JCIDS/DAS.

> **C2 System.** JFCs exercise authority and direction through a C2 system, which consists of the facilities; equipment; communications; staff functions and procedures; and personnel essential for planning, preparing for, monitoring, and assessing operations. The C2 system must enable the JFC to maintain communication with higher, supporting, and subordinate commands in order to control all aspects of current operations while planning for future operations. (CJCS 2017, III-11)

Similarly, JP-3 provides critical context as well as defines, describes, and decomposes the remaining warfighting functions. In addition to the doctrinal perspective, a comprehensive review of the JFD elements should be conducted when developing systems.

5. Missions.

Requirements for U.S. military systems are founded on the need to conduct sustained global large-scale combat, when called upon. These capabilities also enable the joint force to respond to additional missions, as needed, that may not be combat related. Typical joint missions and descriptions are provided in Table 2.

Table 2. Joint Missions. Source: CJCS (2017).

Mission	Description
Combat	Joint Force…operations to achieve national strategic directives…or protect national interests.
National Evacuation Operation (NEO)	…evacuation of noncombatants from…foreign countries as…directed by Department of State (DOS) or other appropriate authority due to…war, civil unrest, or natural disaster.
Peace Operation (PO)	…multiagency and multination…humanitarian, reconstruction, and military missions to contain conflict, restore peace, and shape the environment…and…transition to legitimate government.

Mission	Description
Foreign Humanitarian Assistance (FHA)	…relieve or reduce human suffering…due to… disease, hunger, or privation in countries outside of the US. Executed on short notice.
Strike	…damage or destroy an objective or a capability.
Raid	…temporarily seize an area…to secure information, cause enemy confusion, capture personnel/equipment, or destroy an objective or capability.
Homeland Defense (HD)	Protect…U.S. sovereignty, territory, population, and critical DoD infrastructure…
Defense Support to Civil Authorities (DSCA)	…military, DoD Civilian/Contract personnel/assets/ agencies, and National Guard…assistance to civil authorities.
Disaster Relief (DR)	Humanitarian response to manmade or natural catastrophic events.

With this breadth of missions, SoS/Systems that have been architected, designed, and tested to combat capabilities may exhibit negative emergent behaviors when organized unexpectedly and operated in non-combat missions. For example, C2 and intelligence functions and Unity of Action, were impacted by relationship, communication, and interoperability challenges when conducting FHA, NEO, and DR missions with non-traditional partners/systems in austere environments (JCOA 2010; JCOA 2011; JCOA 2015).

6. Operational Context

Joint warfighting capability is developed and sustained through the JFD Life Cycle (Figure 7). Joint Concepts provides idea-based solutions to operational challenges that advance joint warfighting. The combined activities of concept development and assessment, joint training, and joint exercises, result in improved joint warfighting. Implementation and sustainment of those warfighting improvements is accomplished through joint doctrine development, education, lessons learned, and training and education. Lessons learned, along with active engagement, expose joint warfighting gaps and issues (CJCS 2013) requiring either a JFD, materiel, or comprehensive/combined solution.

Considering this complete body of joint warfighting knowledge from JFD provides the authoritative contextual underpinnings for solution development activities.

7. Systems of Systems

System capability employed for joint operations is typically in the form of a SoS architecture (Figure 3). These systems deliver tactical effects in the OA as well as provide information/data for decision-making and react to authoritative direction to meet objectives. From the operational level of war perspective, SoS capabilities are aligned to functions. Since there are seven recognized joint warfighting functions, alignment of SoS capabilities to those functions is necessary. Additionally, this alignment supports the higher level direct, synchronize, and integrate purpose of the warfighting functions.

> There are significant complexities to effectively integrating and synchronizing Service and combat support agency (CSA) capabilities in joint operations. These challenges are not new, and they present themselves with consistency. For example, simply getting the joint force to form and deploy in a coherent and desired manner requires integration of organization, planning, and communication capabilities and activities. But to fully employ the joint force in extensive and complex operations requires a much greater array of capabilities and procedures to help the commander and staff integrate and synchronize the joint force's actions. These types of activities and capabilities center on the commander's ability to employ the joint force and are grouped under one functional area called *command and control*. In a similar manner, many other functionally related capabilities and activities can be grouped. These groupings, we call *joint functions*, facilitate planning and employment of the joint force. (CJCS 2013, I-17)

B. TRANSFORMING JOINT OPERATIONAL KNOWLEDGE INTO ARCHITECTURE FORM

To effectively engage systems engineers at the operational level of the DoD enterprise, and subsequently apply systems engineering methodologies to develop episodic operational capability, both the operational community and the engineering community must find some common ground. Warfare at this level is too complex to simply review and assess the plethora of documents and products that describe the as-is and to-be joint force (joint concepts, doctrine, lessons learned, reports, assessments, etc.) and subsequently provide thoughts/solutions for review/acceptance. Recall from Figure 11 that there are more than 83 Joint doctrine publications, as well as revisions to the publications, that provide necessary operational context. Beyond joint doctrine, a cursory review of a single joint concept, Joint Concept for Rapid Aggregation (CJCS 2015d), reinforces the challenges of an unorganized approach to document/information review. The purpose of the concept is to increase speed, effectiveness, and efficiency of the joint force's ability to assemble and organize in response to a crisis. Figure 40 provides some insight into the episodic nature of the concept as the joint force rapidly aggregates for an operation and then returns to a steady state posture. Through JFD, the joint force will train and exercise to operationalize this concept, assessments will be conducted, doctrine will be updated, and lessons learned shared/published. Therefore, the state of joint knowledge will likely be in motion during any systems engineering endeavor, exacerbating the size and complexity associated with an unorganized approach to reviewing joint warfighting knowledge, and subsequently realizing sufficient clarity.

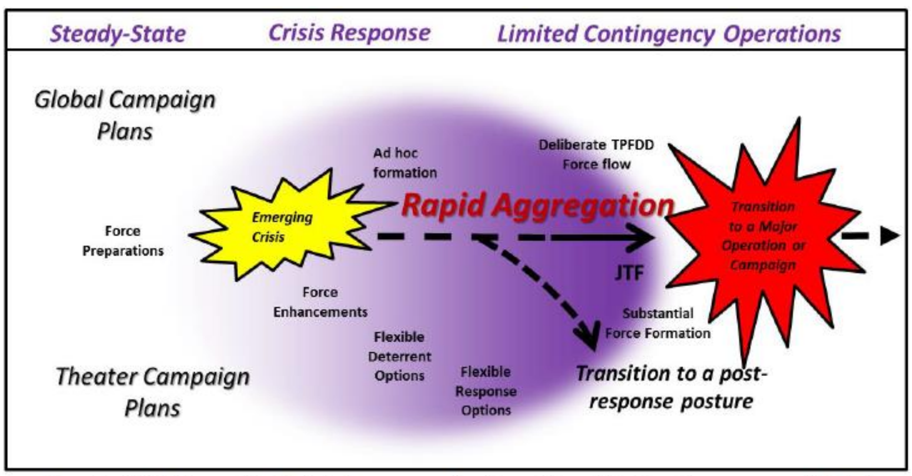

Figure 2: JCRA Scope. Steady state force preparation through transition to crisis response and limited contingency operations

Figure 40. Joint Concept for Rapid Aggregation Scope. Source: CJCS (2015).

Furthermore, the relationships and interdependencies of this concept with other concepts must be accounted for in systems engineering activities. Figure 41 provides a visual orientation. Note that the Joint Concept for Rapid Aggregation supports the Joint Force 2020 Capstone Concept for Joint Operations, is nested within the six Joint Operating Concepts (JOCs), and is linked with other joint concepts.

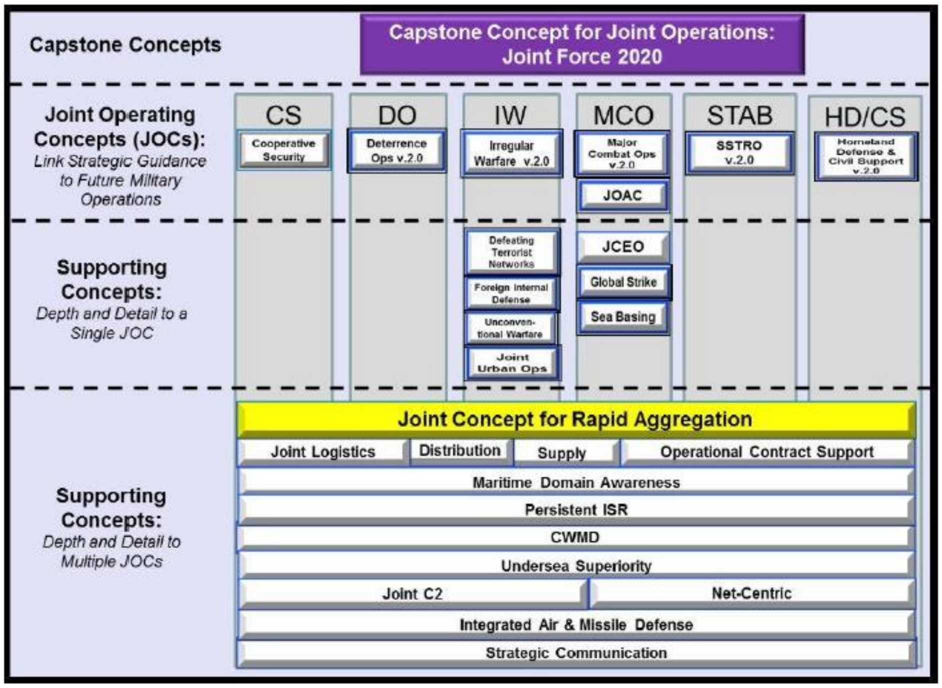

Figure 3: JCRA within the family of Joint Concepts

Figure 41. Joint Concept Relationships. Source: CJCS (2015d).

Recalling that Joint Warfighting Capability is improved through joint concepts and created through joint doctrine and lessons learned, those relationships and interdependencies must also be understood before the systems engineering effort can advance. Lastly, this body of joint knowledge (concepts, doctrine, and lessons learned) spans the full range of joint warfighting capability (Strategic, Operational, and Tactical).

To facilitate meaningful engagement between operators, subject matter experts, and engineers toward a harmonized capability development effort, this vast authoritative body of joint knowledge requires organization and framing.

1. Organizing Construct

The elements of joint operational capability and their purpose are organized in Table 3, below. These are the primary contributors to, and enablers of, episodic operational level capability as described earlier. The elements are consistent with the doctrinal language in the authoritative documents, with a few exceptions.

Table 3. Organization of DoD Operational Mission Capability.

Operational Element	Purpose
Unified Action - Lines of Communication - Command Authorities - Command Relationships - Inter-organizational Coordination	Synchronize, coordinate, and integrate government and partner activities - Information and supply connections - Authorizations from orders and directives - Relationships established through authorities - Coordination for achieving objectives
Organization - Operational Area - Headquarters - Forces	Prepare and Arrange - Geographic operational area - Command Installation - Assigned or attached military elements
Operational Design - Objectives - Center of Gravity - Lines of Operation - Lines of Effort - Termination	Construct an operations framework - Gain an operational advantage - Identify focal points - Time and space orientation - Intent-cause-effect linkage - Criteria for conclusion
Operational Actions - Shape - Deter - Seize Initiative - Dominate - Stabilize - Enable civil authorities	Plan and execute to common actions - Set conditions for success - Prevent undesirable actions - Early crisis resolution - Breaking the will to resist - Restore stability - Support civilian governance
Assessment - Measures of Effectiveness - Measures of Performance	Measure progress and capability effectiveness - Desirable effects or conditions created - Task accomplishment to standards
Operational Environment - Operational Area - Information Environment - Electromagnetic Spectrum - Systems - Technology - Domain	Identify conditions, circumstances, and influences affecting capability employment and decision making - Geographic operational area - Systems, organizations, and individuals; collect, process, disseminate, act - Frequency range of electromagnetic radiation - Political, Military, Economic, Social, Information, Infrastructure - Lethal and non-lethal systems and devices - Land, air, sea, space, cyberspace
Warfighting Functions - Command and Control	Integrate, synchronize, and direct - Exercise commander authority and direction

Operational Element	Purpose
- Fires - Intelligence - Movement and Maneuver - Protection - Sustainment - Protection	- Employ weapons and systems to create effects - Understand the operational environment - Disposition of forces to secure positional advantage - Active and passive defense, technology, and emergency management - Provision logistics and personnel services - Management, application, and integration of information to influence relevant-actors
Mission	Task, purpose, and reason for actions to be taken
Operational Context	Relevant principles, guidance, and knowledge
Systems of Systems	Interoperating warfighting systems

The model used for both joint planning and execution, Figure 33, is captured in the Operational Actions Element, rather than an Element for each. The application to both planning and execution is addressed in the Purpose column. This organizing approach reduces the number of elements without losing the purpose or contribution.

The other exception is the Operational Context Element. As described earlier, the body of joint knowledge resides in the JFD Life Cycle, and is dynamic. Only by including relevant concepts, doctrine, and lessons learned can the full operational context be considered in systems engineering activities.

The Systems of Systems Element is not specifically identified in JP-3. SoS or system capabilities are referred to generically as "capabilities" in the joint publication. To facilitate discussion with the joint warfighter and acknowledge the existence of SoS/systems in operational level capability, they are identified as an Operational Element with the interoperability and warfighting perspective captured in the Purpose column.

The Operational Elements and associated Purpose statements represent the high-level requirements for episodic operational capability and are in the common language/terminology of the joint community. No further translation or decomposition and allocation to system level requirements is necessary for the systems engineer to engage with the warfighter and commence systems engineering activities. With the operational level of war distilled and organized into ten primary Operational Elements, transition to an architectural representation provides a common vision and point of departure for the DoD enterprise's capability development systems and associated systems engineering methodologies.

2. Framework Design

Maintaining architectural alignment is critical when developing enterprise capability that involves multiple enterprises, organizations, systems, or processes. To apply systems engineering at the operational level of war, the initial point of architectural alignment will be established as a framework. Recall that a framework, in this context, "is a broad overview, outline, or skeleton of interlinked items which supports a particular approach to a specific objective, and serves as a guide that can be modified as required by adding or deleting." (Business Dictionary 2017). This approach allows the multiple organizations, which contribute to operational level capability, to employ their native enterprise/ organizational processes and tools, while maintaining a common architectural aim point.

The design of OMAF was heavily influenced by the art of architecting (Maier and Rechtin 2009) and instantiates multiple stakeholder perspectives, immeasurable yet highly valued enterprise philosophies, and experiential insight into architecture form. From the architecting process, the framework's shape, structure, and content are indeed an architectural representation of the DoD enterprise at the operational level. Each of the Operational Elements, previously defined and organized in Table 3, are instantiated in the architecture framework. There are several architecture definitions with the nuances aligned to different communities of interest. The IEEE Architecture Working Group (AWG) P1471 definition resonates with this DoD episodic enterprise systems endeavor:

> **Architecture:** the fundamental organization of a system embodied in its components, their relationships to each other and to the environment and the principles guiding its design and evolution. Source: (Maier and Rechtin 2009).

Recalling that achieving **Unified Action** leads to the desired Unity of Effort across the joint force and partners, this element is placed at the top. Since the commander plays a central role in unifying the joint force, this placement is consistent with both the hierarchical command culture of the DoD enterprise and the doctrinal role of the joint force commander (Figure 42).

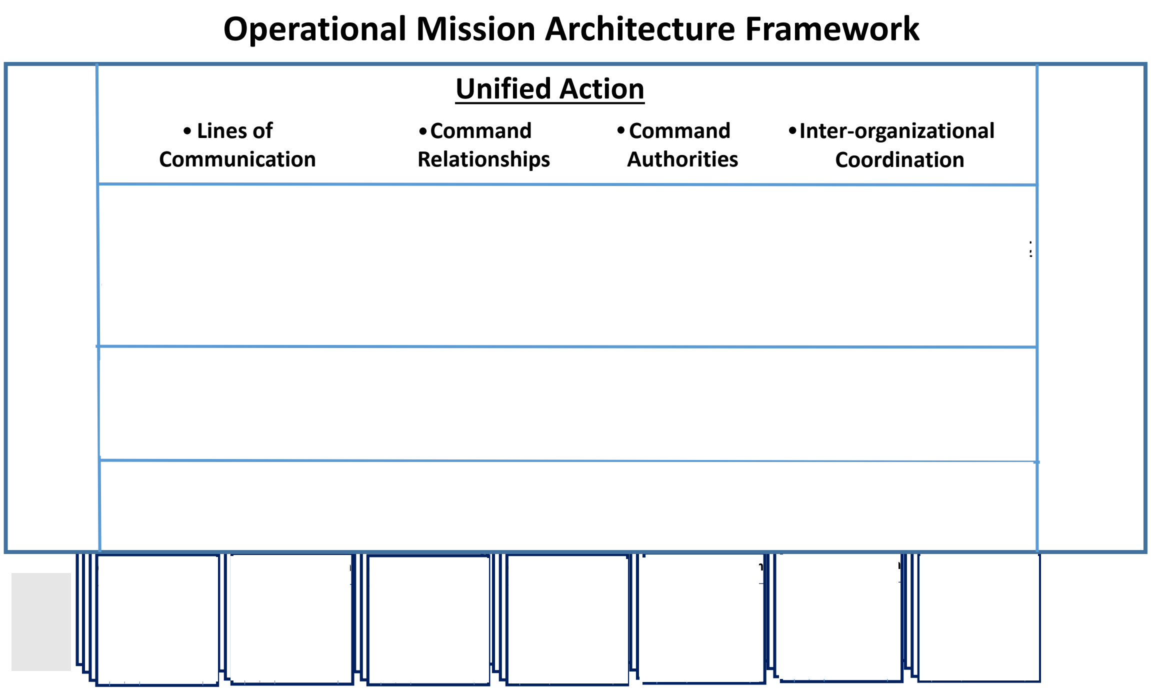

Figure 42. OMAF Unified Action Representation.

Operational art promotes unified action. This cognitive approach by both commander and staff is focused on integrating ends, ways, and means through the **organization** of the **OA**, **HQ**, and **forces**, **design** of **operations**, **planning and executing operational actions**, and **assessing** the effectiveness of the joint force. These foundational activities enable unified action and are therefore the **Core** elements of the **Operational** architecture and positioned directly under the Unified Action Element (Figure 43).

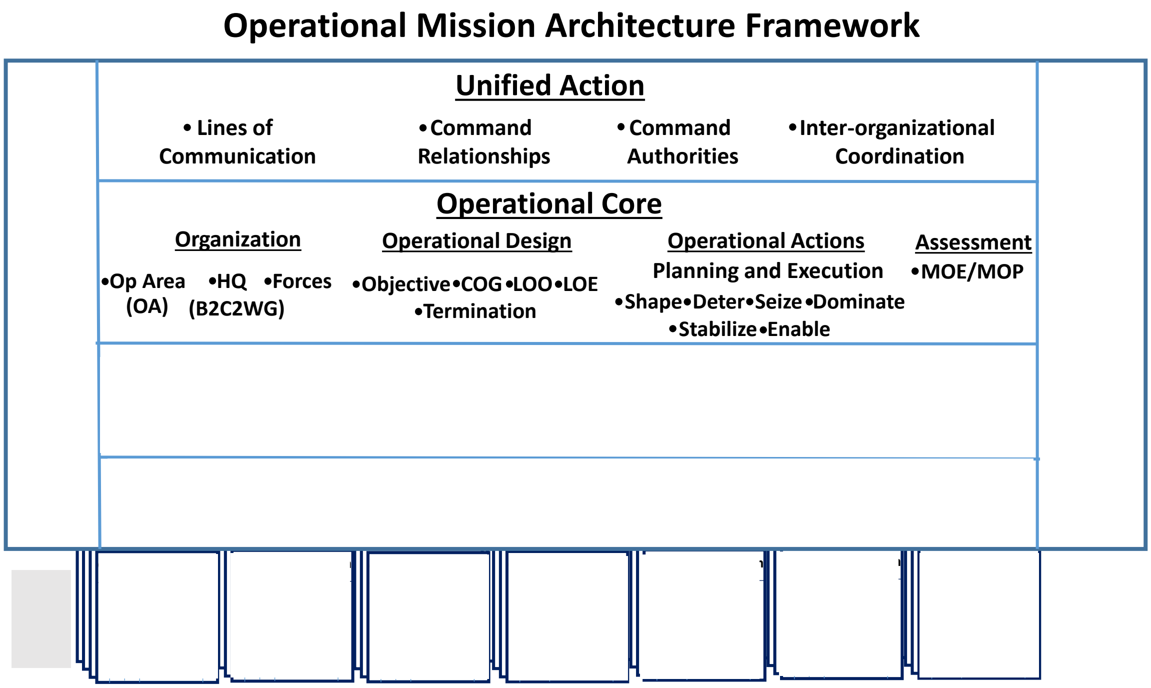

Figure 43. OMAF Operational Core Representation.

The character and composition of the **Operational Environment** affects the planning, execution, organization, and design decisions made by the commander, supported by the staff. The OE is therefore positioned in the architecture directly below the operational core (Figure 44).

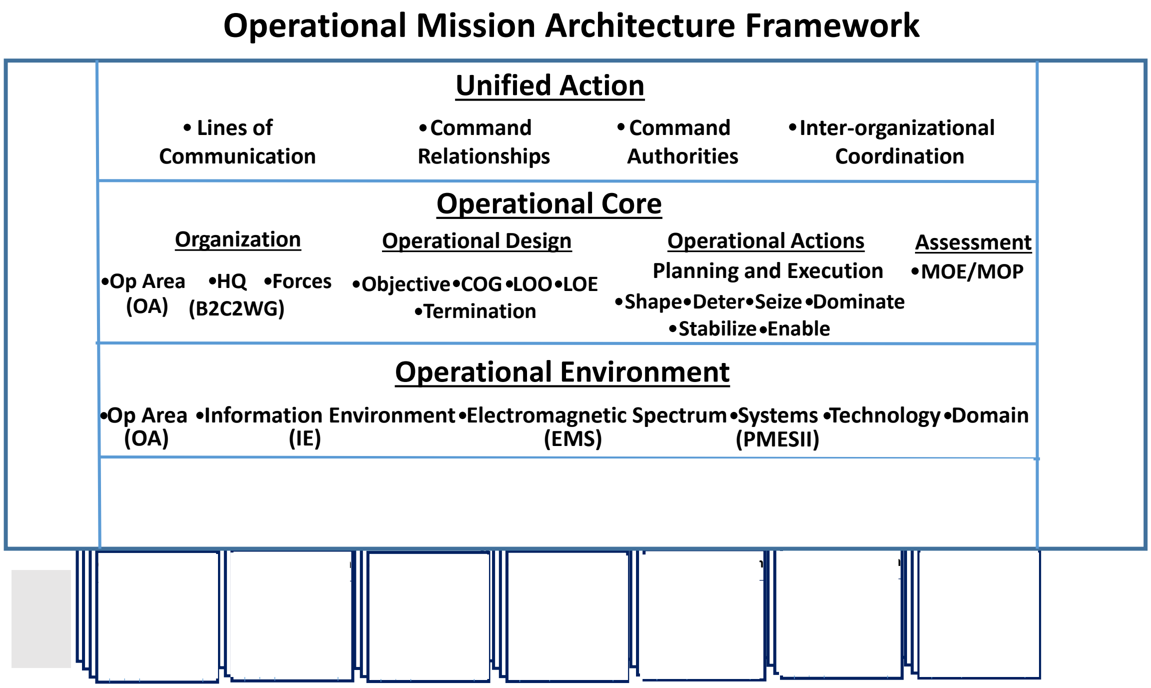

Figure 44. OMAF Operational Environment Representation.

Joint functions are groups of related capabilities and activities that provide **integrating, synchronization, and direction** support to the commander of the joint force. Application of these functions is influenced by the particular operating area and larger operational environment. To reflect both the relationship with the operational environment and the capability groups, this element of the architecture is positioned between the operational environment and the grouped **SoS** capabilities that enable these functions (Figure 45).

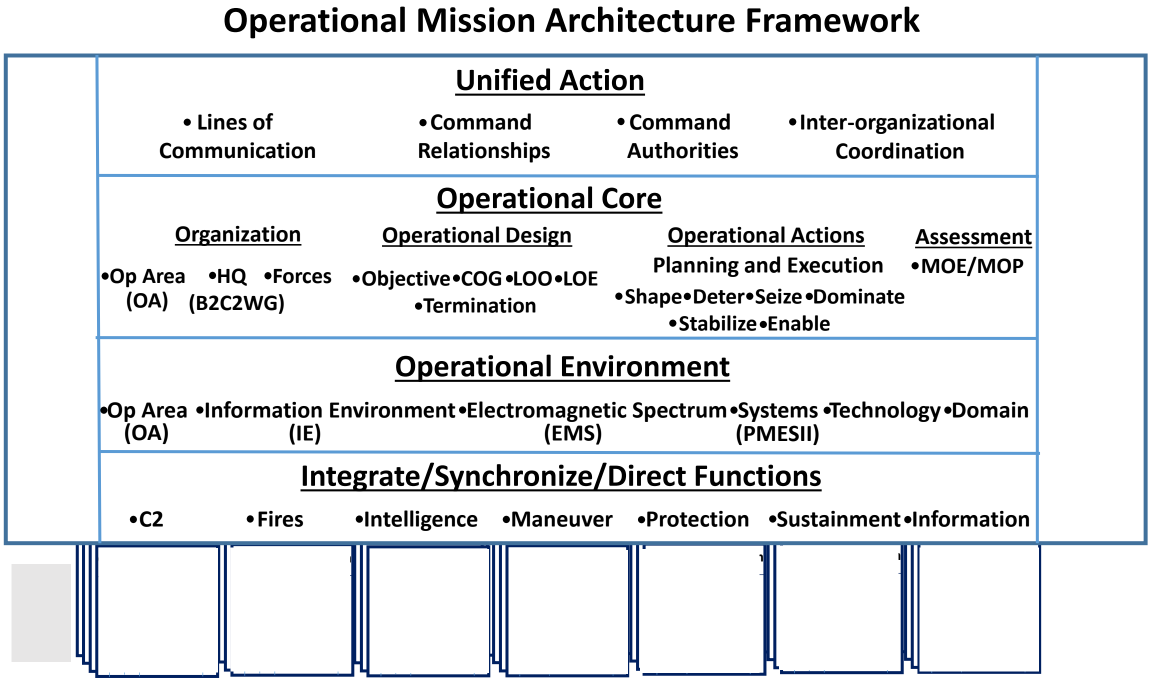

Figure 45. OMAF Joint Functions Representation.

System and **SoS** capabilities are developed through the JCIDS/DAS processes and are typically architected, designed, developed, and tested at the tactical level. Corresponding DODAF products reflect this level of warfare. These grouped material capabilities are viewed as functions from the operational perspective with cross function integration (e.g., Information can enhance Fires) critical to mission success. The **SoS** Element is therefore positioned contiguously with the joint functions element and at the bottom of the architecture to reflect the tactical perspective from which they are developed (Figure 46).

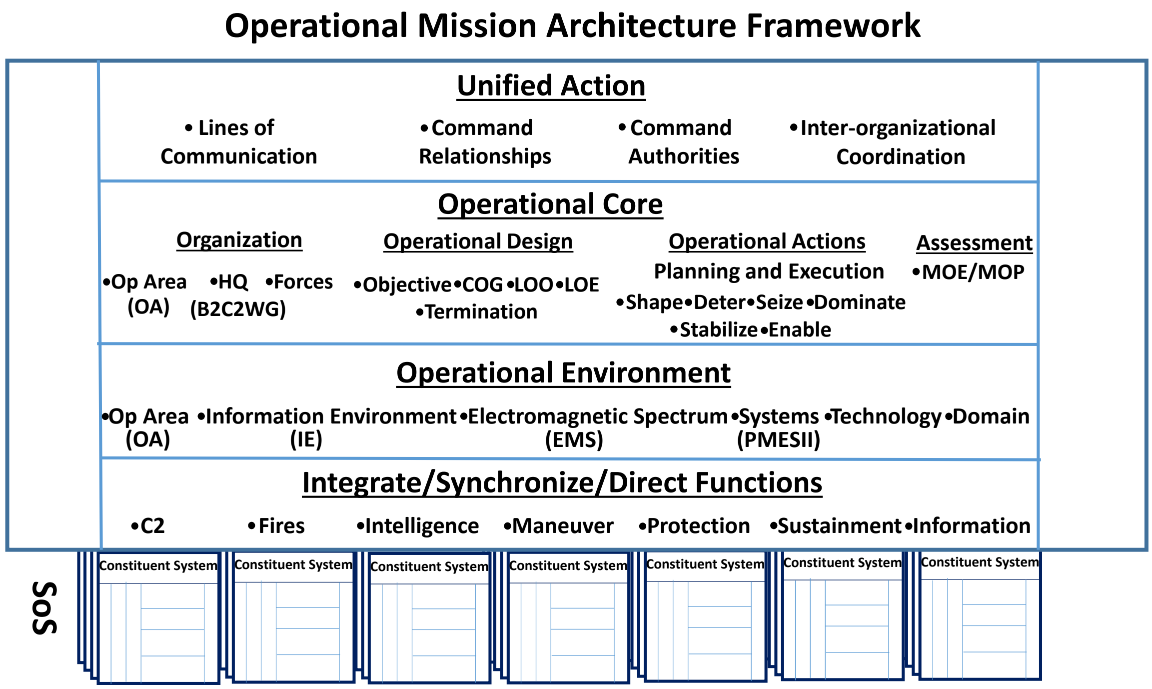

Figure 46. OMAF SoS Representation.

The knowledge-based and material development capabilities of the joint force are developed asynchronously. As discussed previously, joint missions are planned and executed in compliance with authoritative joint concepts and joint doctrine, and improved through Lessons Learned. Relevant operational context (theory, principles, and behaviors, respectively) therefore requires consideration of all three of these JFD. Placement of the **Operational Context** Element on the left side of the architecture communicates this all-inclusive aspect (Figure 47).

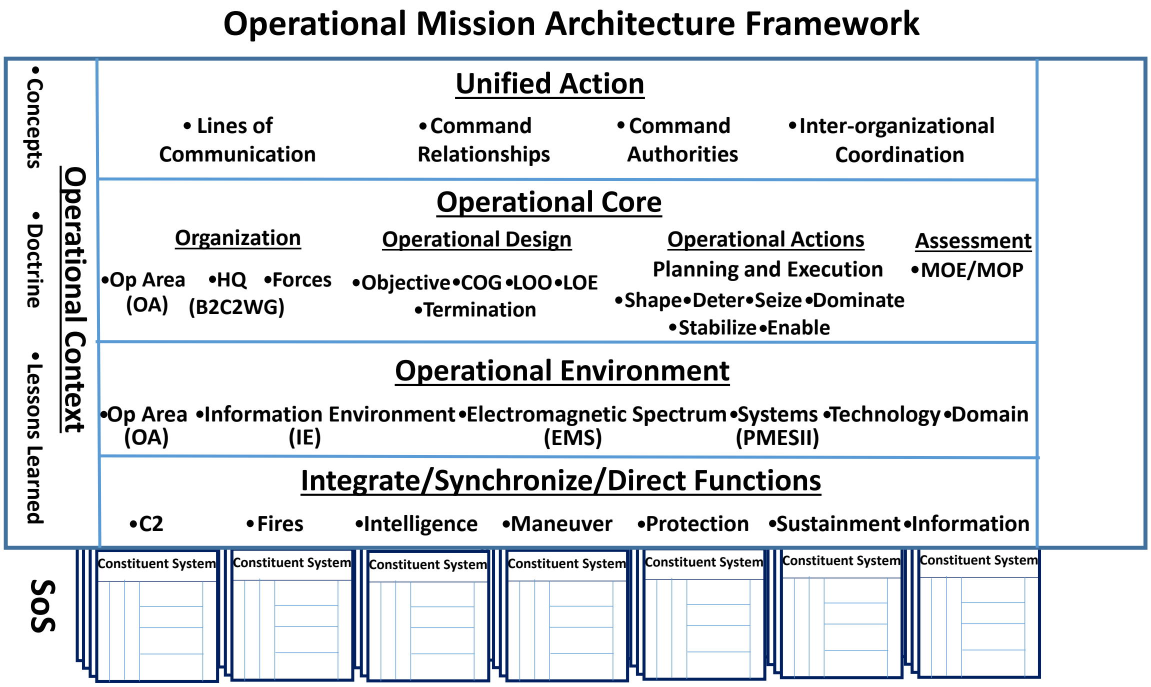

Figure 47. OMAF Operational Context Representation.

The DoD enterprise, through JFD, prepares for and executes a variety of joint missions when called upon, both combat and non-combat, in compliance with authoritative guidance. The **Mission** Element is therefore positioned on the right side of the architecture, spanning the doctrinal elements of the joint enterprise and completing OMAF (Figure 48).

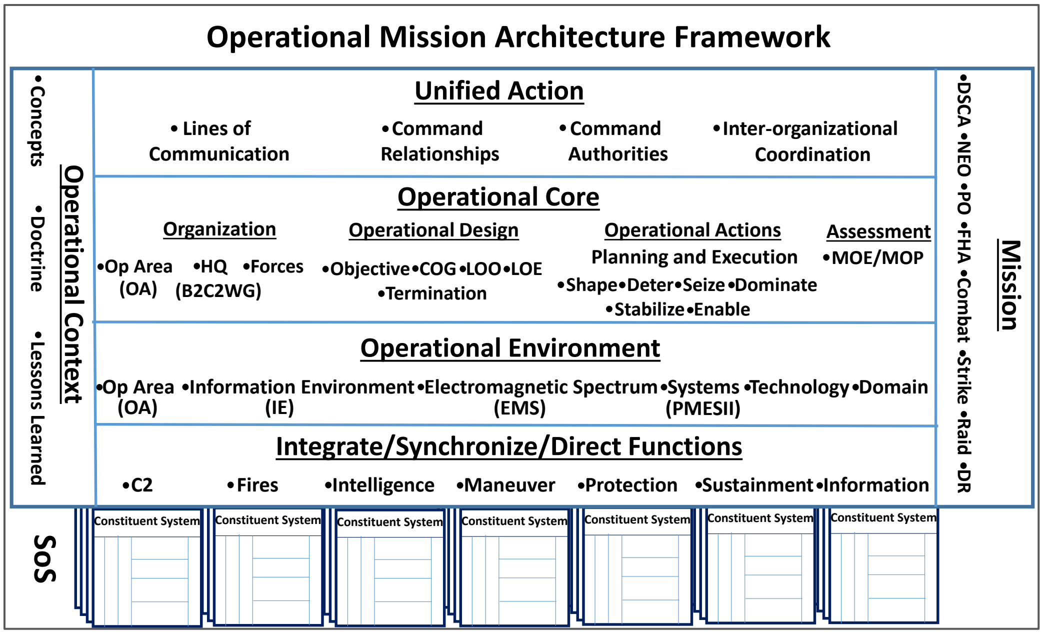

Figure 48. OMAF Mission Representation.

3. Summary

The DoD enterprise's knowledge-based approach to joint operations, resides in a plethora of authoritative documents, publications, and reports. In addition to inherent cultural differences, the ability to systems engineer operational capability, unsynchronized with traditional materiel development efforts, is impacted by the complexity and pace of change of the operational environment, the complexity of joint operations, and the ability to comprehend the enormity of joint knowledge in its current form. Through OMAF, the enterprise's authoritative body of operational knowledge has been distilled down and organized into a framework of ten operational elements that are normalized to joint warfighting language and arranged in architecture form. Enterprise architecture tools can now be applied as part of the systems engineering effort to develop episodic operational capability.

C. OPERATIONAL BLENDED ARCHITECTURE MAP (OBAM)

The organizing construct and design of OMAF is not intended to replace any or all of the DoD capability development systems, but rather to enable the systems engineering of operational level capability. This architecture framework promotes a top-down approach, inherent in systems engineering (Blanchard and Fabrycky 2011), rather than the bottom-up approach of assembling JCIDS/DAS developed systems to meet higher-level enterprise needs.

This architectural representation of the enterprise is intentionally at a high level of abstraction to promote a consistent dialogue with the warfighter and provide a common point of departure for systems engineering mission-unique capability. Existing enterprise architecture tools can now be leveraged to generate the architecture products necessary for solution design.

High-level system architectures that meet program requirements are first generated during the conceptual design phase (Blanchard 2011). With no formal requirements at the operational level, recall that DoD enterprise capability at this level is knowledge-based - a different approach is needed to identify and develop appropriate architecture products that lead to lower-level system specifications. By associating enterprise architecture products with the knowledge-based capability, the lack of requirements is no longer an impediment to developing a conceptual design.

1. Operational Element-Enterprise Architecture Framework Association

Common to both the Zachman Enterprise Framework (Zachman 2007) and the DoD's enterprise architecture framework (DODAF) is the recognition that addressing the standard interrogatives (e.g., who, what, when, where, why, and how) is critical to architecture development (Wennergren 2009). For DoD materiel development programs, a Standard Interrogative Matrix is included in the DODAF version 2.0 implementation memorandum, see Figure 19. By mapping OMAF operational elements to the standard interrogatives, required DODAF viewpoints can be identified and DoD enterprise architecture tools applied at the operational level of warfare.

For example, the Organization Operational Element has three sub-elements: Operational Area, Headquarters, and Forces (refer to Figure 40). Doctrinally, the Operational Area is a bounded area within the land, air, sea, space, and cyberspace warfighting domains (CJCS 2017). The applicable standard interrogatives are therefore "where" and "what." From the DODAF Standard Interrogative Matrix, Figure 16, the associative DODAF viewpoints are AV, OV, SV, SvcV, and DIV. Similarly, Headquarters are organized functionally, with integration and synchronization achieved through bureaus, boards, centers, cells, and working groups. Geographic locations are mission dependent (CJCS 2017). Applicable standard interrogatives are therefore what, where, who, when, and how. The associative DODAF viewpoints from Figure 19 are then AV, CV, PV, OV, SV, SvcV, and DIV. Finally, assigned and attached forces are organized geographically or functionally (CJCS 2017). The standard interrogatives are therefore: who, what, and where. Subsequently, the applicable DODAF viewpoints are AV, OV, SV, SvcV, and DIV for this sub-element. After combining the duplicate views in the sub-elements, the associative DODAF viewpoints for the Organizational Element of OMAF are AV, CV, PV, OV, SV, SvcV, and DIV.

Each OMAF Operational Element, as described doctrinally, can be associated with DODAF viewpoints through this standard interrogative based analysis approach (Table 4). This comprehensive architectural representation of the DoD enterprise allows systems engineers to move forward in the design process for operational level capability. Furthermore, architecture products for JCIDS/DAS developed capabilities can now efficiently include this joint operational perspective and execute a true top-down systems engineering approach.

Table 4. Operational Element DODAF Viewpoint Associations.

Operational Element	**Standard Interrogative(s)** **Who/What/When/Where/Why/How**	**DODAF Viewpoint(s)**
Unified Action		AV CV OV SV SvcV StdV DIV
- Lines of Communication	Who What Where	- AV OV SV SvcV DIV
- Command Authorities	Who What	- AV OV DIV
- Command Relationships	Who Why	- AV CV OV SV SvcV StdV
- Inter-organizational Coordination	Who What	- AV OV DIV
Organization		AV CV PV OV SV SvcV DIV
- Operational Area	Where What	- AV OV SV SvcV DIV
- Headquarters	Who What Where When How	- AV CV PV OV SV SvcV DIV
- Forces	Who What Where	- AV OV SV SvcV DIV

Operational Element	**Standard Interrogative(s)** **Who/What/When/Where/Why/How**	**DODAF Viewpoint(s)**
Operational Design		AV CV PV OV SV SvcV StdV DIV
- Objectives	Who Where	- OV SV SvcV
- Center of Gravity	Who What Where	- AV OV SV SvcV DIV
- Lines of Operation	Who What Where When	- AV CV PV OV SV SvcV DIV
- Lines of Effort	Who What Where Why How	- AV CV OV SV SvcV StdV DIV
- Termination	Who What Where When How	- AV CV PV OV SV SvcV DIV
Operational Actions	All	AV CV PV OV SV SvcV StdV DIV
- Shape		- AV CV PV OV SV SvcV StdV DIV
- Deter		- AV CV PV OV SV SvcV StdV DIV
- Seize Initiative		- AV CV PV OV SV SvcV StdV DIV
- Dominate		- AV CV PV OV SV SvcV StdV DIV
- Stabilize		- AV CV PV OV SV SvcV StdV DIV
- Enable civil authorities		- AV CV PV OV SV SvcV StdV DIV
Assessment		AV CV PV OV SV SvcV DIV
- Measures of Effectiveness	What Who	- AV OV DIV
- Measures of Performance	What Who How When	-AV CV PV OV SV SvcV DIV
Operational Environment		AV CV PV OV SV SvcV DIV
- Operational Area	What Where	- AV OV SV SvcV DIV
- Information Environment	Who What Where How	- AV OV SV SvcV DIV
- Electromagnetic Spectrum	What Where	- AV OV SV SvcV DIV
- Systems	Who What When Where How	-AV CV PV OV SV SvcV DIV
- Technology	What Where How	- AV OV SV SvcV DIV
- Domain	What Where	- AV OV SV SvcV DIV
Warfighting Functions		AV CV PV OV SV SvcV StdV DIV
- Command and Control	Who What Where When How	- AV CV PV OV SV SvcV DIV
- Fires	What Where When How	- AV CV PV OV SV SvcV DIV
- Intelligence	All	- AV CV PV OV SV SvcV StdV DIV

Operational Element	Standard Interrogative(s) Who/What/When/Where/Why/How	DODAF Viewpoint(s)
- Movement and Maneuver	Who What When Where How	- AV CV PV OV SV SvcV DIV
- Protection	Who What When Where How	- AV CV PV OV SV SvcV DIV
- Sustainment	Who What Where When How	- AV CV PV OV SV SvcV DIV
- Information	All	- AV CV PV OV SV SvcV StdV DIV
Mission	All	AV CV PV OV SV SvcV StdV DIV
Operational Context	All	AV CV PV OV SV SvcV StdV DIV
Systems of Systems	All	AV CV PV OV SV SvcV StdV DIV

Although this analysis was performed for the DoD enterprise, the approach is germane to other enterprise architecture frameworks that consider the standard interrogatives (i.e., the Zachman Framework depicted in Figure 17).

2. Enterprise Architecture Framework Mapping

With the associative analysis complete, OMAF Operational Elements and associated DODAF Viewpoints can now be organized into a more useful systems engineering form. The Operational Blended Architecture Map (OBAM) for DoD, Figure 7, is provided again in Figure 49 for ease of reference.

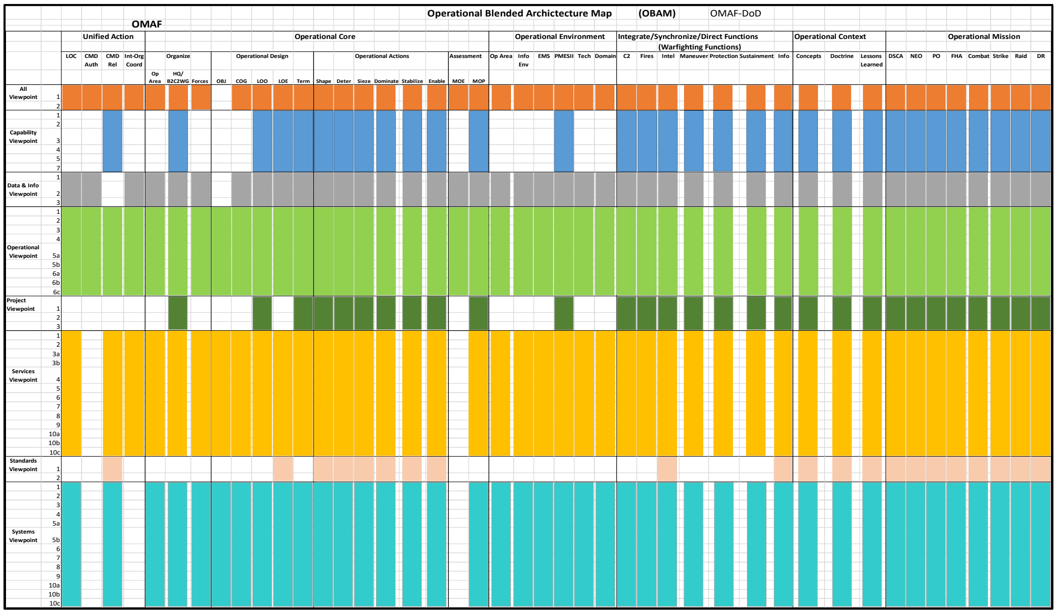

Figure 49. DoD Operational Blended Architecture Map.

OBAM directly maps applicable DODAF viewpoints to the OMAF architectural representation of the operational level of war. The color coding is consistent with the DODAF framework viewpoint colors (Figure 14). This visual representation of the OMAF/DODAF relationship serves as an enabling tool to orient the systems engineer/architect to the doctrinal warfighting elements, facilitating engagement with the warfighter during both capability development and operations assessment. Through this blended approach interactions can be conducted using the warfighter's and the systems engineer's native terminology, reducing the risk of translational errors between frameworks. For example, the warfighter can interact with the systems engineer on Operational Area needs/requirements. OBAM allows the system engineer to easily "see" that Operational Area is nested in both the Organization and Operational Environment elements, and will influence DODAF viewpoints AV, OV, SV, SvcV, and DIV. As architecture products develop/mature, the systems engineer can engage the warfighter through the OMAF operational elements, rather than expect the warfighter to review and comment on specific architecture viewpoints/models.

3. Summary

DoD enterprise architecture tools support the systems engineering of operational level capability. Through a standard interrogatives analysis, DODAF viewpoints were directly associated with OMAF operational elements. The resultant comprehensive mapping, OBAM, provides a visual reference for both the warfighter and architect to interact in their respective normal languages, reducing the risk of translational errors between frameworks. OBAM also supports a top-down design approach for JCIDS/DAS developed SoS/system capabilities.

D. EPISODIC OPERATIONAL CAPABILITY DESCRIPTION AND DEVELOPMENT

> The strategic environment is fluid, with continually changing alliances, partnerships, and national and transnational threats that rapidly emerge, disaggregate, and reemerge. While it is impossible to predict precisely how challenges will emerge and what form they might take, we can expect that uncertainty, ambiguity, and surprise will persist. (CJCS 2017, I-3)

Recall that the purpose of OMAF and OBAM is to aid in development of episodic operational systems, currently realized in the DoD context via the JFD Life Cycle. The DoD enterprise prepares for joint operations through the JFD Life Cycle and executes assigned missions in a complex, uncertain, and rapidly changing operational environment. SoS/system based capabilities, developed and maintained through JCIDS/DAS, have life cycles driven by validated requirements, process compliance, and acquisition strategies. Joint operations however, are not synchronized to either the JFD or JCIDS/DAS development life cycles. Furthermore, SoS/system capability may be used for missions that were not identified during the formal acquisition process. Operational level capability is therefore time sensitive and multi-mission, with a unique mission life cycle.

1. Episodic Operational Systems Description

Through the JFD Life Cycle, the joint force prepares for potential operational missions. Once a mission is assigned and executed, the force returns to a state of readiness. Operational systems must provide warfighting capability throughout the life cycle of each unique mission. From a systems engineering perspective, the episodic nature of joint operations can be characterized through four required system attributes.

a. Temporal

Systems that support joint operational mission capability must be responsive to mission assignment timelines, and return to a readiness state upon mission completion. SoS architectures and systems must be responsive to the organizing, designing, planning, execution, and assessment elements of a joint operation as well as to the enabling of unified action while the mission is active. Post mission, the systems must then support readiness activities (e.g., re-equipping, conducting maintenance, training, and exercising). From a mission perspective, these capabilities are both time sensitive and temporary.

b. Transitional

Episodic operational systems must support the transition from readiness to unique mission activities (and back), as well as the transitions associated with mission changes and phases. Mission partners, and their respective systems, may not commonly participate in readiness activities, and their systems may not be included in typical SoS/system development efforts. Systems must also support the phase/activity group requirements of the operation (Figure 31), as well as the transitions to/from phases/activity groups. Finally, the systems also have to support transitions at the mission level. For example, the joint force may be conducting a political operation when ordered to plan and execute a foreign humanitarian assistance mission.

c. Multi-mission

According to CJCS (2017), "some missions, such as Operation RESTOREHOPE in Somalia, can be dangerous and may require combat operations to protect U.S. forces" (CJCS 2017, xvii). Table 2 lists the typical joint mission types. SoS architectures must support operations that span from major combat, the primary mission for which DoD systems are developed, to humanitarian aid missions in austere operating areas. Additionally, multiple missions may be executed simultaneously, with different partners in separate operating areas. Systems engineers must consider the breadth of missions at the operational level during architecture and design.

d. Asynchronous

Recall that through the JFD Life Cycle, the joint force develops joint warfighting capability. As joint concepts are developed, doctrine updated, lessons learned promulgated, exercises and training conducted, and warfighters are educated, the DoD will continue to be called upon to plan and execute operational missions as needed. Mission specific training and exercising may be conducted to support the transition from readiness to operations, for instance in a mission rehearsal. However, the comprehensive knowledge-based capability contained in the various JFD Life Cycle organizations, documents, and products execute to internal development schedules and enterprise business processes. Similarly, material solutions developed through JCIDS/DAS execute to acquisition program schedules/life cycles/processes to meet formal requirements.

Realizing episodic operational systems capability requires a dedicated systems engineering effort that is informed by and leverages JFD and JCIDS/DAS efforts. Additionally, the systems engineering effort must also inform JFD and JCIDS/DAS so that operational level capability gains are sustained.

2. Episodic Enterprise Systems Development

Through the JFD Life Cycle, human beings apply human centered processes to subjectively identify the systems and integration requirements necessary to deliver a knowledge-based operational capability (that varies episodically). With a high-level architecture now defined (OMAF) and mapped (OBAM) to the DoD enterprise architecture framework (DODAF), tailored systems that are responsive to the episodic nature of joint operations can now be systems engineered.

The operational context and architectural perspective, through OMAF and OBAM, also informs JCIDS/DAS developed SOS/system architectures without requiring changes to those enterprise authorities, policies, processes, and tools. As previously discussed, the pace of change of both the strategic and operational environments, and the episodic nature of joint operations, requires an approach that is not dependent on lengthy efforts typically associated with institutionalizing enterprise changes.

The ideal application of OMAF and OBAM would represent a new reality where we seamlessly apply formal engineering and architecture methods specifically designed to objectively identify the system and integration requirements necessary to deliver an operational mission capability (in a manner that can be repeated episodically). The implementing concept in Figure 50, seen previously as Figure 4, positions OMAF to accept the output of the existing operational capability process (JFD) and existing enterprise systems engineering processes (JCIDS, DAS, etc.) and integrates them to support the development of episodic operational systems.

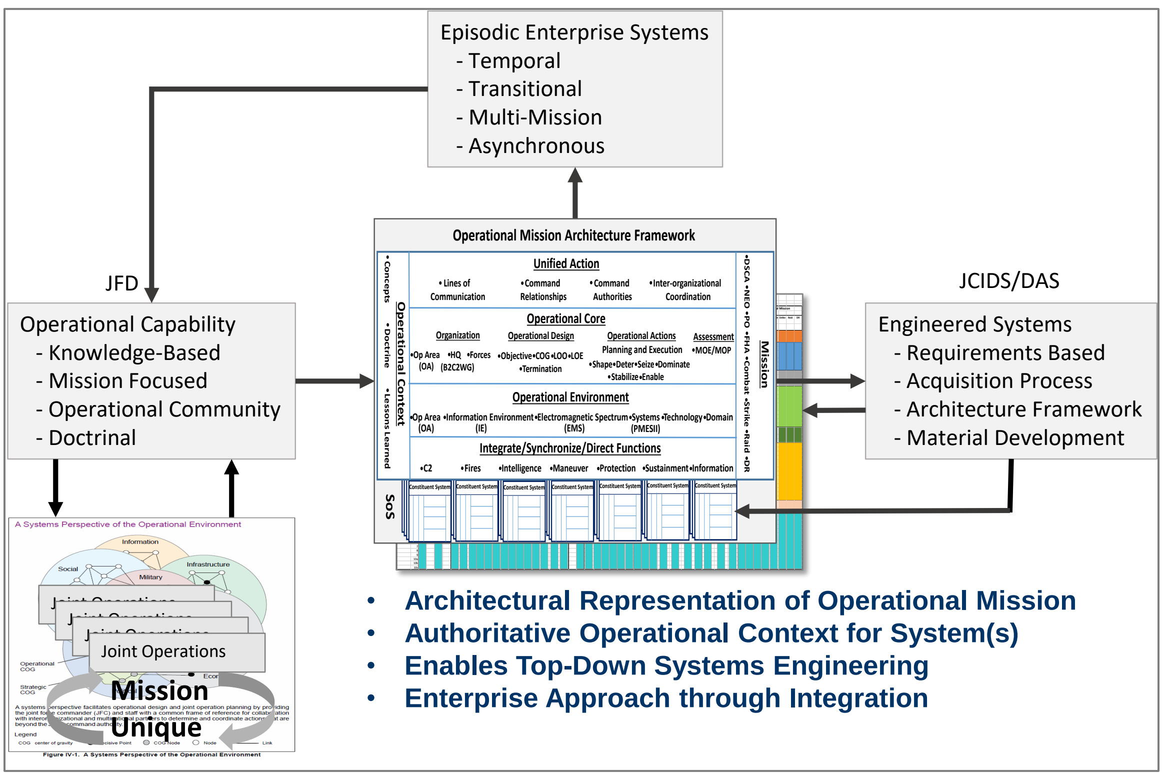

Figure 50. Episodic Operational Systems Engineering Concept. Adapted from CJCS (2017).

For example, lessons learned generated in compliance with the JFD Life Cycle need only be aligned with the doctrinally consistent OMAF operational elements. Systems engineers can then apply systems engineering methodologies, to include a precise application of DODAF, since the viewpoints are already mapped through OBAM. Lessons learned solutions can now be systems engineered in support of joint missions, and current operational context can be included in applicable DODAF products for JCIDS/DAS developed SoS/systems.

Beyond this single lessons learned component of JFD, OMAF/OBAM enables a comprehensive approach for developing episodic operational capability. Systems engineers now have Operational Elements as the engineering center of gravity, and an architecture framework for a top-down approach to episodic systems development.

E. ENTERPRISE CAPABILITY DEVELOPMENT SYSTEMS INTEGRATION

As previously presented, the DoD’s knowledge based capability system (JFD) is not integrated with the material capability development systems (JCIDS and DAS). By defining an architectural framework at the warfighting nexus (operational level of war) OMAF/OBAM become the integrating component of a DoD’s joint warfighting capability enterprise architecture (Figure 51).

OMAF/OBAM is designed to leverage existing capability for episodic enterprise systems development, and inform existing capability development systems to sustain operational capability.

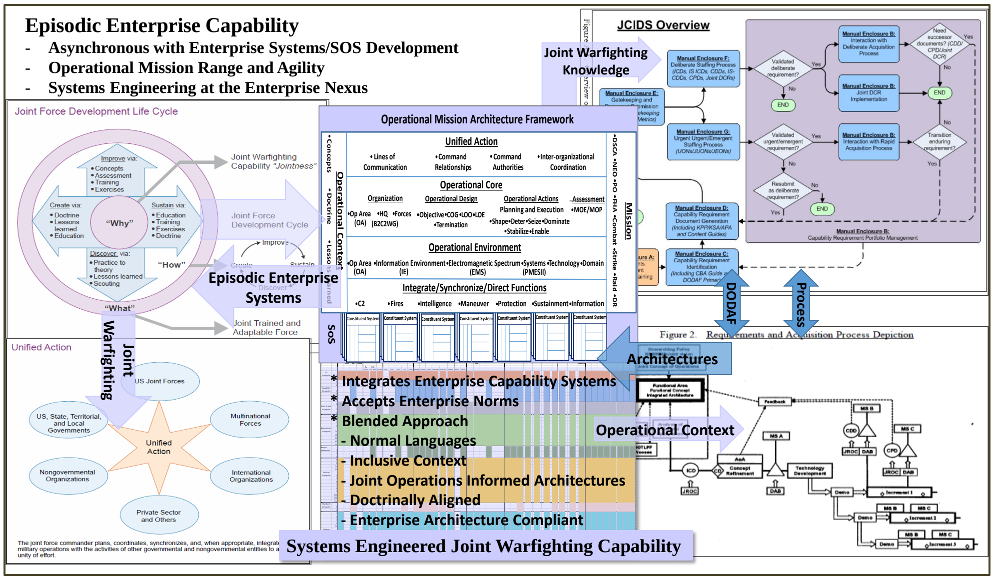

Figure 51. Joint Warfighting Capability Enterprise Architecture. Adapted from CJCS (2015b); CJCS (2013); SECDEF (2003).

As an integrating function, OMAF/OBAM:

1. Organizes JFD Life Cycle document based joint warfighting knowledge into a reference architecture for JCIDS analysis and architecting activities.

2. Organizes JFD Life Cycle document based joint warfighting knowledge into a reference architecture for episodic enterprise systems development.

3. Enables the application of DODAF tools for developing episodic enterprise systems.

4. Provides comprehensive operational context for DAS DODAF products.

5. Enables precise enterprise architecting through OBAM.

6. Blends warfighter and systems engineering cultures at the architectural level.

7. Enables a top-down architecture and design approach for the systems engineering of operational level capability.

The organizing construct and design of OMAF/OBAM allows the DoD enterprise to deliver needed operational level capability through integration vice creating and operationalizing a new development system. Furthermore, OMAF/OBAM implementation also facilitates the establishment of a DoD enterprise architecture for more effective and efficient capability development.

F. OPERATIONAL PLANNING APPLICATION

> Planning translates guidance into plans or orders to achieve a desired objective or attain an end state. The joint planning process aligns military activities and resources to achieve national objectives and enables leaders to examine cost-benefit relationships, risks, and trade-offs to determine a preferred course of action (COA) to achieve that objective or attain an end state. (CJCS 2017, xii)

Planning and managing transitions is a common operating precept for the DoD (CJCS 2017). The OMAF/OBAM methodology, which addresses the transitional attribute of episodic enterprise systems, can also support the generation of key planning documents. The same operational elements in OMAF now in systems engineering form for developing operational mission capability, are also required for planning. For example, the Operational Design element of OMAF provides the "conception and construction of the framework that underpins a campaign or major operational plan and its subsequent execution." (CJCS 2017, xii)

From a systems engineering perspective, there are similarities between capability development activities and enterprise planning activities. The DoD joint planning process includes cost-benefit analysis, risk identification, and options that determine courses of action (COA) (CJCS 2017). Systems engineers typically participate in those same activities for system-based capability development. With OMAF focused on the operational level of the enterprise, the OMAF methodology can therefore be extended to both the planning of operations, or Operation Plan (OPLAN), and the identification of branches and sequels captured in Contingency Plans (CONPLAN) (CJCS 2017).

G. CONCLUSION

The DoD conducts joint operations in an operational environment that is increasingly complex, uncertain, and rapidly changing. These operations are organized, designed, planned, and executed as needed, rather than in synchronous with the knowledge-based or material capability development schedules. The episodic nature of these joint operations challenges the DoD capability development systems.

Currently, joint warfighting capability, is developed through a knowledge-based approach (JFD), without the contribution of systems engineers. Additionally, material solutions are developed to system requirements, through different development systems (JCIDS/DAS) that are organized into SoS architectures and support joint operations. Both individually and collectively, these systems are not positioned to meet the needs of the 21st century joint force.

Defining a reference architecture, at the operational level of war, in the warfighters natural language, facilitates the application of systems engineering at the operational level, provides critical operational context for material development, and produces a resultant enterprise integration function for DoD capability development systems.

By distilling the plethora of authoritative documents into the ten Operational Elements of OMAF, systems engineers are now able to provide capability solutions for those elements. Existing enterprise architecture tools (DODAF) can now be leveraged through the OBAM associative map, enabling a more precise systems engineering effort focused on the Operational Elements of joint warfighting.

This application of systems engineering at the operational level of war introduces a new class of systems; Episodic Enterprise Systems. These joint warfighting systems are necessarily developed asynchronously with enterprise capability development schedules in order to address the temporal, transitional, and multi-mission characteristics of joint operations.

The OMAF/OBAM architectural approach to joint operational capability development enables a top-down systems engineering effort, instead of the bottom-up method inherent in the current material development method. This approach also promotes the use of existing enterprise tools and processes within existing authorities, which promotes efficiency and minimizes enterprise transitions.

The cumulative effect of OMAF/OBAM's purpose, design, and orientation, provides the integrating function for forming a DoD enterprise architecture. Without an enterprise approach, DoD will continue to be challenged to deliver 21st century joint warfighting capability.

THIS PAGE INTENTONALLY LEFT BLANK

IV. OMAF/OBAM PROOF OF CONCEPT

The DoD enterprise prepares for and executes (through the JFD Life Cycle) a variety of joint missions asynchronously with materiel capability development schedules. Missions may have similarities but each one is unique and often time sensitive, leaving inadequate time for mission specific capability development through the traditional enterprise approaches.

As part of the JFD Life Cycle, operational assessments are conducted both in support of an operation and to further advance joint warfighting capability by institutionalizing the lessons learned. These assessments are documented using doctrinal terminology. Recalling that JFD is knowledge based (not systems engineering based), mission issues are inherently not in a form that can be resolved through an enterprise approach (i.e., inclusive of JCIDS and DAS). However, by associating these issues to an architectural representation of joint operations (OMAF), enterprise architecture tools (DODAF) native to JCIDS and DAS can now be applied as part of the desired comprehensive top-down systems engineering approach.

Four different operational assessments, spanning different mission types, locations, and operating environments were analyzed to demonstrate the utility and range of OMAF. Observations/issues were extracted from the text, summarized thematically, and associated to OMAF Operational Elements. This approach facilitated the transition from report form to architecture form. With the issues now characterized architecturally, the systems engineer and warfighter can collaborate on OMAF Operational Element designs that lead to the desired capability. The discussion has now transitioned to one of architecting and designing solutions without abandoning the warfighting lexicon.

Specifically, the operational studies examined here were developed by the Joint and Coalition Operational Analysis (JCOA) organization of the Joint Staff. Foreign humanitarian assistance (FHA), disaster relief (DR), noncombatant evacuation operation (NEO), and combat operations (CO) reports were analyzed. These mission types were selected because they present different challenges to the joint force that can and should influence architecture and design decisions. For example, both FHA and DR missions may be conducted in austere environments. However, following a natural disaster, traditional organizations, communications, and infrastructure that systems were designed to operate on/with, may no longer be available or accessible, impacting the planned execution. Also, a NEO may be conducted in an area where there is hostility and violence. Although not a combat mission, the joint force/systems must also be prepared for potential combat.

A. JOINT OPERATIONAL ISSUES

The analysis and results for the four JCOA reports follows. In each case, it was possible to identify observation/issue themes and the associated OMAF element contributors. Not unexpected, challenges with both JFD and SoS/systems were identified.

1. Decade of War Study

A comprehensive review of combat operations following the September 11th 2001 terrorist attacks on the U.S. homeland spans forty-six JCOA studies (400 different observations/issues) conducted from 2003 through 2012 (JCOA 2012). The themes and OMAF element associations are presented in Table 5. The time span of this study (a decade) alone, provides unique, if not unprecedented insight into sustained joint operations.

From an episodic enterprise systems perspective, problems associated with transitions and timing (both phase and mission), and multiple missions (combat, nation building, etc.) were prominent. C2, intelligence, and information capabilities both from a warfighting function and systems perspective, consistently did not meet expectations and contributed to difficulties in achieving Unified Action.

Intelligence and information shortfalls also contributed to the inability to adequately understand the operational environment and assess the effectiveness of the joint force. Furthermore, the shortfalls affected the force's ability to adapt to changes in the operational environment.

JFD Life Cycle shortfalls were also identified. Joint concepts, doctrine, and lessons learned were not keeping pace with joint warfighting advancements in the field. This lack of current operational context also impacted the commander's ability to achieve Unified

Action, and affected other OMAF elements, particularly the Operational Core (i.e., design and assessment).

Finally, along with intelligence and information shortfalls, coordination challenges with both U.S. and international partners were also prominent throughout the 10 years of war. As strategy, missions, situations, and the environment changed, the need to coordinate with partners was critical to achieving Unified Action.

Table 5. JCOA Decade of War Study, Vol.1. Source: JCOA (2012).

Observation/Issue	OMAF Element
Environment Ambiguity	- Operational Environment: OA/IE/PMESII/ Technology - Functions: Intelligence/Information - Assessment
Ineffective Approaches	- Operational Context: Concepts/Doctrine/ Lessons Learned - Operational Design - Functions: Command & Control - Organization: HQ/Forces - Unified Action: Command Relationships
Ineffective Narrative	- Operational Design/COG/LOE - Assessment - Functions: Information - Operational Context: Concepts/Doctrine/ Lessons Learned - Unified Action: Inter-organizational Coordination
Transitions	- Operational Actions: Planning and Execution - Missions: - Unified Action: Inter-organizational Coordination
Adaptability	- Operational Context: Concepts/Doctrine/ Lessons Learned - Operational Actions: Planning - SoS: Command & Control/Fires/Intelligence/ Information
Integration of Forces	- Organization: Forces/HQ(B2C2WG) - Operational Environment: Op Area - Functions: Fires/Command & Control/ Intelligence/ Information

Observation/Issue	OMAF Element
- Interagency Partners Coordination - Coalition Partner Operations	- Unified Action: Inter-organizational Coordination - Operational Context: Concepts/Doctrine/ Lessons Learned - Assessment
Empowered individuals & small groups	-Unified Action: Inter-organizational Coordination - Operational Environment: Technology/IE - Functions: Intelligence/Information

Of note, since this study was conducted in 2012, a new warfighting domain (cyberspace) and a new warfighting function (information) have been recognized. Additionally, a solution for networking mission partners is now also being developed through both JFD and JCIDS/DAS, more than 16 years after the attacks of September 11, 2001.

2. Operation Unified Response

This disaster relief (DR) joint operation study reviewed the response to the January 2010 magnitude 7.0 Haiti earthquake. A Joint Task Force (JTF) was formed to lead the DoD mission, as part of a larger United States, international community, charitable, and private organization response. The study focused on the challenges associated with forming and operating a JTF in an operational environment lacking critical infrastructure (JCOA 2010).

As discussed earlier, the DoD conducts joint operations other than combat when called upon. When compared to the Decade of War Study, there were common challenges identified. From a functional perspective, intelligence and information shortfalls impacted the ability to understand the operational environment and contribute to assessment actions. C2 of the JTF was also problematic, as well as execution of the sustainment warfighting function (Table 6).

The inability to assess joint force effectiveness and to coordinate with partners were also common issues. The primary contributor to assessment challenges was the devastation from the earthquake that disabled traditional lines of communication. The lack of communication channels also affected force flow, logistics, organization of the JTF, and the ability to coordinate with partners.

Of particular interest, are the severity of the issues associated with the non-traditional organization of USSOUTHCOM. The effects extended beyond the Combatant Command proper and into the JTF's ability to organize, design, plan, execute, assess.

Table 6. Operation Unified Response/DR. Source: JCOA (2010).

Observation/Issue	OMAF Element
- JTF-Haiti formation complicated by SOUTHCOM non-traditional organization - Coordinate and communicate with humanitarian organizations	- Unified Action: Inter-org Coordination/CMD Relationships - Organization: HQ
- Crisis Action Planning	- Operational Actions/Planning
- Lack of Situational Awareness - Systems unavailable or unknown to collect, process, disseminate, act	- Functions: Intelligence/Information - Operational Environment: OA/IE/PMESII
Lack of Assessment Capability	- Assessment
Normal communication channels down	- Unified Action: LOC
Force deployment decisions	- Organization: Forces
JTF C2	- Functions: C2
- Joint Logistics Op Center delayed - Force Flow and RSOI not synchronized	- Functions: Sustainment - Organization: Forces - Operational Design: LOO &LOE

Issues associated with this non-combat mission also span both JFD and JCIDS/DAS developed capabilities. By associating the issues to the OMAF elements, Multi-mission capability can influence architecture and design of systems typically designed to meet combat requirements. Additionally, these DR mission problems are now in a form for systems engineering methods and tools to be applied toward resolution.

3. Operation United Assistance

The study assessed the foreign humanitarian assistance (FHA) mission conducted in response to the West Africa Ebola virus outbreak. DoD support was not initially requested. The delay, along with undefined DoD roles and responsibilities, severely limited the reaction time. The outbreak started in December 2013 while the enhanced response that included DoD commenced in September 2014 (JCOA 2015).

Although there are common warfighting function, unified action, and operational core issues with the Unified Response DR mission, this FHA mission highlights the impact of the time critical nature of the response. Additionally, the austere environment affected the ability to perform the Protection warfighting function (Table 7).

Table 7. Operation United Assistance/FHA. Source: JCOA (2015).

Observation/Issue	OMAF Element
Large planning requirements	- Operational Actions: Planning/Transitions - Organization: HQ/Forces
- Joint Processes and Capabilities - Joint Operations - Overwhelmed Staffs	- Unified Action: LOC/CMD Rel/Inter-org Coord - Organization: HQ/Forces - Operational Actions: Planning - Functions: Intelligence/Sustainment/Information - SoS: Intelligence/Sustainment - Op Context: Doctrine/Lessons Learned
Austere Environment	- Unified Action: Lines of Communication - Assessment - Operational Environment: IE/PMESII - Functions: Protection/Information/Intelligence

The prevalent challenges and issues identified with this FHA mission can be associated with the JFD Life Cycle and are manifested primarily in the ability to plan and manage transitions. As noted previously, the expectation that traditional communication channels would be available did not play a role in planning and transition issues, as they did in the Unified Response DR mission. The austere environment was the primary contributor to those challenges. The need for operational capability that is time sensitive, executes transitions, and adapts to a variety of missions was again identified here, as is in the previous case studies.

4. Operation Odyssey Dawn

This study of the March 2013 noncombatant evacuation operation (NEO) response to the attack on the U.S. Embassy in Libya, centered on command and control challenges. The use of an embarked (vice land-based) JTF (USS Mount Whitney), the supporting role to the Department of State, increasing violence, joint operating area establishment, and larger operational environment influences contributed to the challenges (JCOA 2011).

This case study is particularly useful in exposing the interdependencies. Even with the study focused on the C2 function, unified action, organization, planning, and fires functional shortfalls were also identified (Table 8). Also, the lack of guiding principles (doctrine) for planning and executing an operation this complex was identified.

Table 8. Operation Odyssey Dawn/NEO. Source: JCOA (2011).

Observation/Issue	OMAF Element
Large planning requirements	- Operational Actions: Planning/Transitions - Organization: HQ/Forces
- Joint Processes and Capabilities - Joint Operations - Overwhelmed Staffs	- Unified Action: LOC/CMD Rel/Inter-org Coord - Organization: HQ/Forces - Operational Actions: Planning - Functions: Intelligence/Sustainment/Information - SoS: Intelligence/Sustainment - Op Context: Doctrine/Lessons Learned
Austere Environment	- Unified Action: Lines of Communication - Assessment - Operational Environment: IE/PMESII - Functions: Protection/Information/Intelligence

Executing the NEO mission, required the standup of a JTF while AFRICOM was also planning kinetic operations, forming a multinational coalition, conducting multi-domain operations, and transitioning responsibility to NATO (JCOA 2011). As discussed earlier, there is a nexus at the operational level of war, which is readily apparent here. The episodic nature of joint operations, multi-mission capability, time constraints, and transition challenges are apparent.

5. Summary

These case studies highlight the breadth and complexity of DoD missions as well as the fact that systems developed for the primary purpose of combat operations are also used extensively for other missions, with similar challenges encountered. Across the case studies of these four different mission types, observations/issues were readily associated to OMAF elements, successfully transitioning them into a consistent form for resolution. The need for capability that is time sensitive, multi-mission, and transitional to support the episodic nature of joint operations was consistently identified.

B. OMAF REPRESENTATION OF EPISODIC OPERATIONS

Extracting the issues from the formal JCOA studies and associating them with OMAF elements presents those operational challenges in a form that can be characterized architecturally. A mapping of the mission issues to OMAF, Figure 52, provides an initial architectural representation. The Mission Issue Map provides visual perspective for initiating the systems engineering effort toward issue resolution and/or enduring operational level capability development.

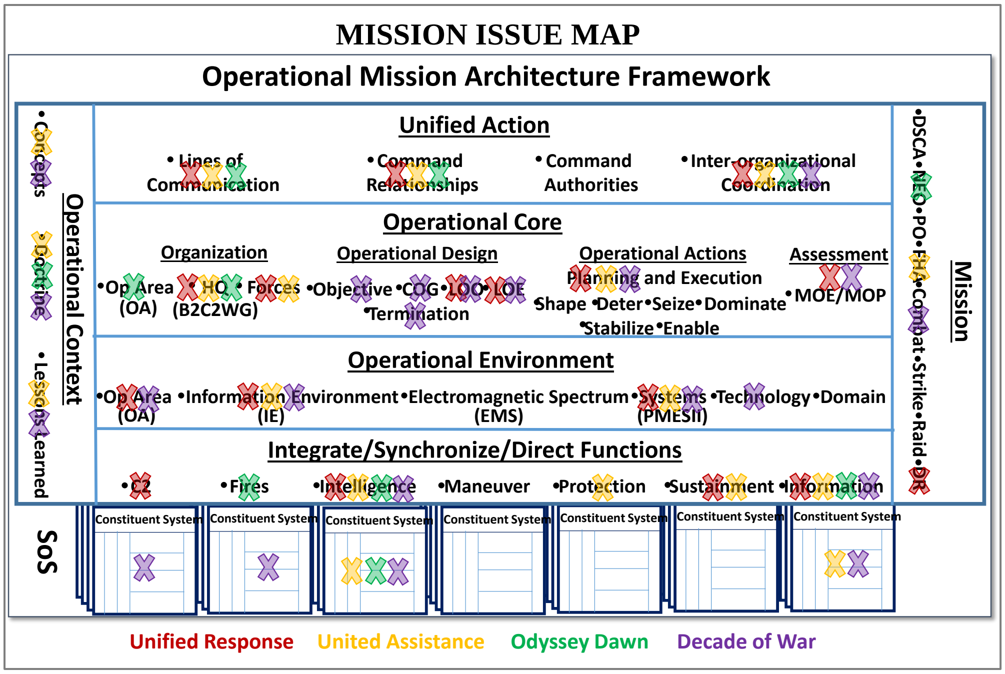

Figure 52. JCOA Studies Mission Issue Map.

At a glance, common issues that are possibly systemic at the operational level, can be identified, or at least guide discussions and analysis. Consistently, the commander's ability to achieve unified action was affected by LOC, command relationship, and partner coordination issues, regardless of mission.

Also, in the core of the architecture, organizing and planning joint operations challenged both the commander and staff. These core actions are affected by both the Unified Action and Operational Environment elements of OMAF as documented in the studies.

As discussed earlier, the pace of change and complexity of the 21st century operational environment challenges the joint force. Ambiguities in the system components (PMESII) and the mission operating areas, as well as the inability to collect and interpret the information impacted the force's ability to organize, design, act, and assess (all elements of the architecture's core), as well as the commander's ability to achieve unified action.

The intelligence and information warfighting functions, which must be integrated with other elements of the architecture, to execute C2 for example, had both functional and system issues identified. These were also affected by the challenges with operational environment ambiguities and changes.

Finally, the guiding principles by which the joint force operates; joint warfighting theories (concepts), authoritative practices (doctrine), and recently discovered knowledge (lessons learned) did not reflect the current state of joint operations.

The “shot groups” on the OMAF mission issue map provide a visual orientation to develop the architecture products for operational level capability. This is a more useful form for characterizing solutions and challenges. Systems engineers and warfighters can then collaborate throughout both the system and cognition-based capability development processes. Essentially, an architectural common point of departure has been established.

C. OBAM FACILITATION OF DODAF ARCHITECTING

The desired top-down approach utilizing enterprise architecture tools is initiated through the blending of the OMAF and DODAF, as previously discussed. The enterprise architecture instantiation of these issues can be seen below (Figure 53).

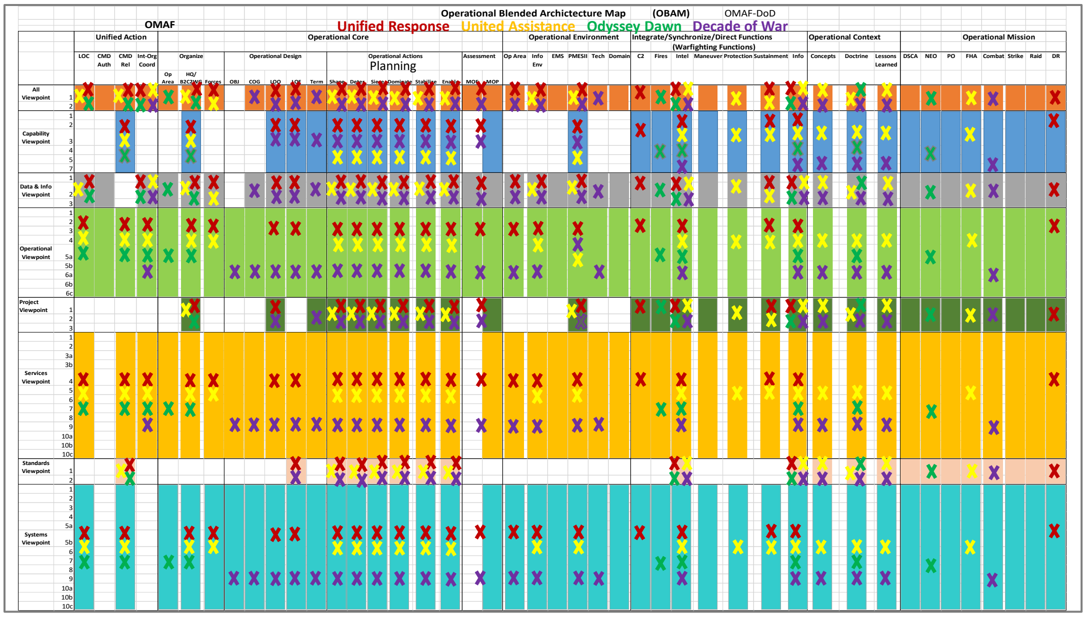

Figure 53. DODAF Instantiation of Operational Issues.

The OBAM for these case studies demonstrates that the full range of DODAF viewpoints can be applied, as with any system capability development effort. Unique to this approach however, is the comprehensive application of DODAF tools (both knowledge based and material based) for solution development. Recognizing that the use of DODAF is common knowledge in the DoD materiel development/systems engineering community, a quick look at the knowledge based capability perspective may be of some value here.

The ability to achieve unified action was impacted by both LOC and Inter-Organizational Coordination anomalies. OBAM indicates that the AV, DIV, OV, and SvcV are appropriate architecture viewpoints for both operational elements, while the SV is only applicable to the LOC element. Recognizing that functioning physical communication channels (LOCs) are required to coordinate (interact, exchange information, etc.) with operational partners, it seems reasonable that the development of architecture products would need to consider both elements.

Furthermore, since LOCs and partners are critical to mission execution (AV), data and information is exchanged (DIV), organizational relationships are agreed upon (OV), and partners are included in mission networks (SvcV) these particular architecture products are appropriate. Recalling that the DODAF viewpoints relationship with OMAF Elements were generated using the standard interrogatives (Table 4), the SV is not necessary for architecting Inter-Organizational Coordination capability. The SV is however appropriate for LOC architecture development since partner systems(s) must be included in the mission architecture. From Table 4, partner geographic location(s) are addressed through the "where" standard interrogative. The SV viewpoint is then introduced into the architecture through the standard interrogative matrix (Figure 19).

The resultant architectural instantiation of these four case studies spanned all DODAF Viewpoints. A visual inspection of the OBAM does not indicate any particular bias toward either materiel capability development elements (SoS) or the knowledge based capability development elements. Systems Engineers/architects are then not constrained by either development system. Through this blended approach, the full capability of DODAF can be employed at the operational level in concert with focused warfighting community collaboration, utilizing doctrinal joint warfighting terminology (OMAF).

D. SUMMARY AND CONCLUSIONS

The joint force consistently experiences operational capability challenges across mission types. Both the JFD and JCIDS/DAS development systems are contributors to the challenges. These operational issues and lessons learned are documented and institutionalized through the JFD Life Cycle. Four formal case studies for different mission types (Combat, FHA, DR, NEO) were analyzed. Issues were summarized thematically and then associated with doctrinally consistent OMAF elements. Using OMAF, a Mission Issue Map was generated, successfully transitioning lengthy narratives to a more precise architecture form. Challenges common to all mission types can now be identified from a visual inspection of the mission issue map. This single visual representation should facilitate a focused dialogue between systems engineers and the warfighter during solution development.

The Mission Issue Map displays common, and perhaps systemic issues, with the guiding principles for joint warfighting (concepts, doctrine, and lessons learned) developed through the JFD Life Cycle. This indicates that the knowledge-based capability necessary for joint warfighting is not keeping pace with operational environment changes.

Recall that at the operational level, achieving Unified Action (through operational art) leads to the desired Unity of Effort. LOC, Command Relationships, and Inter-organizational Coordination challenges impacted the commander's ability to achieve Unified Action. Also, both the commander and staff were consistently challenged to organize, design, act, and assess as well as to understand the operational environment.

Issues with both the information and intelligence functions and their associated SoS capabilities were prevalent. These shortfalls were the primary contributor to the challenges associated with understanding the operational environment.

With the issues oriented architecturally through OMAF, enterprise architecture tools can now be applied. Utilizing the OBAM tool, issues were instantiated in DODAF viewpoint form, enabling an informed and precise architecting effort. DODAF products can now be developed in compliance with enterprise processes while interacting with the warfighter in doctrinal/natural terms. This blended approach fosters the collaborative development environment necessary to expedite solution development.

THIS PAGE INTENTIONALLY LEFT BLANK

V. CONCLUSION

A. SUMMARY

The DoD plans and executes operations when called upon, not necessarily synchronized with capability development schedules. Typically, to meet mission requirements, existing capabilities (personnel and equipment) are assembled from across the enterprise into a joint force that operates in a complex and uncertain environment. These time-sensitive joint operations are often missions that are other than combat. The capacity and multi-domain capability of the DoD is often called upon to support other government agencies and nations with humanitarian aid, emergency evacuation, and disaster relief missions.

Both materiel (SoS/systems) and knowledge based capabilities (i.e., doctrine, training, lessons learned, and education) are required for all joint mission types. The DoD enterprise has three systems for developing these capabilities. Two of the three systems are focused on materiel development. Acquisition programs typically managed by the individual Services apply systems engineering methodologies as required by both statute and policy. Systems engineering for DoD, includes an enterprise architecture framework (DODAF) tool. The architecture products are required to support acquisition program decisions and improve interoperability.

Joint warfighting capability is delivered through a knowledge based capability system, using a life cycle methodology, focused on the cognitive capabilities of the joint force. The state of knowledge, at a particular point in time, may be used to inform material capability decisions, but the life cycle is not synchronized with those schedules. Also, the primary requirements for materiel development are for combat capability, where joint warfighting capability spans all mission types and operating domains.

The DoD recognizes three levels of warfare; strategic, operational, and tactical. Material development programs are typically focused at the tactical level (employment of forces) with operational context described by DODAF OV's. These systems, developed from a tactical perspective are organized into SoS architectures in order to realize additional capability.

However, the DoD operates as a joint force, across all three levels of warfare. At the operational level of war, where the focus is on the cognitive approach to mission execution, a Joint Task Force will be organized. In compliance with authoritative guidance, commanders and staffs use operational art to plan, execute, organize, design, integrate, and assess these joint missions. From a joint warfighting perspective, operational level capability is therefore knowledge based, and not SoS based. However, operational mission success is certainly dependent on employed systems both achieving tactical effectiveness and supporting joint commanders' and staffs' decision-making.

This joint knowledge resides in a plethora of documents, products, people, and locations managed through the JFD Life Cycle. Problems with this system's ability to deliver timely knowledge based capability to both the operational force and system developers have been consistently identified. Likewise, architecture and design decisions during system development have introduced problems at the operational level.

The DoD as an enterprise, needs to deliver joint warfighting capability when needed, not as development schedules dictate. Applying systems engineering methodologies at the operational level of war, in a complimentary manner to existing development systems, enables an efficient approach to delivering episodic enterprise systems for joint warfighting.

Consistent with systems engineering best practices, a top-down approach is enabled by defining an architecture framework at the operational level. Pertinent information was identified and extracted from the multitude of joint warfighting documents and organized into a doctrinally consistent architecture framework composed of ten elements. The OMAF design reflects the hierarchical culture (commander focus at the top, followed by principal staff activities, and tactical SoS capability at the bottom). Systems engineers can now architect, design, and develop capability directly at the operational level, collaboratively with the joint warfighting community.

The concept and value of operational systems engineering was explored by the National Academy of Engineering and the USIP. The systems engineering methodology included a decision-making framework and the application of systems dynamics modeling. The influence of both context and guiding principles on mission execution was recognized. The systems engineering of multi-mission, multi-domain capability of the DoD enterprise requires a comprehensive architectural framework that goes beyond the mission decision-making element of joint operations. Architecting must be an activity conducted in the systems engineering effort. OMAF/OBAM delivers the all-inclusive architecture framework for DoD, facilitating the architecting element of systems engineering using enterprise tools and processes. Additionally, OMAF/OBAM delivers an operational mission reference architecture that enables the necessary top-down approach for MIM/ME implementation.

Another exploration of systems engineering applications at the operational level was discovered in the literature search. Sitton and Reich recognized that ESE, SoS, and SE approaches did not address the asynchronous need for operational capability and referenced the need for an operational architecture framework. However, a framework was not defined or developed. They also proposed a different view of operational systems as "systems of arrays of systems (SAS)." (Sitton and Reich 2015). The OMAF/OBAM approach is more direct, introducing a new class of systems characterized by the desired attributes (temporal, transitional, asynchronous, and multi-mission) rather than a new arrangement for the enterprise to manage. Additionally, OMAF/OBAM defines the operational architectural framework and advances implementation by enabling the use of existing enterprise tools, authorities, and processes through integration.

Case studies of DoD joint missions identified operational issues across mission types. An enterprise approach to delivering the necessary capability has not been developed. During the literature search, only a few examples of systems engineering approaches for operational capability were discovered. Neither included a comprehensive architecture or enterprise strategy to deliver.

The OMAF/OBAM concept transforms the knowledge based joint warfighting capability into an architectural framework, enabling the application of systems engineering beyond traditional material development. Episodic operational capability can then be realized by integrating the DoD capability development systems at the architectural level, delivering a new class of systems: episodic enterprise systems.

This blended approach is unique. It leverages existing tools, authorities, and processes to create a collaborative enterprise approach. OMAF/OBAM enables precision architecting of temporal, transitional, asynchronous, and multi-mission capability not achievable through existing systems engineering methodologies.

B. CONCLUSIONS

The joint force continues to encounter operational capability challenges, across a variety of missions. Obstacles have been attributed to each of the DoD development systems (JFD and JCIDS/DAS) indicating that required capability cannot be developed by one system or the other. Therefore, joint mission capability must be developed, advanced, and sustained through an enterprise approach. However, neither capability development system is exclusively able to respond to the time sensitive, multi-mission nature of joint operations. A comprehensive effort is required.

Furthermore, existing systems engineering methodologies (ESE, SOS, SE) do not address the operational level of the enterprise. Recall that the National Academy for Engineering and USIP for example, together explored the concept of “operational systems engineering” while, Sitton and Reich proposed a new arrangement (SAS) as well as the need for an enterprise operational architecture.

The DoD’s proposed implementation of MIM moves the enterprise toward the systems engineering of operational mission capability through ME. However, the ME focus is still at the tactical level of warfare and SoS architectures. Without an operational mission architecture, and an approach to bridge the engineering and operational communities, ME will not adequately meet the intent of MIM.

The nature of joint operations requires episodic operational capability. Through this research, the enterprise’s knowledge based approach was analyzed, distilled down, and organized into architecture form. OMAF transformed operational level capability from a narrative form into a structured form, enabling the application of systems engineering methods and tools to resolve operational issues and develop episodic enterprise systems. This new class of systems is characterized by their temporal, transitional, asynchronous, and multi-mission attributes that drive design. Beyond the DoD, the notion of episodic capability applies to all enterprises. An ability to address unique challenges utilizing existing enterprise systems, processes, and relationships to achieve desired outcomes extends to all enterprises seeking to remain relevant in a rapidly changing 21st century technology landscape.

The challenges associated with designing episodic operational capability are mitigated by leveraging existing enterprise architecture tools and processes. The standup of another capability development system to meet the time sensitive nature of joint missions is both unnecessary and too disruptive to the DoD bureaucracy. By characterizing OMAF elements in terms of the standard interrogatives, the appropriate DODAF viewpoints could be identified. The resultant map of operational elements and DODAF viewpoints blends the warfighting lexicon with systems engineering at the architectural level. OBAM creates the necessary collaborative environment for precision systems engineering and efficient multi-mission capability development.

A variety of mission types was analyzed. Observations/issues were readily associated with OMAF elements and subsequently transformed to DODAF viewpoints through OBAM. The breadth and effectiveness of the OMAF design and architectural approach has been demonstrated. Also, the instantiation of mission issues as DODAF viewpoints, demonstrates the integrating function of OBAM. DoD enterprise architecture tools can indeed be employed to develop operational capability.

Through this endeavor, enterprise operational capability has been defined architecturally, the concept of episodic enterprise systems introduced, and the integrating function to create an enterprise architecture for joint warfighting capability has been presented. Additionally, systems engineers are now positioned to participate in enterprise activities beyond the traditional development of systems-based capabilities. For example, in addition to the application of the OMAF methodology, systems dynamics modeling can also contribute to operations and contingency planning. Furthermore, systems engineers can now contribute directly to improving knowledge-based capability. MBSE techniques can also be applied to both concept development and doctrine development, as well as to provide mission insight to joint operations by incorporating prospective lessons learned.

Given the interdependencies of the disparate development systems, the history of issues exhibited at the operational level of war, and an increasingly complex and uncertain operational environment, status quo is not acceptable for DoD. A comprehensive multidisciplinary (i.e., systems engineering) approach that delivers episodic operational capability is urgently needed to deliver 21st century joint warfighting capability. By implementing OMAF/OBAM, the DoD can leverage enterprise strengths and help to deliver unity of effort for our warfighters.

C. FUTURE RESEARCH

The DoD recognizes and prepares for three levels of warfare (strategic, operational, tactical). Through this endeavor, an architectural representation and blended development approach (OMAF/OBAM) for the operational level was developed in order to engage systems engineers at the joint warfighting nexus. Further research is necessary to fully implement OMAF/OBAM and deliver episodic operational capability:

1. Define and implement a "top-down" episodic enterprise systems engineering methodology.

2. Develop reference operational mission architectures.

3. Explore design approaches for desired episodic system attributes.

4. Develop DODAF database management capability to include the operational level

5. Develop DODAF database design enhancements to include the operational level.

6. Explore the application of MBSE to identify "prospective lessons learned."

7. Explore the application of behavioral modeling to the OMAF Elements.

8. Explore the application of systems dynamics modeling to operational missions.

9. Extend OMAF/OBAM to the strategic level of war.

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF REFERENCES

Baumeister, Joachim, and Albrecht Striffler. 2015. "Knowledge-Driven Systems for Episodic Decision Support." *Knowledge-Based Systems* 88: 45–56. https://doi:10.1016/j.knosys.2015.08.008.

Blanchard, Benjamin, and Fabrycky, Wolter. 2011. *Systems Engineering and Analysis*. 5th ed. Upper Saddle River, NJ: Prentice Hall.

Business Dictionary. S.v. "framework." Accessed October 14, 2017. https://www.businessdictionary.com/dictionary/framework.

Department of Defense. 2003. *Operation of the Defense Acquisition System* DoD Instruction 5000.2. Washington, DC. Department of Defense.

Department of the Army. 2012. *Army Doctrine Reference Publication (ADRP)*. Washington, D.C.: Headquarters, Department of the Army.

Giachetti, Ronald. 2010. *Design of Enterprise Systems: Theory, Architecture, and Methods*. Boca Raton: CRC Press.

Giachetti, Ronald. 2016. "Systems Engineering Thesis Research Methods." Monterey, CA: Naval Postgraduate School

Gold, Robert. 2018. "Mission Integration Management NDAA 2017 Section 855." *NDIA Systems of Systems Committee Meeting 2Mar2018.* Washington, DC: Department of Defense.

Goranson, H. T. 1999. *The Agile Virtual Enterprise: Cases, Metrics, Tools*. Vol. 21. Wesport, CT: Quorum Books.

Hernandez, Alejandro S., Tahmina Karimova, and Douglas H. Nelson. 2017. "Mission Engineering and Analysis: Innovations in the Military Decision Making Process." *Proceedings of the American Society for Engineering Management 2017 Annual Conference*.

Hernandez, Alejandro, William Hatch, Anthony Pollman, and Stephen Upton. 2018. "Computer Experimentation and Scenario Methodologies to Support Integration and Operations Phases of Mission Engineering and Analysis." *2018 Winter Simulation Conference*.

Joint and Coalition Operational Analysis. 2011. *Libya: Operation Odyssey Dawn A Case Study in Command and Control*. Suffolk VA: Joint Chiefs of Staff.

Joint and Coalition Operational Analysis. 2012. *Decade of War, Volume I Enduring Lessons from the Past Decade of Operations.* Suffolk VA: Joint Chiefs of Staff.

Joint and Coalition Operational Analysis. 2015. *Operation UNITED ASSISTANCE Study*. Suffolk VA: Joint Chiefs of Staff.

Joint Center for Operational Analysis. 2010. *USSOUTHCOM and JTF-Haiti… some Challenges and Considerations in Forming a Joint Task Force*. Suffolk VA: U.S. Joint Forces Command.

Joint Chiefs of Staff. 2012a. *Capstone Concept for Joint Operations: Joint Force 2020*. Washington, DC: Joint Chiefs of Staff.

Joint Chiefs of Staff. 2012b. *Joint Publication 3–33 Joint Task Force Headquarters*. Washington, D.C.: Joint Chiefs of Staff.

Joint Chiefs of Staff. 2013. *Joint Publication 1 Doctrine for the Armed Forces of the United States*. Washington, DC: Joint Chiefs of Staff.

Joint Chiefs of Staff. 2014. *CJCSI 3500.02B UJTL Program*. Washington, DC: Joint Chiefs of Staff.

Joint Chiefs of Staff. 2015a. *Joint Training System: A Guide for Senior Leaders*. CJCS Guide 3501. Washington, DC: Joint Chiefs of Staff.

Joint Chiefs of Staff. 2015b. *Joint Capabilities Integration and Development System (JCIDS)* CJCS Instruction 3170.01I. Washington, DC: Joint Chiefs of Staff.

Joint Chiefs of Staff. 2015c. *Joint Concept for Cyberspace*. Washington, DC: Joint Chiefs of Staff.

Joint Chiefs of Staff. 2015d. *Joint Concept for Rapid Aggregation*. DC: Joint Chiefs of Staff.

Joint Chiefs of Staff. 2016. *Integration of Lethal and Nonlethal Actions*. Suffolk VA: Joint Staff.

Joint Chiefs of Staff. 2016. *Joint Operating Environment 2035*. Washington, DC: Joint Chiefs of Staff

Joint Chiefs of Staff. 2017. *Joint Publication 3–0, Joint Operations.* Washington, DC: Joint Chiefs of Staff.

Lankhorst, Marc. 2017. *Enterprise Architecture at Work: Modelling, Communication and Analysis*. The Enterprise Engineering Series. 4th ed. 2017 ed. Berlin, Heidelberg: Springer. doi:10.1007/978-3-662-53933-0. https://ebookcentral.proquest.com/lib/[SITE_ID]/detail.action?docID=4821995.

Maier, Mark, and Eberhardt Rechtin. 2009. *The Art of Systems Architecting*, edited by Eberhardt Rechtin. 3rd ed. ed. Boca Raton: CRC Press.

Merriam-Webster. 2017. S.v. “episodic.” Accessed March 25, 2018. https://www.merriam-webster.com/dictionary/episodic.

Nightingale, Deborah. 2009. “Principles of Enterprise Systems.” *Second International Symposium on Engineering Systems.* Massachusetts Institute of Technology. Cambridge, MA: Deborah Nightingale.

Rebovich, Jr, George. 2005. *Volume 2: Systems Thinking for the Enterprise: New and Emerging Perspectives*. Bedford, MA: MITRE Corp.

Reilly, Jeffrey M. 2012. *Operational Design*. Maxwell Air Force Base, AL: Air Force Research Institute, Air University Press.

Rhodes, D. H., A. M. Ross, and D. J. Nightingale. Mar 2009. “Architecting the System of Systems Enterprise: Enabling Constructs and Methods from the Field of Engineering Systems.” 2009 3rd Annual IEEE Systems Conference. 2009: 190–195. https://dx.doi:10.1109/SYSTEMS.2009.4815796.

Robertson, Andrew, and Steve Olson. 2013. *Harnessing Operational Systems Engineering to Support Peacebuilding*. National Academy of Engineering and United States Institute of Peace Roundtable on Technology, Science, and Peacebuilding Workshop Report. Washington, DC: The National Academies Press and National Academy of Sciences.

Rouse, William B. 2009 *Enterprise Transformation.* Hoboken, NJ: John Wiley & Sons.

Rouse, William B. and Marietta L. Baba. 2006. “Enterprise Transformation.” *Communications of the Association of Computing Machinery* 49: 67–72.

Rowlett, Rick. 2013. *Back to Basics JP1 Doctrine for the Armed Forces of the United States*. Suffolk VA: Joint Chiefs of Staff

Sitton, Miri, and Yoram Reich. 2015. “Enterprise Systems Engineering for Better Operational Interoperability.” *Systems Engineering* 18 (6): 625–638. Wiley Periodicals, Inc. http://doi:10.1002/sys.21331.

Sowa, John, and John Zachman. 1992. “Extending and Formalizing the Framework for Information Systems Architecture.” *IBM Systems Journal* 31 (3).

United States. 2011. *Title 10, United States Code Armed Forces (as Amended through January 7, 2011)*. Washington: U.S. G.P.O.

Vaneman, Warren. 2015 “SE4950 Lecture.” Monterey, CA: Naval Postgraduate School.

Wasson, C. S. 2016. *Systems Engineering Analysis, Design, and Development*. 2nd ed. Hoboken, NJ: John Wiley & Sons.

Wennergren, David. 2009. *The Department of Defense Architecture Framework (DODAF) Version 2.0*. Washington, DC: Department of Defense.

Wong, Yuna Huh, Michael Bailey, Karen Grattan, C. Steve Stephens, Robert Sheldon, and William Inserra. 2017. "The Use of Multiple Methods in the Joint Irregular Warfare Analytic Baseline (JIWAB) Study." *The Journal of Defense Modeling and Simulation: Applications, Methodology, Technology* 14 (1): 45–55. doi:10.1177/1548512916680917. http://journals.sagepub.com/doi/full/10.1177/1548512916680917.

Zachman, John. 2007. *Zachman Framework Enterprise Engineering and Manufacturing.* La Canada, CA: Zachman International.

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California