STATUS OF DEPARTMENT OF DEFENSE ARCHITECTURE

FRAMEWORK (DoDAF) IMPLEMENTATION WITHIN THE

AERONAUTICAL SYSTEMS CENTER (ASC)

THESIS

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(DoDAF) IMPLEMENTATION WITHIN THE AERONAUTICAL SYSTEMS

CENTER (ASC)

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Abstract

The purpose of this research was to identify the current status of the use of the Department of Defense Architecture Framework (DoDAF) systems architecture products within the Aeronautical Systems Center (ASC) program offices. There are regulatory requirements dictating the creation of DoDAF products as annexes to programmatic documentation, such as the Joint Capabilities Integration Development System (JCIDS) requirement for systems architectures as annexes for acquisition milestone decision documentation. In addition, the DoDAF itself identifies several products as being highly applicable for the development of acquisition strategies. The research issue was to investigate the use or systems architectures, and particularly the DoDAF products, within the context of Air Force weapon systems acquisitions, as represented by ASC.

The research indicated two conclusions: while programs required to follow the new acquisition processes are doing so, very few are employing systems architectures systematically, and at this point, at least within ASC, the benefits to acquisition program management personnel derived from an architectural context are not yet being realized. These conclusions result in several recommendations to ASC, the DoDAF Working Group, and the systems engineering community in general as to how to make systems architectures more a way of doing business within Air Force weapon system acquisitions efforts.

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I would like to thank the members of the ENV GSM team lead by Lt Col McNutt. Lt Col McNutt came in to the program in the middle and had a tremendous influence on how successful I was in the program overall, and with this thesis specifically. My teammates in GSM, Capt Bryan Edmunds and Capt Jon Manternach, were also very helpful. Bryan and I tag-teamed our interviews and were able to bounce ideas off each other in an effort, I hope, to make both of our thesis better. Jon took the mantle of Section Leader and never once was bitter that he had the added responsibility and yet (by rank) I should have had it.

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The most important people in my life were forced at times, to take a back seat in terms of my attention so that I could finish this product. My wife and my sons have demonstrated their love and commitment to me. I will strive to reciprocate as long as I live. I love you guys.

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STATUS OF DEPARTMENT OF DEFENSE ARCHITECTURE FRAMEWORK (DoDAF) IMPLEMENTATION WITHIN THE AERONAUTICAL SYSTEMS CENTER (ASC)

1. Introduction

1.1 Background

In February 2004, the Department of Defense Architecture Framework (DoDAF) Volume 1 was released for implementation. This was actually the 3rd version as the framework intended for all DoD systems acquisitions was expanded from the previously adopted Command, Control, Communications, and Computer, Intelligence, Surveillance, and Reconnaissance (C^4ISR) Architecture Framework used for the development of software intensive applications and systems. The framework was part of a larger Department of Defense (DoD) effort to reinvigorate the systems engineering process within weapon system development and procurement. The framework presents suggested formats for the modeling of systems architecture products useful at various stages of the weapon systems development process.

Systems architecting is not a new concept, having been employed in the development of software for close to a decade. In 1996, Hilliard, Rice, and Schwarm defined architecture as: "the highest level conception of a system in its environment" in a paper attempting to expand the architecture metaphor beyond the software development realm into the general systems engineering arena (25:1). In 2001, the Defense Acquisition University (DAU) further defined system architecture as "all the products (including the enabling products) that are necessary to support the system and, by implication, the processes necessary for development, production/construction, deployment, operations, support, disposal, training, and verification" (13:7).

It has only been since the release of the DoDAF that a formal, specific framework has been in place for the development of systems architectures for military systems. In addition to supporting the reemphasis on quality systems engineering within the military, the DoDAF products also align well with the DoD shift to capabilities-based weapon system development and the specifically. However, there is always a temptation with a new tool to attempt to make it all things to all people.

1.2 Research Problem

Acquisition professionals deal with a multitude of regulatory requirements when it comes to managing an Air Force weapon system program. Depending on the Acquisition Category, the oversight and guidance may come from the Under Secretary of the Air Force for Acquisition (SAF/AQ). With respect to acquisition program management, the Joint Capabilities Integration and Development System (JCIDS) (which replaced the previous 'Requirements Generation System') calls for architecture views as annexes to required programmatic documentation. Further, any system which communicates with other systems - and it seems hard to imagine systems being developed in today's net-centric environment that do not have a requirement to interact with other systems - is required to include a net-readiness key performance parameter (NR-KPP) as one of its requirements. Finally, the DoDAF itself identifies several views for program managers to make use of with respect to acquisition strategy development.

In terms of formal policy, Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 3170.01, *Joint Capabilities Integration and Development System Instruction* and CJCSI 6212.01, *Interoperability and Supportability of National Security Systems, and Information Technology Systems* directly impact program managers and engineers in program offices. CJCSI 3170 establishes the policies and procedures for "a joint concepts-centric capabilities identification process" (8:1,2). JCIDS calls for specific DoDAF architecture views as annexes to documents such as the Initial Capability Document (ICD), Capability Development Document (CDD), and Capability Production Document (CPD) required at each milestone of the development. CJCSI 6212 "details a methodology to develop interoperability Key Performance Parameters…based on the format and content of the integrated architecture products described in the most current version of the DoDAF (17: 2-7).

In addition, the Architecture Framework Working Group (AFWG) identified eight DoDAF views as "highly applicable" to the development of a successful acquisition strategy (17:3-12). Although not specifically addressed in policy, these views are intended to serve as an aid to the program manager in the actual management of the weapon system program. System program office (SPO) personnel are deluged with advice and guidance on how best to successfully manage their weapon system acquisition programs. For example, "acquisition Reform" has been in the program manager's lexicon for several years now. Further, recently the emphasis has been on "Transformation" in all aspects of the DoD, with certain efforts aimed at cycle-time reduction of the weapons systems the warfighter requires. How are systems architectures, and the DoDAF specifically, being implemented "in the trenches" of USAF weapons systems acquisitions?

1.3 Research Objective

The objective of this study is to examine the state of DoDAF systems architecting within ASC and make recommendations to improve the DoDAF use for acquisition program managers. Specifically, the Defense Architecture Working Group is in the early stages of developing Version 2.0 of the DoDAF and should benefit from recommendations resulting from an analysis of the current implementation effort at the program office level. Further, in a November 2004 presentation, the ASC Chief Architect made the following assertion: "(Wings/Direct Reporting Groups) W/DRGs are underway in developing an 'architectural understanding' and the requisite technologies for new net enabled capabilities" (43:19). Therefore, as a result of this study, the ASC Chief Architect will have better insight as how to improve DoDAF implementation across ASC.

1.4 Thesis Overview

Chapter 2 will provide a definition of systems architecting, a discussion of the expected benefits of the DoDAF for acquisition program managers, and some potential pitfalls to implementation at the program office level. The DoDAF is not the first, nor is it the only, systems architecting framework and Chapter 2 describes two others as well as the evolution of the DoDAF. The next section introduces the DoDAF views and summarizes the expected benefits to weapons systems acquisition of implementing the DoDAF. The final section of Chapter 2 provides an overview of previously identified obstacles to using systems architectures, and the DoDAF specifically, for product development. Chapter 3 describes the data collection and analysis methodology followed in the completion of this inductive study. The results of data analysis outlined in Chapter 3 are presented in the Findings and Conclusions sections of Chapter 4. Finally, recommendations for the AFWG and the ASC Chief Architect are presented as well as potential areas for additional research in Chapter 5.

2. Literature Review

2.1 Overview

As discussed in the previous chapter, the publication of the DoDAF Version 1.0 in 2004 was not the first foray into systems architecting as part of the overall systems engineering process. This chapter provides a summary of the relevant literature pertaining to systems architectures, the DoDAF, and Air Force weapon systems applications. The systems architecting community is not as vast as one might think. There are recognized experts who have written extensively as well as a few studies that look at the process, products, or outcomes of systems architecting. The wide range of literature in this area is captured below.

First, the need for systems architectures as part of the overall effort to reinvigorate systems engineering practices within DoD weapon systems development programs is presented. Following this introduction are several definitions and descriptions of systems architectures as background. A brief primer on the Zachman framework and the IEEE Std 1471 is also presented as representative of other architecture frameworks. This leads to the evolution of the DoDAF from C^4ISR Architecture Framework to today with descriptions of the products and views that make up the framework. Next is a discussion of the rationale behind using systems architectures, and particularly the DoDAF, in Air Force weapons systems acquisitions, presenting both general as well as regulatory guidance. Finally, recent information concerning the application of the DoDAF in weapons systems acquisitions is presented with an emphasis on the 2003 Air Force

Inspection Agency (AFIA) Eagle Look report on architecture-based acquisitions. The Eagle Look report will lead into the final section of this chapter, which deals with roadblocks or issues with using system architectures within Air Force weapon systems acquisition efforts that have been previously identified.

2.2 Systems Architectures as Part of Systems Engineering

In February 2004, Michael Wynne, acting Under Secretary of Defense for Acquisition Technology and Logistics (AT&L), issued a policy letter intended to begin the process of reinvigorating systems engineering (SE) within DoD weapon systems acquisitions. Mr. Wynne stated the importance of rigorous systems engineering discipline in order to develop and maintain needed warfighting capability. Specifically, the letter called for:

> All programs responding to a capabilities or requirements document, regardless of acquisition category, shall apply a robust SE approach that balances total system performance and total ownership costs within the family-of-systems, systems-of-systems context.

He went on to say, "collectively these actions will reinvigorate our acquisition community…thus assuring affordable, supportable, and above all, capable solutions for the warfighter" (44:1).

This emphasis on systems engineering was echoed at the Air Force level in comments made previously by both the Secretary of the Air Force Dr. James Roche and further by the Secretary of the Air Force for Acquisition Dr. Marvin Sambur. In a 24 June 2002 *Air Force Times* article, Dr. Roche stated in response to questions dealing with issues relating to recent Air Force acquisition program budget and schedule breaches, “Increasingly, I’m convinced that the systemic problem is in the field of systems engineering” (10:3). In his 9 April 2003 memo “Incentivizing Contractors for Better Systems Engineering”, Dr. Sambur said, “An immediate transformation imperative for all programs is to focus on the application of systems engineering principles and practices throughout the system life cycle” (40:4). One systems engineering practice looked at to help in this reinvigoration is systems architecting.

An underlying rationale behind the Air Force’s insistence on improved systems engineering, is the increasing level of complexity inherent in current weapons systems development, an issue with inherent systems engineering implications. Systems architectures offer a tool to deal with this issue. In a systems architecture tutorial presented at the 2004 National Defense Industrial Associates (NDIA) Systems Engineering Conference, presenters from Kasse Initiatives, LLC stated: “Generating a system architecture as part of the systems engineering process can be seen as a deliberate approach to deal with the uncertainty that characterizes these complex, unprecedented systems” (26:6). Further, Howard Eisner offers the following in his book, *Essentials of Project and Systems Engineering Management*, “Architecting a large-scale complex system is the centerpiece of systems engineering” (20:348). Hilliard, Rice, and Schwarm go so far as to offer the architectural metaphor as an appropriate foundation for the systems engineering field as opposed to grounding systems engineering in other disciplines, ranging from set theory to systems theory to category theory to psychology (25:1).

Whether foundational or not, “the current interest in architecture is motivated by the desire to build our systems ‘faster, better, and cheaper’” (25:1). “Faster, better, and cheaper" has been a weapons systems development goal for years, with systems engineering being the methodology for converting requirements into systems through the DoD acquisition process. "The system engineering effort is integrated into the systems acquisition process such that the activities associated with systems engineering support and strengthen the acquisition process" (13:23). Just as systems engineering integrates with the acquisition process, "systems architecting is an essential part of the system engineering process and relies on many of the methodologies that have been developed over time" (19:41). As with any entity, multiple perspectives have developed over time. These perspectives are, in some way, captured in the multiple definitions of systems architecture in the literature.

2.3 Systems Architectures and Frameworks Defined

There are a number of definitions of what an architecture is in a systems context. Beyond the numerous definitions, there are several frameworks for systems architectures; these include the Federal Enterprise Architecture Framework, The Open Group Architecture Framework, the IEEE 1471 Standard, the Zachman Framework, and the DoDAF. Each of these frameworks has its own definition of system architecture as well in addition to recommended format for products. The similarities and distinctions between these different definitions are worth noting. Irrespective of the differences in these definitions, the bottom line is that for Air Force weapon system acquisitions, the definition and framework that applies most is the DoDAF.

Beyond the three frameworks mentioned above, there are other widely accepted definitions of system architectures. Dr. Mark Maier, author of *The Art of Systems*

Architecting, has a high-level conception of systems architectures and defines the process of architecting as "the art and science of developing systems solutions in ill-structured problem environments" (2:1). Further, he believes "the concrete, deliverable products of the architect, therefore, are models (or abstracted designs) of the system" (33:18,139). This high-level perspective is shared by Hilliard et. al., who stated: "Systems are situated in their environments. An architecture reflects the whole system in response to that environment" (25:1).

NASA's definition deals with functions and their interactions: "How functions are grouped together and interact with each other. Applies to the mission and to both inter- and intra-system, segment, element, and subsystem" (20:249). The Defense Acquisition University has the following definition that seems all-inclusive:

> The System Architecture identifies all the products (including enabling products) that are necessary to support the system and, by implication, the processes necessary for development, production/construction, deployment, operations, support, disposal, training, and verification. (13:7)

Other definitions deal with architectures role in the design of the system. Howard Eisner, author of *Essentials of Project and Systems Engineering Management,* believes architecting is "fundamentally a design or synthesis process" and defines architecture as "an organized top-down selection and description of design choices for all the important system functions and subfunctions, placed in a context to assure interoperability and the satisfaction of system requirements" (20:347,273). In his book, *The Engineering Design of Systems Models and Methods,* Dennis Buede defines an operational architecture as providing

> A complete description of the system design, including the functional architecture allocated to the physical architecture, derived input/output, technology and system-wide, trade off, and qualification requirements for each component… and complete documentation of the design and major design decisions. (6:246)

Finally, Lawrence McCaskill believes the Federal Chief Information Officer Council's definition is clearer regarding what architectures are, and their intended use:

> A strategic information asset base, which defines the mission, the information necessary to perform the mission and the technologies necessary to perform the mission, and the transitional processes for implementing new technologies in response to the changing mission needs. (37:3)

These definitions, however distinct, all present an architecture as a representation of a system that facilitates the transition from user/customer concept to actual hardware or software implementation. Whether high-level and abstract or extremely detailed and technical, the point is still the same: communicate the requirements, design, and constraints involved with the development of the system. Hilliard et. al. sum it up: "An effective architecture shows how to build a system to satisfy clients' needs, in the context of that client's goals and vision" (25:3). In order to achieve some consensus, frameworks have been developed to provide some structure to the architecting process.

Three frameworks for architectural representation include the Zachman Enterprise Architecture Framework, the IEEE 1471 Standard, and the DoDAF. John Zachman created and published a Framework for Enterprise Architecture in 1987 and extended it for broader applications in 1992 (45:5). IEEE Std 1471-2000 *IEEE Recommended Practice for Architectural Description of Software-Intensive Systems* was published in

October 2000 following five years of development. And "in the early 1990s the DoD undertook the development of an architecture framework for Command, Control, Communications, Computing, Intelligence, Surveillance, and Reconnaissance (C4ISR) systems" (33:223) which has evolved into the DoDAF.

The Zachman Framework.

In his article, "Architecture, Enterprise Architecture, Frameworks, and Processes", Kevin Kreitman describes the Zachman framework as "perhaps the oldest and most extensive framework in use today" (27:12). The Zachman framework consists of six categories along the horizontal axis (data, function, network, people, time, and motivation) and five categories along the vertical axis (scope, business model, system model, technology model, and detailed representations). Although designed for enterprise applications such as reengineering, David Brown wrote in the Spring 2000 *Acquisition Review Quarterly* that "the Zachman framework provides an excellent template for developing the architecture of just about anything" (5:125). Further, in Brown, Zachman defines architecture as "that set of design artifacts, or descriptive representations, that are relevant for describing an object such that it can be produced to requirements as well as maintained over the period of its useful life" (5:122). Brown also believes "the Zachman framework can make important contributions to acquisition reform" (5:125).

IEEE Standard 1471.

"In April 1995 the IEEE Software Engineering Standards Committee (SESC) convened an Architecture Planning Group (APG) to study the development of an architecture standard for software-intensive systems". Their final report was presented in 1996, followed by the IEEE Architecture Working Group holding bi-monthly meetings from 1996 to 1999 (24:4). This resulted in the publication of IEEE 1471 Standard 1471 – 2000, *Recommended Practice for Architectural Description of Software-Intensive Systems* in 2000. "IEEE 1471 establishes a set of content requirements on an architectural description – a collection of products to document an architecture" (23:1). The IEEE Definition of architecture, "the highest level (essential, unifying) concept of a system in its environment" (22:4), however vague, is still considered by many the archetypical definition. Mark Maier offers the following critique of the 1471 effort:

> The 1471 project was intended to codify the areas of Community consensus on architecture description. In the end , consensus only developed around a framework of views and viewpoints and an organizing structure for architecture descriptions, but there was no prescription of any particular views. (33:230)

Even before the publication of the standard, Hilliard, Rice, and Schwarm offered a proposal in 1996 to extend the architectural metaphor beyond software engineering to the field of systems engineering in general.

The Evolution of the DoDAF.

It is this broadening of perspective that characterizes the evolution of the DoDAF from a software and C^4ISR-intensive system framework to one that applies now to all weapon systems development. As Maier recounts:

> In the early 1990s the DoD undertook the development of an architecture framework for Command, Control, Communications, Computing, Intelligence, Surveillance, and Reconnaissance (C4ISR) systems. The stated goal for this project was to improve interoperability across commands, services, and agencies by standardizing how architectures of C4ISR systems are represented. (33:223)

The Architecture Working Group (AWG) published version 1.0 in June 1996 and version 2.0 in December 1997; version 2.0 is commonly referred to as the C4ISR Architecture Framework (CAF) (33:223-224). An early 1998 Joint Staff memorandum mandated the CAF for all C^4ISR architecture descriptions (17:1-6).

The DoD broadened the application of the framework beyond C^4ISR systems based on the utility of the CAF and both Federal (Clinger-Cohen Act of 1996, etc.) and DoD policy encouraging the use of architectures (17:1-6). The result was the publication in 2004 of the DoDAF Version 1.0 Volumes I and II. The stated purpose of the DoDAF Version 1.0, is "to provide guidance for describing architectures for both warfighting operations and business operations and processes" (17:1-1). DoDAF Volume I defines architecture as: "the structure of components, their relationships, and the principles and guidelines governing their design and evolution over time" (17:1-1). Even though the ASC Chief Architect defined architecture in his November 2004 presentation on Network Enabled Warfare, as "a systematic, rigorous, reproducible methodology for capturing, organizing and communicating data about complex systems to support analysis" (43:29), the DoDAF definition is the one used and implied throughout this study.

Description of the DoDAF.

The DoDAF consists of multiple products known as views. There are four types of views, the All Views, Operational Views, Systems Views, and Technical Standards Views. Several of these views are collected in what is called an "integrated architecture" referred to extensively in the JCIDS documentation. These are the architecture products referred to throughout this research effort.

DoDAF Volume Two defines architecture products as:

> Those graphical, textual, and tabular items that are developed in the course of gathering architecture data, identifying their composition into related architecture components or composites, and modeling the relationships among those composites to describe characteristics pertinent to the architecture's intended use. (18, 2004:1-1)

Thus, architecture products can take the form of Power Point charts, Excel spreadsheets, tables and charts, as well as any other graphical product that conforms to the standard above. The DoDAF is careful not to specify a certain development methodology. In fact, it is purposely intended to be methodology independent (12).

There are four categories of views within the DoDAF: the Overview and Summary, Operational, Systems, and Technical Standards Views. The All Views category captures essential overview information about the architecture.

> The Overview and Summary (AV-1) is essential for documenting the assumptions, constraints, and limitations that may affect high-level decision processes involving… architecture. AV-1 also identifies the approving authority,

> the completion date, and records level of effort and costs required to develop the architecture as well as the time frame covered and the organizations that fall within the scope of the architecture. (17:3-10)

"The Operational View (OV) describes the tasks and activities necessary to successfully perform the mission, the participating nodes, and the associated information exchanges" (17:3-2). Further, "OV descriptions are useful for…defining the operational requirements to be supported by resources and systems" and "a pure OV is materiel independent" (17:3-2). In order to deliver a weapon system, the tasks and activities modeled in the OVs are allocated to systems, which are themselves modeled in Systems Views. "The Systems View (SV) describes the systems of concern and the connections among those systems in context with the OV" (17:3-3). Finally, "the Technical Standards View (TV) describes a profile of the minimum set of time-phased standards and rules governing the implementation, arrangement, interaction, and interdependence of systems" (17:3-4). The DoDAF defines an integrated architecture (a term used throughout JCIDS and other documents) as the AV-1, AV-2, OV-2, OV-3, OV-5, SV-1, and TV-1, at a minimum) (17:1-5). The 26 views are summarized in Figure 1.

Applicable View	Framework Product	Framework Product Name	General Description
All Views	AV-1	Overview and Summary Information	Scope, purpose, intended users, environment depicted, analytical findings
All Views	AV-2	Integrated Dictionary	Architecture data repository with definitions of all terms used in all products
Operational	OV-1	High-Level Operational Concept Graphic	High-level graphical/textual description of operational concept
Operational	OV-2	Operational Node Connectivity Description	Operational nodes, connectivity, and information exchange needlines between nodes
Operational	OV-3	Operational Information Exchange Matrix	Information exchanged between nodes and the relevant attributes of that exchange
Operational	OV-4	Organizational Relationships Chart	Organizational, role, or other relationships among organizations
Operational	OV-5	Operational Activity Model	Capabilities, operational activities, relationships among activities, inputs, and outputs; overlays can show cost, performing nodes, or other pertinent information
Operational	OV-6a	Operational Rules Model	One of three products used to describe operational activity—identifies business rules that constrain operation
Operational	OV-6b	Operational State Transition Description	One of three products used to describe operational activity—identifies business process responses to events
Operational	OV-6c	Operational Event-Trace Description	One of three products used to describe operational activity—traces actions in a scenario or sequence of events
Operational	OV-7	Logical Data Model	Documentation of the system data requirements and structural business process rules of the Operational View
Systems	SV-1	Systems Interface Description	Identification of systems nodes, systems, and system items and their interconnections, within and between nodes
Systems	SV-2	Systems Communications Description	Systems nodes, systems, and system items, and their related communications lay-downs
Systems	SV-3	Systems-Systems Matrix	Relationships among systems in a given architecture; can be designed to show relationships of interest, e.g., system-type interfaces, planned vs. existing interfaces, etc.
Systems	SV-4	Systems Functionality Description	Functions performed by systems and the system data flows among system functions
Systems	SV-5	Operational Activity to Systems Function Traceability Matrix	Mapping of systems back to capabilities or of system functions back to operational activities
Systems	SV-6	Systems Data Exchange Matrix	Provides details of system data elements being exchanged between systems and the attributes of that exchange
Systems	SV-7	Systems Performance Parameters Matrix	Performance characteristics of Systems View elements for the appropriate time frame(s)
Systems	SV-8	Systems Evolution Description	Planned incremental steps toward migrating a suite of systems to a more efficient suite, or toward evolving a current system to a future implementation
Systems	SV-9	Systems Technology Forecast	Emerging technologies and software/hardware products that are expected to be available in a given set of time frames and that will affect future development of the architecture
Systems	SV-10a	Systems Rules Model	One of three products used to describe system functionality—identifies constraints that are imposed on systems functionality due to some aspect of systems design or implementation
Systems	SV-10b	Systems State Transition Description	One of three products used to describe system functionality—identifies responses of a system to events
Systems	SV-10c	Systems Event-Trace Description	One of three products used to describe system functionality—identifies system-specific refinements of critical sequences of events described in the Operational View
Systems	SV-11	Physical Schema	Physical implementation of the Logical Data Model entities, e.g., message formats, file structures, physical schema
Technical	TV-1	Technical Standards Profile	Listing of standards that apply to Systems View elements in a given architecture
Technical	TV-2	Technical Standards Forecast	Description of emerging standards and potential impact on current Systems View elements, within a set of time frames

Figure 1 DoDAF Views (DoDAF, 2004)

2.4 The DoDAF and Air Force Weapon System Acquisition

The views mentioned above are intended to aid the weapon system designer in translating requirements into capability to the warfighter. Weapon systems design and development is the purview of program managers and engineers within Air Force acquisition program offices. Beyond the notional benefits to systems engineering, the DoDAF Working Group prescribed several views as beneficial to the program manager in acquisition strategy development. Further, as Zinn noted, with the Clinger-Cohen Act and Office of Management and Budget circular A-130, "the use of architectures had not only been recommended but essentially made law" (46:17), at least for information technology systems. In addition, JCIDS, NR-KPP, and Information Support Plan guidance calls for the production of systems architecture products as well. These are requirements program office personnel must meet.

The most basic task the acquisition program manager has, albeit far from a trivial one, is to translate operational requirements into a contractual specification that will result in the development of a system meeting the user's needs. This is the core capability systems engineering efforts provide. Systems engineering has become more and more complicated as the level of complexity of the systems under development increases as well as the requirements for these systems to interact also increase. Therefore, "the architectural approach is needed most as systems become more complex and multi-disciplinary, and for systems customized to individual clients" (3:1). The DoDAF Working Group stated:

> Using an integrated architecture ensures that the system to be acquired is addressed in the context of a whole environment rather than a separate entity. The architecture

> can support identification of operational dependencies outside the sphere of the specific system under development. (17:3-21)

Further In a 2002 paper, Dr, Harry Crisp related how systems architectures can aid in this effort, stating: "Architectures provide the framework for FoS/SoS (Federation of Systems/Systems of Systems) systems engineering and acquisition", a feeling echoed by Dr. Steven Long (see Figure 2 below) as well as the Air Force Chief Architect, Dr. Alexander Levis (12:86). This belief is further outlined in the *Architecture Playbook* developed by the Enterprise Integration Forum Architecture Process Team as a guide for the use of systems architectures: "an architecture-based approach can provide a formal methodology and associated language for determining and representing similar information about complex system (system-of-systems) and relationship to their environments" (19:1).

Systems architectures are another tool in the program office tool box that, when combined in an overall management and execution effort, can lead to success:

> Together, integrated architectures, executable architectures, analytical tools and methods render quantitative actionable information, which, in turns supports funding decisions, acquisitions, system engineering, and investment decisions. (39:11)

Architectures are also a tool designed to aid in program management. Program managers "need to be able to analyze these architectures to locate, identify, and resolve definitions, properties, facts, constraints, inferences, and issues both within and across architectural boundaries that are redundant, conflicting, missing, and/or obsolete" (39:3). In fact, this tool can be considered necessary, "creating a system's C4ISR/DoDAF architecture is one of several necessary activities to advance from a mission concept to reality" (32:10).

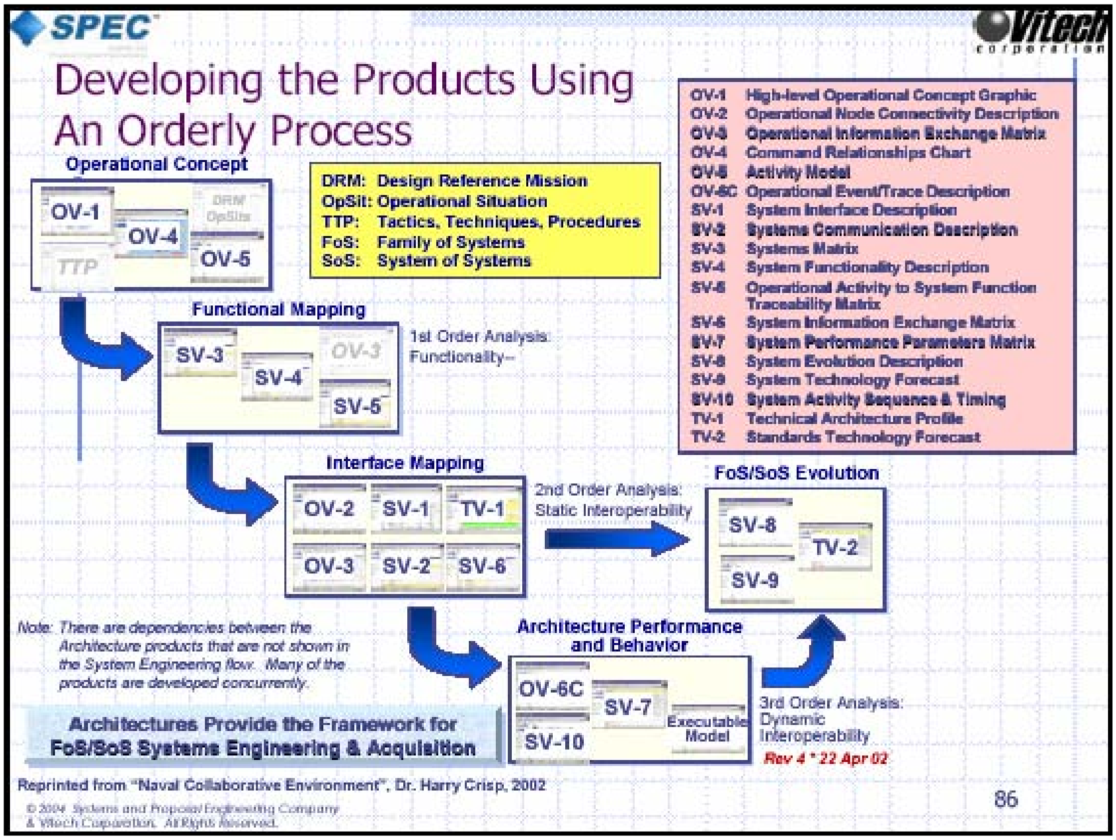

Figure 2 Architectures as Part of Development Process (Long, 2004)

In DoDAF Volume I, the DoDAF Working Group identifies eight views as "highly applicable" to the development of a weapon system acquisition strategy. Systems architecting can be very useful in this early stage of the development effort.

> The role of systems architecting in the systems acquisition process depends upon the phase of that process. It is strongest during conceptualization and certification, but never absent. Omitting it at any point, as with any part of the acquisition process, leads to predictable errors of omission at that point to those connected with it. (33:23)

Figure 3 depicts the "Recommended Uses for Architectures" as identified by the DoDAF Working Group. Notice, under 'Acquisition Process', the first line is Acquisition

Strategy. There are eight views that are highlighted as “highly applicable” with another three as “often or partially applicable”. In addition to these, Levis describes Dickerson and Soules’ proposal for the following products as useful for acquisition strategy development: SV-8, SV-9, TV-2, and CV-6 (Capability Views never implemented in DoDAF) (31:5-62).

APPLICABLE ARCHITECTURE PRODUCTS

RECOMMENDED USES OF ARCHITECTURE:	All View		Operational View (OV)							Systems View (SV)											Tech Stds View	
	1	2	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	9	10	11	1	2
Planning, Programming, Budgeting Execution Process																						
Capability-Based Analysis for IT Investment Decisions	●	●	●	●	●	●	●	●	⊙	●	⊙	●	●	●	●	●	●	●	●		●	⊙
Modernization Planning and Technology Insertion/Evolution	●	●	⊙	●	⊙	⊙	●	⊙		●	⊙	⊙	⊙	●	⊙	●	●	●			●	●
Portfolio Management	●	●		●			●	⊙		●			⊙	●		⊙	●				⊙	
Joint Capabilities Integration and Development System																						
JCIDS Analysis (FAA, FNA, FSA)	●	●	●	●	⊙	⊙	●	●		●	⊙		⊙	●							⊙	
ICD/CDD/CPD/CRD	●	●	●	●	●		●	●		●	⊙	⊙	●	●	●	⊙	⊙	⊙	●		●	⊙
Analysis of Alternatives (AoA)	●	●	●	●	⊙		●	●		●	⊙	⊙	●	●	⊙	⊙	⊙	⊙			⊙	⊙
Acquisition Process																						
Acquisition Strategy	●	●	●	●	⊙		●	⊙		●	⊙			●							●	
C4ISP	●	●	●	●	●		●	●		●			⊙		●	⊙					●	⊙
System Design and Development	●	●		●	●		●	●	⊙	●	●	●	●	●	●	●	●	⊙	⊙	⊙	●	⊙
Interoperability and Supportability of NSS and IT Systems	●	●	●	●	●	⊙	●	⊙	⊙	●	⊙	●	●		●	●	⊙	⊙	⊙	⊙	●	⊙
Integrated Test & Evaluation	●	●		●	●	⊙	●	●	⊙	●	●	●	●	●	●	●			●	⊙	●	
Operations (Assessment, Planning, Execution, …)																						
Operations Planning & Execution	●	●	●	●	●	●	●	●	⊙	●	●	⊙	⊙	●	⊙	⊙					⊙	
CONOPS & TTP	●	●	●	●	●	●	●	●		●	⊙	⊙	⊙	⊙							⊙	
Communications Plans	●	●	●	●		⊙	⊙			●	●						⊙	⊙			●	⊙
Exercise Planning & Execution	●	●	●	●	●	●	●	●		●	●	⊙	⊙	⊙	⊙						⊙	
Organizational Design	●	●	●	●	●	●	●	⊙	⊙	⊙	⊙			⊙								
BPR/FPI	●	●	⊙	●	●	●	●	●	⊙													

● = Product is highly applicable
⊙ = Product is often or partially applicable
(dark shading) = Product is specifically addressed in policy
(light shading) = Product is required for an integrated architecture
blank = Product is usually not applicable

Figure 3 Recommended Uses of Architecture (DoDAF, 2004)

Figure 3 also highlights the JCIDS systems architecture requirements. Notice that the views under the JCIDS header are not only “highly applicable”, but are also “specifically addressed in policy”; in this case CJCSI 3170. In addition, DoD Instruction “Operation of the Defense Acquisition System,” May 12, 2003 “defines how integrated architectures are to be used in the requirements and acquisition processes” (17:2-5).

"JCIDS implements a capabilities-based approach that better leverages the expertise of all government agencies, industry and academia to identify improvements to existing capabilities and to develop new warfighting capabilities" (7:A-1). In fact, the assumption that "integrated architectures are the preferred method for describing operational, technical and systems interactions and assessing future capability needs" has been an underlying theme for the revised JCIDS documented in CJCSI 3170.01D (35:3).

Program managers attempt to get their system through the acquisition milestones to full production and sustainment. In order to accomplish this, they are required to produce the appropriate documentation at each milestone review. "Integrated architecture products must be included in mandatory appendixes for the ICD, CDD, and CPD" (17:2-7). Further, mandatory integrated architecture products for CRDs (Capstone Requirements Documents) include AV-1, OV-2, OV-4, OV-5, OV-6C, SV-4, and SV-6 (8:E-A-6).

In addition to the JCIDS requirements, architectures are also required documentation for Information Support Plans (ISPs – formerly C^4I Support Plans) and as part of the documentation required to identify net-ready key performance parameters (NR-KPP). Both Figures 3 and 4 (below) identify the architecture views required for ISP/C^4ISP development. According to Chairman Joint Chiefs of Staff Instruction (CJCSI) 6212.01C, "all CDDs (Capability Development Documents) that exchange information will have a NR-KPP" which is "derived from a completed architecture and developed from" mandatory architecture products (see Figure 4 below) (9:F-1). In fact, the instruction goes on to say "development of the NR-KPP begins with designing the architecture for the proposed system" (9:F-2).

Document	Net-Ready Key Performance Parameter Products																	LISI Profile
	Supporting Architecture Products														NCOW RM	KIP Compliance	IA Compliance	
	AV-1	OV-1	OV-2	OV-3	OV-4	OV-5	OV-6C	SV-1	SV-2	SV-3	SV-4	SV-5	SV-6	TV-1				
ICD		X													X			
CDD	X		X		X	X	X				X	X	X	X	X	X	X	X Basic
CPD	X		X		X	X	X				X	X	X	X	X	X	X	X Complete
CRD		X		1		2									2	2	2	
ISP	3	3	3		3	3	3	3			3	3	3	3	3	3	3	3 Complete

Note: X = Required
(1) Old CRDs Updates
(2) New CRDs
(3) ACAT, NON ACAT and Fielded Systems. NR-KPP products produced for the CDD and CPD will be used in the ISP.

Figure 4 JCIDS Documents/NR-KPP Products Matrix (CJCSI, 2003)

National Security Space (NSS) Acquisition Policy guidance is provided in *NSS Acquisition Policy 03-01* and, although separate and distinct from the more general weapon systems acquisition guidance in the DoD 5000 series, emphasizes the use of systems architecture products. "It is the responsibility of JCIDS and National Security Space Architect's (NSSA) processes to develop integrated architectures and initial operational view (OV) products for NSS systems" (42:10). Further, conducting system architecture development efforts and producing initial SV and TV architecture products is included in phase readiness review and entry criteria checklists (42: 35). Systems architectures are therefore pervading all aspects of DoD weapon systems development.

In a presentation before the Software Technology Council in 2003, Thilenius and others presented the following statistic highlighting the increased role architectures are playing in weapon system acquisition: "Architecture products directly responsible for $1.17B in O3 POM" (41:26). Therefore, as the Air Force, and indeed all of DoD moves to a more capability-based development process, systems architectures will continue to be prevalent. This fact is highlighted by the increased interest in how architectures should integrate in the weapon system acquisition process.

In September 2003, the Air Force Inspection Agency published its findings during an Eagle Look investigation into architecture-based acquisition. Submitted by the Electronic Systems Center, the purpose statement was to "assess the ability of the Air Force to integrate enterprise architecting into the acquisition process by identifying policy strengths and shortfalls, as well as enablers and impediments to integration" (2:no page). The Eagle Look team interviewed key individuals involved with architectures from the following types of organizations (113 interviews, predominantly senior leaders – 70% were in the grade of Lt Col or higher for military and GS-15 and above for government civilians): Secretary of the Air Force and Headquarters United States Air Force Functional Offices, Unified and Major Commands, Product Centers and Product Groups, and Department of Defense (DoD) Functionals and Program Offices. The team found that "94% of the personnel in, or involved with, the acquisition process consider architectures (both warfighting and business) to be of significant value in improving how products or systems are acquired and sustained" (2:no page).

2.5 Roadblocks to DoDAF Implementation Within Air Force Product Centers

In addition to the positive perceptions with respect to system architectures in acquisitions, the EAGLE LOOK team also identified several areas of concern. There are others experienced in systems architectures that have also recognized potential roadblocks to the successful implementation of systems architectures within Air Force weapon systems acquisitions. At the 2004 Command and Control Research and Technology Symposium, Lawrence McCaskill offered his analysis of the DoDAF and its implementation. Beyond the use of the DoDAF products, there are concerns about the views themselves. One of the recurring critiques of systems architectures is their static nature, leading to the call for executable architectures. Finally, there is a danger in program office personnel creating architectures for architecture sake.

AFIA EAGLE LOOK.

Interviewees responding to the 2003 AFIA Eagle Look investigation identified the following issues to be addressed in order to move to an acquisition system driven by architectures (see Table 1).

Table 1 EAGLE LOOK Issues

	Issues
1.	Leadership may not sustain the focus needed to fully implement the architecture construct.
2.	A significant portion of the workforce was unconvinced that architectures are a valuable construct to pursue.
3.	Policy and guidance to implement an architecture-based acquisition process was insufficient.
4.	Organizationally- or functionally-centric, or 'stovepiped' processes will impede the move to an enterprise architecture-based system.
5.	Full integration of enterprise architecting into key Air Force and DoD processes, such as the CRRA (capabilities review and risk analysis) and the Planning, Programming, Budgeting, and Execution (PPBE) processes, has not occurred.
6.	Air Force personnel lacked the needed education, training, and experience to effectively pursue enterprise architecting.
7.	Funding strategy was insufficient to accomplish this task

(AFIA, 2003)

In addition, "the EAGLE LOOK team identified workforce attitude as a potential impediment to integrating architecture concepts into the acquisition business", which is not surprising seeing as the team also found "the Air Force does not include architectural development skills as a core skill set for program managers" (2:16, 41).

Many EAGLE LOOK interviewees felt architectures were too information technology-centric, with one respondent stating "(Architecture) policy…doesn't apply to weapon systems" (2:16, 67). This latter feeling is echoed in the fact that the only mention of systems architecture products in the Interim Guidance Preceding Air Force Instruction 63-101, *Capabilities Based Acquisition System* is in the section outlining information technology as an important management consideration (14:20). And finally, with respect to the integrated architectures JCIDS refers to, "none of the overarching joint operational architectures are in place, so the Services continue to do what they've always done" (2:36).

McCaskill's Study.

Lawrence McCaskill, an employee of Whitney, Bradley, & Brown, Inc., presented a paper, *"Integrated DoD/C4ISR Architectures: It's not About the Framework…"*, for the 2004 Command and Control Research and Technology Symposium in which he identified several concerns with the way architectures were being used. His study set out to "clarify the overarching purpose of integrated architectures…and describe a methodology by which the architecture community can improve the process of developing and maintaining architectures" (37:1).

With respect to the CRRA integration issue identified in the EAGLE LOOK report, McCaskill found that due to architectures not having complete financial and scheduling information, architecture-based analysis in the CRRA "requires lots of manual processes to put together" (37:17). Referring to acquisition program office personnel reactions to the requirement for architecture products, McCaskill stated: "This process put the architectures at the wrong end of the acquisition chain; the architectures didn't drive the requirements to create the respective systems – they ended up being the product of the system being built (and often, an afterthought, after the system had already been built)" (37:9). Ultimately, McCaskill found "current efforts, especially with regard to C4ISPs/ISPs are 'reinventing the wheel' every time one of these requirements documents is created, thus creating semantic mismatches for the same information, and in the endgame, misusing resources" (37:16).

Issues With the Products Themselves.

Despite the fact that the DoDAF has been embraced by the DoD as the best tool to add discipline, structure, and context to our new and modernized systems, there are some issues with the products used to represent the architecture. There are issues with their comprehensive applicability or effectiveness for acquisition management, capability-based analysis, and systems engineering applications. The United Kingdom (UK) is developing its own architecture framework, in part, to address deficiencies it sees in the DoDAF. Members of the Joint Staff, specifically the J-8, have also expressed doubts concerning the utility of system architecture products for the capability-based analysis and decision-making they perform. Another issue with the products themselves involves the ability to measure the level of functionality or capability identified in the architecture.

Hilliard et. al. questions how complete the DoDAF products are with respect to the types of analysis they are intended to aid.

> It is tempting to prescribe predefined views (as the DoDAF does), "however, we do not yet have enough experience to prescribe these, or any, views for all systems. Sometimes, a system's most critical architectural concerns fall outside this familiar set. (25:4)

Further, Dam and Long unearthed another issue with the completeness of the DoDAF architecture products. In terms of comparison, there is no standard set of levels; for instance, how do I know I am at the same level of OV when looking at 2 architectures (12)? And, in terms of engineering, Long, Macdonald, and Maley concur with the notion the DoDAF is less than complete, believing additional detail beyond that required to generate the views is needed. “Otherwise, the team performs ‘engineering by viewgraph’ which is well known as an inadequate approach for the design of complex systems” (32:3).

Maier has stated the following in terms of the systems engineering aspects of weapon systems acquisition:

> One clear issue is that it (CAF) is often being used for purposes for which it was not intended. The goals, at least as discussed in the CAF documentation, did not include defining a standard that was complete with respect to an acquirer’s concerns. For example, there is no place in the views for performance models, cost models, or other management models. Yet all those are clearly necessary when the client is an acquirer and must make acquisition decisions. (33:226)

With respect to making acquisition decisions, the DoDAF has not improved upon this deficiency. As such, the United Kingdom Ministry of Defense (MoD) is working on its own standard, the Ministry of Defense Architecture Framework (MoDAF). The MoDAF builds on to the DoDAF with 12 additional views, including two new categories of views; Capability and Acquisition Views. These additional views are intended “to handle temporal and other procurement aspects where the DoDAF…doesn’t cover these aspects” (36: M-5). The ultimate goal is to develop “a common language set to describe systems and systems-of-systems” and obtain a “context for system procurement” not previously achievable (36:M-3). Even though the intent of the DoDAF is to bring interoperability, consistency and cohesiveness to the development of new capabilities, the products from these tools impose an additional data and semantic interface that the requirements engineering and systems engineering teams must resolve” (32:3).

In a 17 May 2004 presentation outlining concerns the J-8 Staff has with integrated architectures US Navy Captain Mike Mara declared architectures to be resource-intensive and not as valuable as hoped as planning and decision-making aids. He said, "Architectures tend to be brittle, static at best, or worse, outdated. DoDAF architectures require significant fiscal and manpower resources to produce" and "architectures can not be produced or revised on a timeline that matches the tempo of analytic questions facing decision makers" (35:4). In terms of utility and value, Mara said, "Most of the DODAF architecture views are not necessary to conduct capability-based assessments and do not include data needed to support this process. Additionally, no architecture views capture the robust relationships between capabilities, attributes and metrics needed for capability-based assessments" (35:4). These beliefs have lead the J-8 to the conclusion that they "no longer assert that architecture is the preferred method" to "evaluate how well a system or system-of-systems attains a desired capability" (35:5).

An additional concern with the DoDAF products is their inability to provide information on the level of capability or effectiveness of the architecture modeled. Mara also recognized this deficiency in a 2003 paper,

> The framework only show(s) a binary relationship between systems and operational activities – a system either has the functionality or it doesn't. In reality, there needs to be recognition and some assessment of *how much* functionality a system has". (34:9)

McCaskill also noted architecture's inability to provide measures of effectiveness:

> While this answers the 'first order' question of 'is there a system being developed that answers the requirements of the capability,' it does not answer the question of 'how effective' the FoS/SoS is in accomplishing this capability. Thus, this only provides the 'first step' towards the

> analysis that the decision-maker will need to make acquisition decisions" (37:14).

Executable Architectures.

One way to answer the 'how effective' question McCaskill brings up above is to run an executable model of the architecture and analyze the system/capability performance. However, the DoDAF does not include an executable architecture among its products: "There are currently no standards for the format or process for constructing executable architectures" (17: 7-2). Issues of timing and latency, as well as outcome measures of effectiveness could be addressed with the development of executable architectures.

The need for executable architectures lies in the static nature of the DoDAF products. "Static operational models only show that activities 'must be capable of' producing and consuming information. They do not provide details on how or under what input/output conditions information is actually produced/consumed" (39: 8). In another paper, Ring and others concluded: "These static products…fail to provide a good vehicle for conducting detailed dynamic 'behavioral' analysis of how the systems are supposed to interact with each other" (17:3). James Long describes the need for executable models as: "Static diagrams may or may not actually work, since in reality many of the processes interact with one another and functional decomposition can miss critical interfaces" and "simulation enables the execution of these models, thus ensuring that the design is executable (i.e., will work)" (12:125). And, in his thesis dealing with the implementation of a specific architecture, Capt Gregory DeStefano noted that despite the dynamic behavior captured in some of the DoDAF views (in particular the OV-6), "some vehicle is needed to take these products and put them into motion" (15:2-14).

Although the DoDAF does not include formats or processes for executable architectures, it does define what they are. DoDAF Volume I defines executable architecture as "the use of dynamic simulation software to evaluate architectural models" (17:7-1). These executable architectures would provide value to acquisition program office personnel, as stated by the Enterprise Integration Forum Architecture Process Team:

> The derivation of an executable model of the architecture from the three views and the associated integrated dictionary, provides a basis for understanding the interrelationships among the various architecture products and establishes the foundation for implementing a process for assessing and comparing architecture. (19:41)

There are efforts underway to address this issue and develop or improve existing discrete event simulators to have the capability to perform dynamic analysis of the capability or system under development. In a recent Air Force Institute of Technology thesis, it was shown that the DoDAF architectures provide all the information required for any modeling and simulation required to analyze competing design decisions (46:91). However, at this point there are no well accepted methods for a program office engineer to execute an architecture.

Architecting for Architectures Sake

Irrespective of the issues with systems architecting as a systems engineering tool or with the DoDAF and its views, there is also the issue that the architecture becomes the focus, as evidenced in the following caution from Jeffrey Harris, former Director of the National Reconnaissance Office:

> Recent years have increased the focus on architectures… While (this) is beneficial, it is easy to allow the architecture and its processes to become the focus rather than the users' desired effects". (21:47)

The DoDAF Deskbook attempts to head off this issue by providing a notional six-step process that includes four steps before any architecture products are actually built (see Figure 5 below).

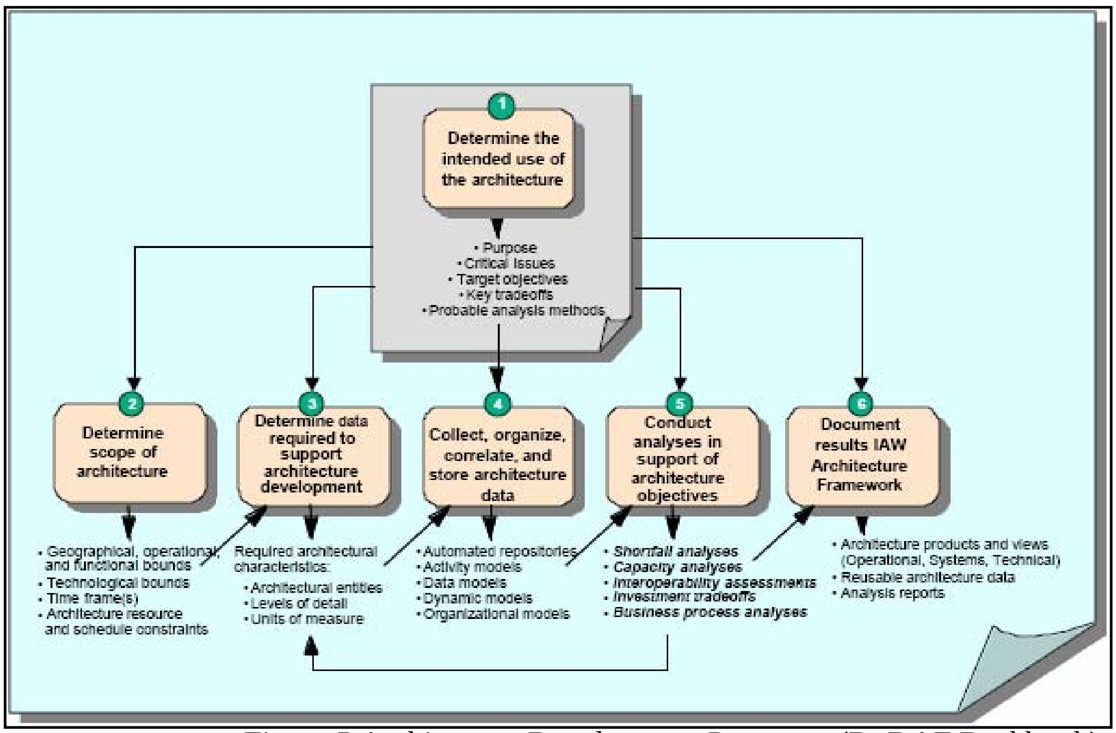

Figure 5 Architecture Development Process (DoDAF Deskbook)

Further, McCaskill also cautions that "while the *Framework* plays a large part in providing a common lexicon by which the primitives that compose integrated architectures are described, delving directly into 'spreadsheets and boxologies' misses the point of why we're creating integrated architectures" (37:3). It would be a shame for those earnestly working on systems architectures in an effort to improve their systems engineering rigor, to lose focus on the reason for the system architecture and indeed the systems engineering work at all.

System architecture products are required by direction for Air Force weapon systems acquisition efforts. The JCIDS process identifies capability requirements that evolve into the weapon systems that are developed in Air Force Materiel Command product centers. These product centers employ program managers and engineers skilled in taking a user's requirement and turning it into a hardware or software solutions, that is systems engineering. The DoDAF provides a framework for capturing the early systems engineering work performed and communicating the complex interactions of the system or capability under development. However, the DoDAF has not yet been universally accepted as a systems engineering tool and practice. There are several obstacles to the full implementation of a systems architecture mentality within the trenches of Air Force weapon systems acquisition.

3. Data Collection and Analysis Methodology

3.1 Overview

Chapter 2 summarized the literature supporting the notion that systems architectures are useful and valuable for Air Force weapon systems acquisitions. However, there were also several issues or roadblocks identified. Chapter 3 lays out the methodology for investigating the level to which these obstacles have been overcome (at least within ASC). This study is inductive in nature, relying on interviews with "people in the know" and critical analysis of the results. First, the "people in the know" had to be identified – the population from which to collect data. Then, the data was collected via structured interviews. This data was collated and formatted for analysis of the results. This analysis involved grouping respondents by their level of DoDAF implementation. Along the way, significant additional information concerning systems architecting, the DoDAF, capabilities-based system development, and even the new ASC organizational structure was also collected.

3.2 Research Design

This is a qualitative case study of the implementation of system architectures, specifically the DoDAF, within ASC. Whereas the 2003 AFIA Eagle Look, described in Chapter 2, took a broad brush look at architectures in acquisition across the Air Force at a senior leader level, the focus here is collecting detailed information to determine the level to which the DoDAF has permeated throughout ASC to the program manager and engineer level. Data was collected through interviews (and in rare cases e-mail correspondence) with personnel representing the highest level of acquisition program management execution. These interviews lead to follow-up interviews with specific program personnel within each Wing or DRG. In total, 39 interviews were conducted.

3.3 Data Collection Methodology

The data collected through these interviews was intended to provide a characterization of the level of system architecture work previously done, currently ongoing, or planned. The questions posed during the interviews gathered information as to rationales behind decisions concerning architecture efforts within each organization. In addition, data was collected concerning the level of education, training, and general familiarity in systems architectures each person interviewed possessed. In total, this data would be collated by program and then by Wing or DRG in order to portray an overall picture of systems architecting within ASC as a whole.

The interviews generally took no more than 30 minutes and were facilitated by a standard note-taker template. Access to the interviewees was made possible through the ASC Commander's Action Group and through personal connections with the Wing and DRG Executive Officers. Each interviewee was assured that their individual identities would not be revealed. Confidentiality is accomplished by reporting the responses tied to organizations rather than specific persons or even job titles.

Although no two interviews were exactly the same, the same basic questions were asked to all interviewees. Example questions included:

- Does your organization (Wing/DRG/Program, depending on the level of authority of the person being interviewed) make use of the DoDAF systems architecture framework/process?

- If yes;

    -- To what degree do you make use of the architecture products during the execution and management of your program?

    -- Which views are more/less useful to you in executing your program?

    -- Who creates the views; in-house (program office personnel and contractors), outside contractor support, the user (Major Command)?

    -- How much training or education do the people creating and reviewing the architecture views have in the DoDAF and systems architecting, in general?

    -- What tools do you use to create the systems architecture views (Popkin, Visio, Power Point, etc.)?

- If no;

    -- Why not? What is keeping your organization from adopting this framework?

    -- Does your organization employ another systems architecture framework (IEEE 1471, Zachman, etc.)?

    -- Do you have another method for capturing the output of your systems engineering processes?

- How could systems architecting, and specifically the DoDAF, be more useful to you?

The population for this study was selected in order to best meet the research objective. ASC provided a population experiencing the expansion of the role of the DoDAF. The DoDAF is expanding the realm of systems architecting from C^4ISR systems to all systems. As such, studying the implementation at the Aeronautical Systems Center seemed appropriate. The level of acceptance and use within ASC should serve as a barometer for overall acceptance of the DoDAF within Air Force weapon systems acquisition programs, which traditionally have not been dominated by networked C^4ISR capabilities.

ASC was undergoing a significant reorganization. In June 2004, ASC began operating under a wing, group, and squadron structure. Over 40 separate program offices were organized into five acquisition systems wings and two direct reporting groups for fighter attack, long range strike, reconnaissance, mobility, agile combat support, special operations forces and training aircraft. In January 2005, the structure was formally recognized (1:2). The new structure is depicted in Figure 6. ASC was the first product center to operationalize this reorganization with all the others soon to follow.

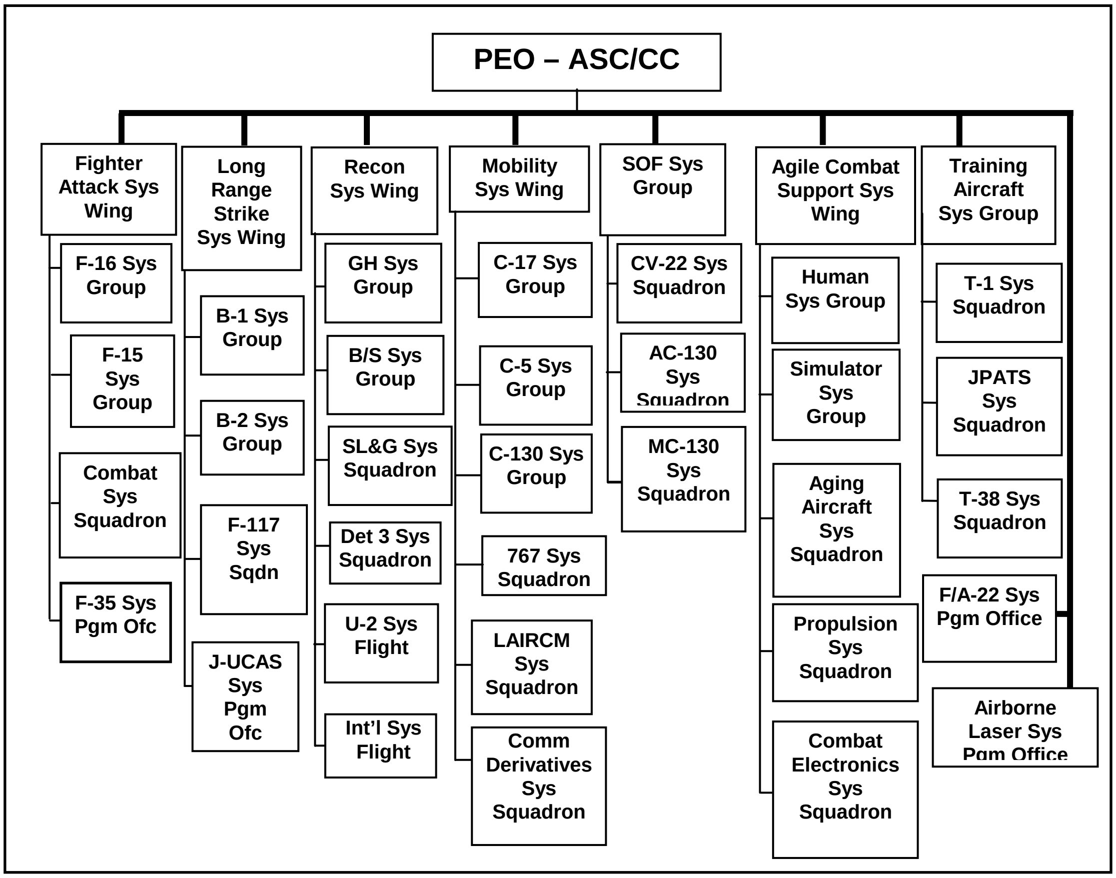

Figure 6 ASC Reorganization Chart (ASC, 2005)

Within ASC, interviews were performed at various levels. The first interviews were with members of the ASC Commander's Action Group (CAG). The CAG is responsible for being the liaison between the Wings and DRGs and the Commander. They review documentation and generally make sure both the Commander is informed about the Wings/DRGs and the Wings/DRGs are informed about the concerns of the Commander. The CAG was chose first in order to get an overall picture of the Commander's requirements with respect to systems architecture. For instance, does the Commander review the systems architecture products included in the programmatic documentation that flows from the programs? Also, the CAG provided connections within the Wings and DRGs for further interviews.

Within each Wing/DRG, the first interviews were conducted with senior program office personnel with program management and engineering responsibilities. These leaders were a mix of active duty Air Force officers (Majors, Lieutenant Colonels, and Colonels) and government civilians (GS-13, 14, 15, and SES). These interviews were intended to provide an overview of the systems architecture work ongoing within the organization as a whole as well as the senior leader perspective on systems architecting in general. When systems architecting work was indicated within specific programs within the organization, follow-up interviews were scheduled with the appropriate programmatic personnel.

The follow-up interviews concentrated on the specific program application of systems architecting. Interviews were conducted with program managers, engineers, and other program office personnel. These interviewees included a wide range of active duty Air Force officers, government civilians, and support contractors. The focus of this sampling group was an in-depth review of the program status and any system architecture work ongoing or planned. This group was also best suited to respond to questions dealing with education, training, and experience as they represent the "hands-on" architecture workforce.

Within ASC, three other groups were also interviewed in order to broaden the scope of the study to encompass the entire organization. First, as part of the ASC reorganization a Capabilities Planning and Integration Directorate, ASC/XR was stood up. This organization is intended to be the origin of new system development efforts within ASC by coordinating the user's initial capability requirements with the appropriate Wing or DRG. Since this group has a program initiation function, they made likely candidates for architecture work. The next two groups are related in their support function within ASC. ASC/PM provides education and career management support to the program managers assigned to ASC, while ASC/EN performs the same function for the engineering personnel. Both of these organizations had the potential to effect architectural implementation through their policy and standards and education roles. The personnel interviewed in these organizations were government civilians in the grades of GS-13 and above.

Additionally, interviews were conducted with systems architecture and DoDAF subject matter experts. In the course of reviewing the relevant literature with respect to systems architectures and the DoDAF, these experts' names and contact information became available as resources for data collection. The three experts interviewed were all government support contractors with vast experience in either systems architecting and/or the DoDAF, in particular. These interviews (all conducted via e-mail) focused on gathering expert opinion on the current issues surrounding program office implementation of the DoDAF systems architecture framework.

3.4 Data Analysis Methodology

This study involves an interpretational analysis methodology. In Leedy, Gall et. al. describe this process as "examining the data for constructs, themes, and patterns that can be used to describe and explain the phenomenon studied" (30:158). The phenomenon, in this case is the implementation of the DoDAF system architecting framework within ASC. The data collected provides information enabling "an inductive process of organizing data into categories and identifying patterns (relationships) among the categories" (McMillan & Schumacher quoted in 30: 165). Combining these ideas, the analysis methodology for this study involves grouping like organizations in a three-tiered scale in terms of level of architectural implementation and identifying overarching patterns of behavior with respect to systems architecting. Representative quotes from interviewees were collected in order to support the characterization of each organization.

The interviews provide data with which to characterize each program, DRG, or Wing with respect to the level of systems architecting implementation. The organizations can then be plotted on a continuum representing various levels of systems architecture implementation. A generic continuum is presented in Figure 7. This continuum will provide a graphical depiction of the number of organizations in each stage of systems architecture implementation. This depiction, along with selected quotes and other data to clarify each organization's placement on the continuum, should prove and could provide a baseline for further ASC architecture implementation as well as background for the development of version 2 of the DoDAF.

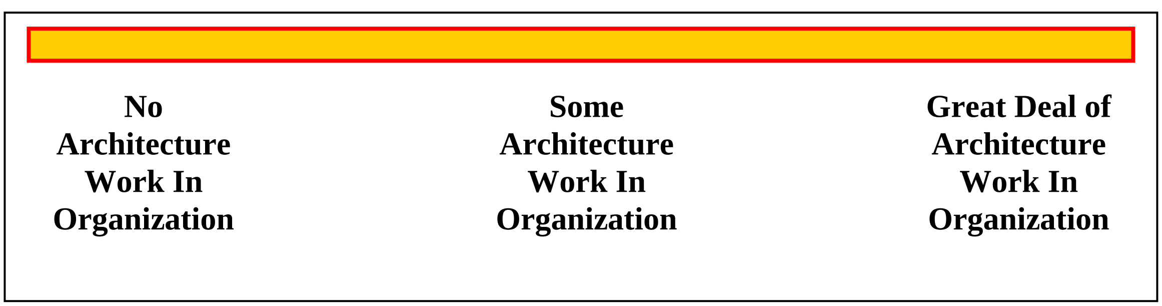

Figure 7 Architectural Implementation Continuum

The second portion of the analysis involves recognizing the overall themes and patterns of systems architecture behavior within ASC. This data is culled from questions dealing with the perceived value of systems architectures to acquisition program management as well as recommendations suggested by interviewees. The results of this analysis will be presented in verbal form with representative quotes from the interviewees.

3.5 Validity and Reliability

In a qualitative study such as this, there appears to be no "single, commonly accepted standard for judging the validity and reliability" (30:168), however this does not lessen the concerns with respect to ensuring these aspects of the study are maintained at a high level. Validity deals with the effectiveness of the measure; does it measure what it is supposed to measure? How comprehensively? How accurately? (30:32). Reliability deals with the consistency with which a measurement performs. Does the instrument consistently measure the factors it was designed to? Does it do so accurately (30:35)? Both issues are addressed below.

In Leedy, Altheide and Johnson refer to four types of 'interpretive validity' which can be used to judge the validity of qualitative research: usefulness, contextual completeness, research positioning, and reporting style. Usefulness involves the level to which the study "enlightens those who read it or moves those who were studied to action". Contextual completeness deals with how comprehensive the view of the situation is that is provided. "Research positioning refers to researchers' awareness of their own influences (both subtle and direct) in the research setting." These influences can include beliefs, values, and/or biases. Finally, the reporting style employed by the researcher can have an effect on the study's overall credibility (30:168). Steps taken to address each of these issues are described below.

With respect to usefulness, the ultimate determination can only be made some time after the study. However, as no such study has been attempted previously, the results will inherently be enlightening to all intended audiences (i.e. the ASC Chief Architect, DoDAF Working Group, systems engineering community in general). Even if the results confirm long-held beliefs as to the level of implementation of the architectural mindset, this study provides data and justification for those beliefs. In terms of driving organizations to action, this study includes several recommendations in order to address any deficiencies in architectural implementation within ASC. Again, the final determination will be made in how many, if any, of the recommendations are followed through.

Altheide and Johnson recommend the following measures to address contextual completeness: "including information about the history of the phenomenon; the physical setting; the activities, schedules, and routines of the participants; as well as their individual perceptions and meanings" (30:168). This study deals with the issue of contextual completeness by capturing the evolution of the DoDAF and its expansion from C^4ISR systems to all weapon systems development efforts. Further, the physical setting in ASC, the activities of the personnel with systems architecture responsibilities, and their perceptions were captured as part of the data collection process.

The final two characteristics of validity deal with the researcher: the researcher's positioning and reporting style. The beliefs, values, and biases of the researcher with respect to systems architecting and the DoDAF are presented in the Limitations section of this chapter. Full disclosure of any issues that may affect the credibility of this study is the goal. In terms of reporting style, this study is presented with the researcher's interpretations of interviewee views as expressed in the interviews conducted. The overall findings and conclusions (i.e. the analysis) are based on these interpretations; following a triangulation methodology involving the collection of like statements from several interviewees, "similar themes are noted in data collected from a variety of sources" in order to increase credibility in the interpretations (30:169). Where appropriate, to bolster the weight of the analysis, representative quotes pertaining to the subject matter are presented. Finally, outlier analysis examined cases that differed markedly from the majority of situations investigated, identifying what was present or absent in these cases compared to the more common examples (30:169).

In addition to the triangulation method described above, Cooper identifies a number of different strategies researchers can employ to increase the reliability of their research designs (11:6). Specifically, she recommends variety in data collection, which involves collecting data from a number of different locations or sources (11:12). This technique is similar to the triangulation method described above and was accomplished by interviewing personnel with systems engineering (and presumably then, systems architecture) responsibilities at various organizations within ASC (e.g. Wings, DRGs, XR, CAG, PM, EN) and at different levels within these organizations. Further, a detailed literature review pertaining to systems architecture in general, the DoDAF, and systems architectures within ASC, in particular, provided a variety of additional sources of information.

The limitations of this study are common to qualitative studies employed in other disciplines and are tightly coupled with the researcher's assumptions. Specifically, the key limits to the completeness and accuracy of this study are access to the right people, the researcher's positioning with respect to the topic of study, and the researcher's ability to interpret and correctly portray the true state of systems architecting within ASC. In terms of interviewee selection, the primary assumption was that starting with the Wing and DRG commanders and Directors of Engineering, other personnel with systems architecture responsibilities would be identified. Although this occurred in many cases, there is a small chance someone with data pertaining to this study was not identified and therefore not interviewed. With respect to the researcher's positioning, one assumption was that most, if not all, organizations within ASC were involved in at least some level of systems architecture work. This could lead to a limitation in terms of the data collected in the very first interviews. Finally, the most significant potential limitation results from not having another research cross check the interview data in order to ensure the researcher's ability to correctly analyze the data collected and display the actual state of affairs such that the reader has the same picture as the researcher.

Assumptions and limitations aside, the documented methodology suits the overall purpose of this study which is to provide a status of systems architectural implementation within ASC. The data was collected through numerous interviews and grouped according to like themes/beliefs. These groupings facilitated analysis of the data to determine the current state and also trends in systems architecture implementation within ASC. The analysis leads to the derivation of significant findings and conclusions. This analysis is described in Chapter 4.

4. Analysis and Findings

4.1 Overview

Chapter 3 outlined the data collection and analysis methodology. Data was collected through structured interviews intended to allow the identification of general groupings of architectural implementation and overall themes within ASC. There are two types of analysis techniques at work. First, there is the logical grouping of like organizations/groups on the continuum presented in Figure 7. This grouping facilitated the second type: descriptions of the groups themselves. Finally, the analysis leads to five findings of significance, four dealing directly with the research objective and a fifth having ancillary connection with the topic.

4.2 Logical Grouping Along Implementation Continuum

As outlined in the previous chapter, this continuum provides a glance into the state of architectural implementation within ASC. Based on similarities in responses/comments from interviewees, organizations were placed along the continuum indicating whether they performed “No Architecture Work”, “Some Architecture Work”, or a “Great Deal of Architecture Work”. The placement of organizations interviewed is depicted in Figure 8 below. The characteristics that distinguish each group are discussed in the next section.

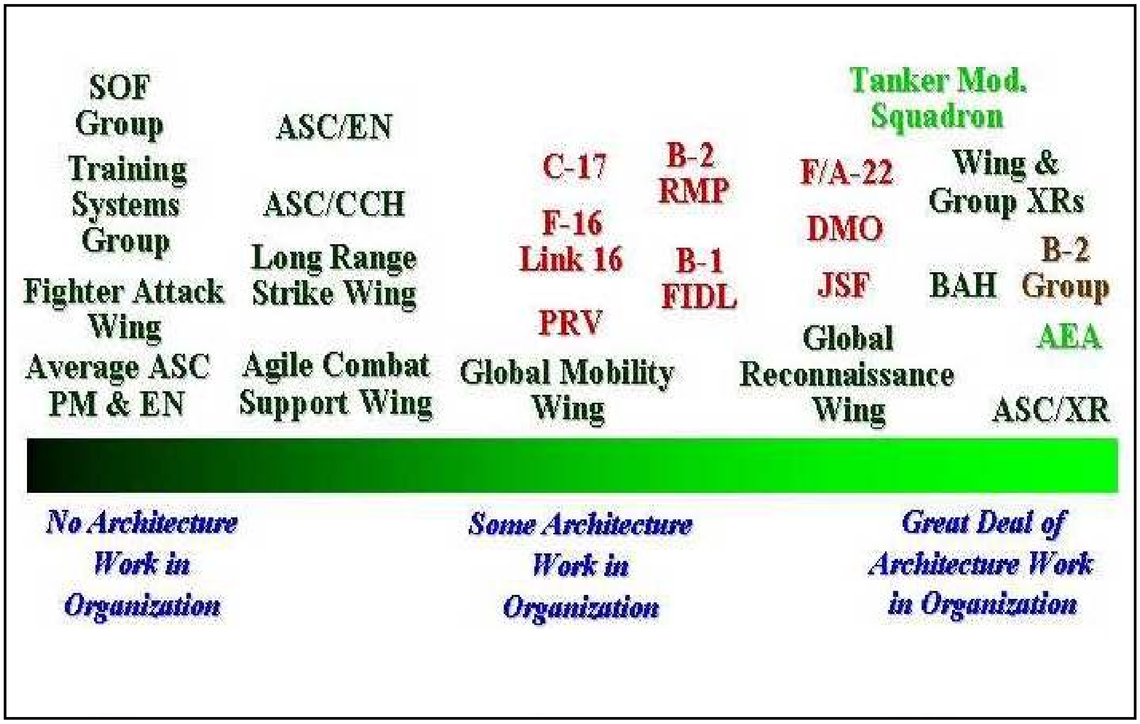

Figure 8 ASC Architecture Implementation Continuum

It is interesting to note that the organizations grouped on the left side of the continuum, the "No Architecture Work in Organization" section, are the Wings and Direct Reporting Groups within ASC. However, systems within many of these organizations are grouped in the middle of the continuum, the "Some Architecture Work in Organization" section. These groupings are highlighted in Figure 9 below.

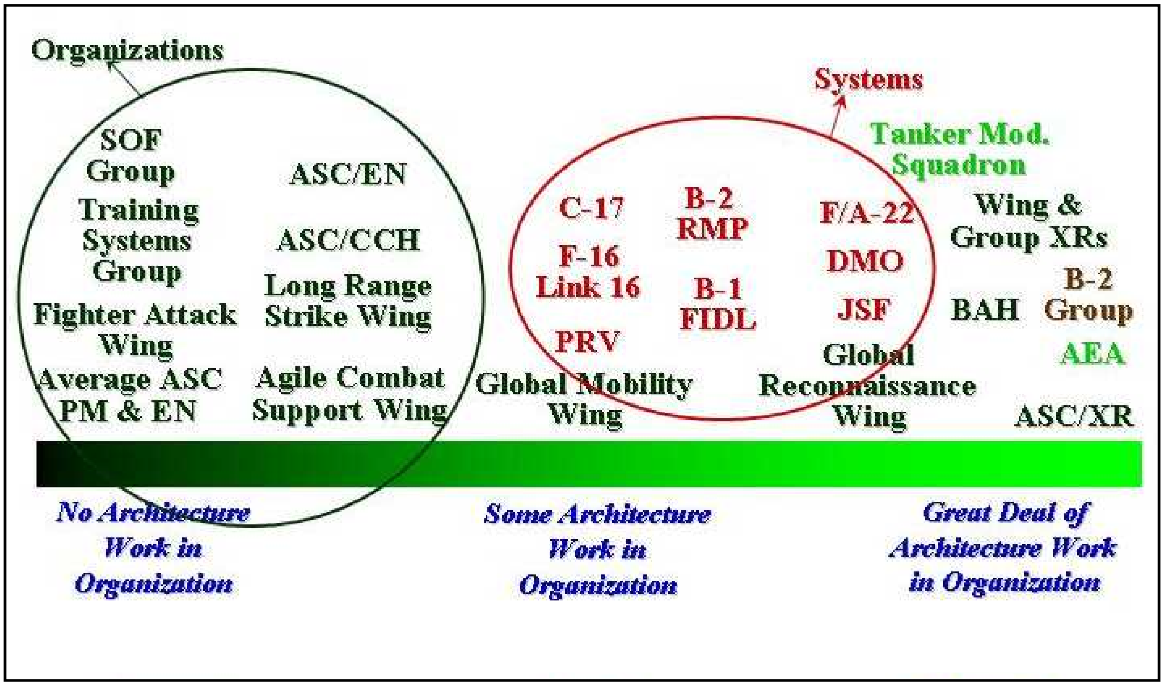

Figure 9 Annotated ASC Architecture Implementation Continuum

In order to further depict this phenomenon, Figure 10 highlights the Long Range Strike Wing position on the continuum – specifically, to the left, while three of the systems or sub-organizations within the Wing are placed toward the right side of the continuum. This indicates that while senior leadership within an organization would respond that, at least "corporately", there is little-to-no architecture work ongoing within the organization, there is indeed some, and in at least this particular case, a great deal of architecture work in progress. This phenomenon is discussed further in the Findings sections.

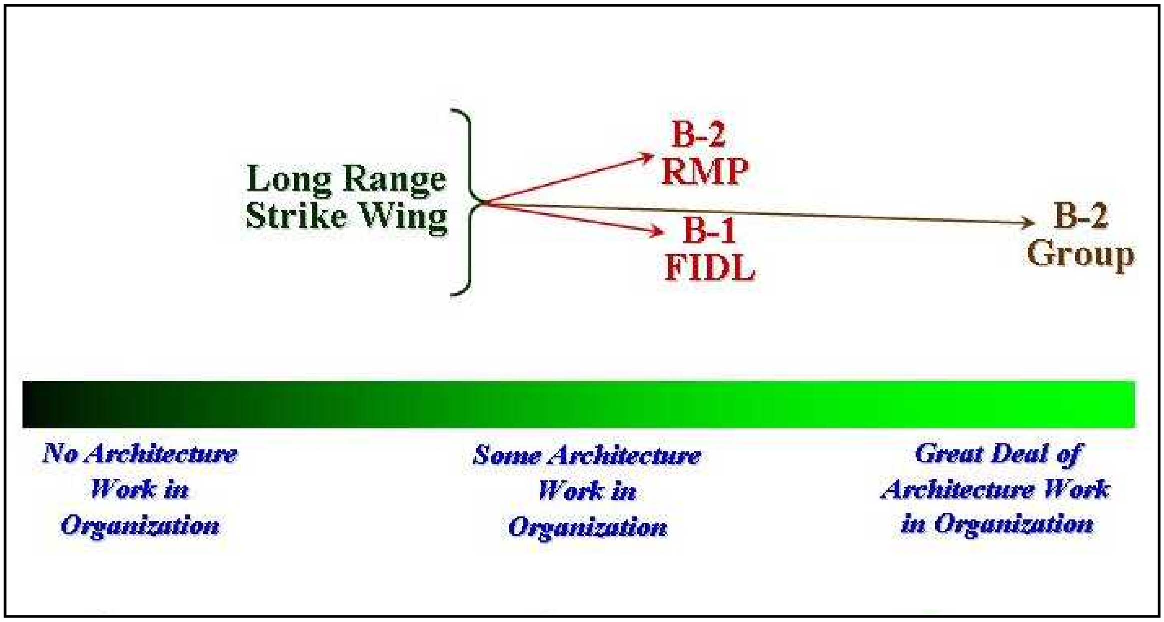

Figure 10 ASC Corporate Inconsistency in Implementation Reporting

4.3 Characteristics of the Three Groups of Organizations

Within each of the three groups identified in Figure 8, there are similar beliefs and behaviors that characterize each. These similarities involve the level of understanding of the value of systems architectures within acquisition programs, the amount of exposure in terms of training and education in systems architectures, and the DoDAF in particular, and the different regulatory requirements levied upon them. Further, organizations/systems grouped within each category also often shared general acquisition program characteristics such as location in the acquisition development cycle (i.e. pre-Milestone A, Milestone B, Sustainment, etc.). Each grouping is described below with a general explanation of the characteristics of the organizations in the group.

Organizations in the "No Architecture Work" Category

Organizations in "No Architecture Work in Organization" category are most generally characterized as being legacy platforms operating under existing Operational Requirements Documents, as opposed to the newer JCIDS and DoD 5000 series operating instructions. Organizations such as the Long Range Strike Wing with the B-1, B-2, and B-52, the Fighter Attack Wing with the F-15 and F-16, the Training Group with the T-1, T-6, and T-38, and the Special Operations Forces Group with their C-130 variants all have systems predominantly in sustainment phase of development. Further, these programs have capability "roadmaps" in lieu of integrated architectures to address future development options. Also, the personnel assigned have virtually no training or experience with the DoDAF.

Organizations in the "Some Architecture Work" Category

Organizations in "No Architecture Work in Organization" category are characterized by new acquisition policy driving production of architecture views, architecture products created simply as an output of good systems engineering practice, and, at least in one case, a Major Command (MAJCOM) emphasis on integrated architectures. These organizations create architecture products, in most cases, because they are required to manage information flows. This is perhaps an indication of how architectures could become a part of the weapon systems acquisition process. Program office personnel who otherwise may not have taken an interest in the DoDAF will gain exposure because of necessity. The other two cases, organizations with above average systems engineering practices and the MAJCOM driven architecture efforts represent special cases within this group.

In terms of the new acquisition policies, JCIDS, ISP, and NR-KPP requirements have lead some organizations to the creation of architecture products. The B-1 Fully Integrated Data Link, B-2 Radar Modernization Program, and the Personnel Recovery Vehicle programs all created DoDAF products as a result of an approaching milestone decision review. In this instance, the views were created by in-house personnel (either government employees or support contractors) with limited training which included the DAU Systems Architectures course, SYS 283, training on the Popkin System Architect tool, and DoDAF training through the Air Force Chief Architect's office.

A second group driven by regulatory requirements involves programs creating ISPs and the need to address NR-KPP requirements. The F-16 Link 16 program is facing testing through the Joint Interoperability Testing Center, which requires the production of an ISP, which in turn requires the production of architecture products. Further, the C-17 program has taken an even stranger trip to arrive at the need for architecture products. As a result of a recent Unit Compliance Inspection, the program was found to be lacking a Program Protection Plan (PPP). The PPP requires an ISP as an annex. And, of course, the ISP requires several DoDAF views. Although one respondent stated, "In order to meet these (documentation requirements), you need to understand the architecture", the views are predominantly created by contractors as the government personnel had no exposure to the DoDAF. It is interesting to note that the programs facing a milestone turned to in-house personnel to create the architecture products, while those facing ISP requirements outsourced the creation of the documents.

Two special cases are included in this group: organizations that create architectures as a part of good systems engineering practice, and organizations working together with their MAJCOM on integrated architectures. Organizations in the first category include the Global Mobility Wing, the Joint Strike Fighter avionics organization, and the F/A-22 program. These organizations are not necessarily driven by JCIDS, but have been performing systems engineering with a great deal of rigor and would be able to produce DoDAF products simply as a byproduct. Finally, the other organization in this category enjoys a relationship with their MAJCOM where the MAJCOM emphasizes integrated architectures. The Air Mobility Command drives Global Mobility Wing efforts through architecture products created in their A-6 organization.

Organizations in the "A Great Deal of Architecture Work" Category

Organizations in "Great Deal of Architecture Work in Organization" category are characterized by an emphasis on future systems/capabilities, having embraced the benefits of systems architecting, and having personnel with significant experience in systems engineering, and to some extent, trained in the DoDAF. ASC can be generally characterized as having many programs that have been in development for a long time (F-15, B-52, C-130, and even the F/A-22). However, the truly new capabilities and systems that are coming into ASC for development include the Airborne Electronic Attack (AEA) capability and the Tanker Modernization Squadron. These capabilities/systems originate in ASC with the ASC/XR Capabilities Planning organization. ASC/XR also deploys personnel throughout the Wings and DRGs as liaisons for introducing new development efforts. Certainly these organizations have a regulatory reason to perform system architecting, however, they have also simply embraced the benefits of systems architecting to acquisitions. They are not alone however, as the B-2 Group has also bought into the positive aspects of systems architecting within their organization – and further, the use of the DoDAF. All of the organizations in this group are characterized by personnel having significant experience in systems engineering, and to some extent, trained in the DoDAF.

The three groupings and the information underlying the placement of each organization within the groups lead to five significant findings. The first four relate directly to the research question and objective – what is the state of DoDAF system architecture implementation within ASC. The last finding, although not directly answering the research question, is closely related; dealing with the transition from system oriented to capability-based weapon system acquisition processes within ASC. These findings are described below.

4.4 Findings

The data collection and analysis process lead the recognition of five findings:

1. ASC organizations are not doing much architecture work "corporately".

2. If the organization isn't developing a new capability or doesn't have an 'X' in their office symbol, they are not likely doing any architecture work.

3. There is no consensus among ASC personnel as to the benefit of systems architectures to acquisition program management.

4. The leadership and organizations attempting to instill an architectural mindset in ASC programs are not succeeding.

5. The transformation to a capabilities-based weapon system acquisition process is not complete.

Each finding is detailed below with a general description followed by representative comments from interviewees.

Finding One: ASC organizations are not doing much architecture work "corporately".

Six of the seven Wings/DRGs (or 85.7%) are only doing "Some" or "No" architecture work. There is no high-level acceptance of system architectures, as indicated through interviews with the Commander's Program Execution Group as well as the senior leaders of each of the Wings and DRGs. Although the senior leaders interviewed indicated little to no architecture work ongoing, there were cases where organizations or programs within the corporate organization were creating architecture products due to regulatory or other requirements (recall the Long Range Strike Wing example in Figure 10). Many organizations are contracting for their architecture development because they felt the expertise/knowledge/experience is not resident in ASC organically.

Comments representative of this finding include:

- "The Center is not really taking advantage of architectures".

- "Lack of architecting work has a lot to do with the work and how it gets to ASC". That is, in platform chunks via Program Management Directives – the old acquisition standby: funding and requirements.

- One interviewee identified the lack of implementation as essentially "pragmatism", believing program office personnel have distinct direction (funding and requirements again), which are difficult enough to achieve without the additional burden of systems architecting.

- Most of systems engineering work is done by contractors…"we have no one left in ASC to do it".

Finding Two: If the organization isn't developing a new capability or doesn't have an 'X' in their office symbol, they are not likely doing any architecture work.

This finding involves two groups – those with an 'X' in their office symbol (ASC/XR and the Wing/DG XR offices) and the rest of ASC. The 'rest' of ASC is predominantly described above in Finding One. The organizations with an 'X' in their office symbol are focused on new capabilities and systems development. However, even within this group, members still lack the training and experience to use their architecture products as a systems engineering and capability-based analysis decision-making tool. Within those who do make use of architectures, there are three groups. The first, group includes organizations working on new systems and either required to under JCIDS documentation requirements or see the value added (XRs, new programs like AEA and Tanker Modernization). The second, and most exclusive group is those who create the products (or more appropriately, could create the products if required) as a result of rigorous application of systems engineering practices (Global Recon Wing, etc.). And finally, the largest group of organizations that make use of architectures are those directed to (programs/organizations such as the C-17, B-2 RMP, and F-16 Link).

The organizations making use of the architectures due to seeing the value added are described in greater detail later in this chapter. Specifically, the AEA, Tanker Modernization Squadron, and B-2 Group are highlighted as Success Stories. Details pertaining to these organizations are included later. However, below are representative comments dealing with the rationale behind the organizations without the ’X’ in their office symbols are not using architectures.

- “Can’t very well change the architecture of a legacy system”.

- Bottom Line: “Putting these requirements on sustainment systems is a waste”.

- Program managers are too busy putting “rubber on the ramp”.

Finding Three: There is no consensus among ASC personnel as to the benefit of systems architectures to acquisition program management.

It is clear from the respondents there is no consensus as to the value of systems architecting within acquisition program offices, at least as far as ASC is concerned. There are some that see them as a benefit in terms of a tool in the system engineer’s toolbox. While others believe program offices are not the real users of the architecture products. Still others believe the products and process are too complex. Finally, there are many who believe there are issues with the products themselves.

For those who see system architectures as a benefit in terms of as a tool in the system engineer’s toolbox, representative comments include:

- Architectures are a good communications tool to HQ (the people who integrate systems).

- The Systems and Technical Views are what provide value to program offices.

- The TV-1 is an important product that establishes the standards with which the rest of development work will be based upon.

- These products would really benefit complicated commands like Air Combat Command and Special Operations Command, where complex interactions and connectivity are the norm.

The organizations who believe program offices are not the users of the architecture products, had this to say:

- The concept (systems architectures) exists at an Air Force level such that it has not resulted in funding and requirements outside platforms. In other words, the program offices are given a program to execute and the architectures should be included when the acquisition effort starts.

- A lot of this stuff is “too high level”.

- There is “No advocacy at worker-bee level in SPO for architectures”.

- Acquisition personnel need good examples; a “poster child”.

The third sub-finding dealing with a lack of consensus within ASC revolves around a belief that the products and process of systems architecting are too complex. Comments in support of this belief include:

- Architecture products are “Complex, time-consuming, and expensive”.

- They are “labor and intellect-intensive matters”.

- There is a danger in creating something so “cumbersome” that it is too abstract in the mainstream of the management of the program.

And the final sub-finding in this area deals with what respondents consider issues with the DoDAF products themselves. Representative comments include:

- The “views are not well defined”.

- “See a lot of people running around creating products that are not really integrated”.

- Many products lack description of timing and latency.

- We need a consistent approach for the implementation of the views into the modeling and simulation environments. Specifically, they need to be translated into dynamic system-of-system operations research models and we have to be able to tie OVs & SVs together into an executable models that are good for management and operational assessments (trade-offs, impacts, what ifs, etc.).

Finding Four: The leadership and organizations attempting to instill an architectural mindset are not succeeding.

This finding deals with attempts by the leadership and organizations who are attempting to instill an architectural mindset. According to the interviewees, these organizations and leaders are not succeeding. Comments in support of this assessment include:

- “Death by viewgraph” or, “in the ether frequently”. There is a belief that these organizations are really good at putting together Power Point presentations, but that the material is over the audiences heads.

- With respect to the position of ASC Chief Architect; most interviewees didn’t know who the Chief Architect was – and, in some cases, that ASC even had one.

- The ASC/XR (Capabilities Planning Division) plays a leading role in capabilities-based analysis and planning (with architectural pieces to both), but interviewees believed they may not have ability to do what we need to have done with respect to systems of systems development planning; specifically the trades, etc. that keep the product center from getting user-directed solutions.

- Finally, the ASC Program Management home office, ASC/PM and the ASC Engineering home office, ASC/EN, have responsibilities to train and equip the program managers and engineers that populate the program offices. With respect to systems architectures, there is no formal training program for program managers and engineers.

  -- Engineers can volunteer for a systems engineering certification program through the Air Force Institute of Technology that includes a course on systems architecting. However, they self-nominate themselves (i.e. there is no selection and nomination process), there are no positions within ASC that are identified as requiring this certification, and, at least in the past year (2004), there were only four engineers participating in the program.

Finding Five: The transformation to a capabilities-based weapon system acquisition process is not complete.

The previous four findings dealt directly with the research topic of investigating the state of systems architecting within ASC. This last finding, although no less significant in terms of voracity (as it was apparent from the number of interviewees who shared this belief that it was worth reporting), does not tie directly into the research objective. It deals with the adoption of a capability-based acquisition process within ASC. This shift from requirements- and platform-based acquisition is fundamental to the new JCIDS process and therefore subject to similar growing pains in terms of integration into the standard mode of operation as is systems architectures. Indeed the two concepts appear to be following similar paths, at least up to this point within ASC. Comments that elucidate this finding are below.

- "I have a user that doesn't know what a capability is – they want a system".

- Net-centricity and capabilities-based development has not found its way into the infrastructure.

- With respect to the notion of a 'Capability Manager (CM)' where the CM allocates requirement to system; system responsible to make trade-offs to meet multiple capabilities; some thought that this was a dangerous concept if they are not responsible to deliver anything.

- Also, there was concern about the way we manage capabilities/programs?

    -- Bottom-Up (systems perspective) to fill capability gaps, or

    -- Top-Down (capabilities-wise) with multiple systems to meet capability needs?

These findings represent the complete results of the analysis performed of the data collected during this study. Four of the findings provide direct support for answering the research questions, while the fifth provides useful commentary on an ancillary and related topic. Although the tone of the findings presented indicated a lack of architecture work within the product center, there are some who are making it work. Specifically, the AEA, B-2 Group, and Tanker Modernization Squadrons would have to be considered success stories in terms of adopting systems architecture, and the DoDAF mindset.

4.5 Success Stories

While collecting data for this study, three organizations stood out as having successfully applied systems architecture within their sphere of weapon system development. These organizations arrived at their acceptance of architectures, and the DoDAF, in different manners, but all represent the leading edge in terms of architectural integration. AEA is a capability that is being managed as such. The Capability Manager believes systems architectures are vital to the success of a capability management effort. The B-2 Group first encountered architectures as part of a milestone preparation exercise for the Radar Modernization Program, but have since found the DoDAF to be a continued useful tool. Finally, the Tanker Modernization Squadron also started off without the aid of system architectures, but eventually was directed to take a capability delivery approach. Each of these is discussed further.

Airborne Electronic Attack (AEA)

As mentioned above, AEA is not a single program, but rather a capability. At this point, the organization is 'prototyping' the Capability Management concept. The AEA Capability Manager (CM) actually has his own Program Element which allows control of the funding for all aspects of providing this capability. The CM provides funding and requirements to the appropriate Wings/DRGs. The AEA capability is intended to provide support to strike forces, initially in a high threat/limited access environment. The AEA architecture contains multiple systems including the B-52, E-18, and the Joint Unmanned Combat Aerial System (J-UCAS). In fact, the CM believes that "architectures are key to successful capability management".

B-2 Group

The B-2 Group within the Long Range Strike Wing took a unique path to full systems architecture acceptance. Initially the B-2 Group faced a Milestone B decision for the B-2 Radar Modernization Program (RMP). Since Milestone B requires the creation of a CDD, the program office was required to create architecture views. However, during the effort of creating the products for the CDD, the effort blossomed into a B-2 enterprise-wide architecture effort.

The program office personnel realized the value to the program of adopting architectural methodology, and specifically believed it would be faster to do it right (following DoDAF) than to fight it --- and their key is speed. The Group sees architectures as a "lingua franca to go from operational requirements to systems specifications" and maintain information consistency. They hope to develop a consistent lexicon of speech from requirements through implementation. Another positive aspect of the B-2 Group's architectural implementation is their cooperation with the MAJCOM customer. They are working hand-in-hand with ACC/DRA2 (the B-2 requirements office), who buys in to the value of architectures as well.

Tanker Modernization Squadron

The Tanker Modernization Squadron within the Global Mobility Wing is a pre-Milestone B capability development organization looking into replacing the aging fleet of KC-135 air refueling aircraft. This effort began originally as KC-767 Program (the infamous) Tanker Lease program. At the early stages, any architecture work completed by the people in the program was essentially "square-filling". However, when the program was “paused” for political reasons, the program office regrouped and began looking at the requirement from a capability perspective. They were initially driven to architectures by interoperability and information assurance concerns, but have embraced architectures as a capability development tool. Just as the B-2 Group, the Tanker Modernization Squadron is doing it right – working with the MAJCOM on capability-based development; AMC has contracted for the development of the Tanker-X CDD. Both the MAJCOM and the Tanker Modernization Squadron believe this early involvement, coupled with the use of systems architectures, provides an “opportunity to get on top of requirements generation process.”

These three organizations, along with the XR organizations represent the cutting edge of architectural implementation within ASC. They represent the exception, however, not the rule. As mentioned earlier, 87% of the Wings/DRGs reported only some or no architecture work. The data collected in this study lead to the additional findings that there is no consensus within ASC on the value of systems architecting and the leadership attempting to incorporate architectures into ASC acquisitions is not succeeding. Further, the interviewees indicated an additional finding concerning the slow pace of the transformation to effective capabilities-based acquisition. The JCIDS process is intended to create this process, and systems architectures are intended to aid in the execution of this process. Unfortunately at this point, despite the regulatory requirements to create architecture products, the program managers and engineers within ASC are not reaping the intended benefits of systems architectures within their programs.

5. Conclusions and Recommendations

5.1 Overview

This study examined the level to which ASC has implemented systems architectures within their weapon systems development efforts. The literature indicates there are real benefits to be had for acquisition program office personnel. In addition, guidance has been instituted calling for the use of system architectures, specifically the DoDAF products. Despite the benefits and the guidance, there are roadblocks to the successful implementation within ASC. Based on a robust data collection and analysis methodology, five critical findings were identified. These findings provide the justification for the two conclusions outlined below.

5.2 Conclusions

Recall the specific research question this study set out to answer, How are systems architectures, and the DoDAF specifically, being implemented "in the trenches" of USAF weapons systems acquisitions? This study focused the investigation in answering this question on ASC. The data collected point to two conclusions.

1. While programs required to follow new acquisition processes are doing so, very few are employing systems architectures systematically.

2. At this point, at least within ASC, the benefits derived from an architectural context are not yet being realized.

5.3 Recommendations

The findings provide evidence for the following recommendations offered in satisfaction of the research objective. There are recommendations for ASC, for the DoDAF Working Group, and for the systems engineering community in general. Ultimately, these groups should determine the goal of incorporating systems architectures within weapon systems acquisitions and the follow-up with a level of commitment to back up the decision.

1. Lead by the ASC Chief Architect, ASC leadership should clearly determine goals for systems architecting. For instance, if it is a valuable tool that every Wing and DRG should have in their toolkit, then the Chief Architect should come up with architecture standards and then publicize/indoctrinate the program managers and engineers within the center. And the chief engineers within each Wing and DRG (spearheaded by ASC/EN) should take lead in developing architectural mindset within organization. These organizations should also act as conduit to make the high-level (often esoteric) guidance relevant to program office personnel concerned with cost/schedule/performance.

2. The ASC architectural leadership should select an exemplar case as a practical example of how systems architectures can be applied to capability management. This would provide other program offices the example many are clamoring for. Further, a more comprehensive training program should be instituted within the center starting at the "See Dick create an architecture" level. Several training opportunities already exist: AFIT SENG 640 course, DAU SYS 283 course, Aerospace

Corporation Systems Arch. Course, etc. The leadership should continue the current practice of using ASC Focus Week as means of "getting the word out".

3. The Architecture Working Group (AWG) should incorporate these findings to improve DoDAF Version 2.0 products in support of capabilities-based acquisition. The data collected and presented in this study are intended to aid them in making the DoDAF more of a tool for acquisition program office personnel. One imperative is for the AWG to make the case for architectures as systems engineering and program management tool. Capture the examples of successful implementation, AEA/B-2/Tanker Replacement within ASC – but also any others from other product centers or services for that matter, as case studies with practical examples for others to follow. Together with the systems engineering community in general, find some way to address issues raised in Finding #3 above concerning the products themselves; timing and latency, how to address complex, dynamic systems/capabilities with static views.

4. The systems engineering community (SAF/AQ, ASC/EN, Chief Engineers, CSE, OSD/OSSE) should also develop/integrate a syntax and methodology for DoDAF views to be made executable. This effort should be more than just to determine if the architectures will work, but to allow for the development of measures of performance in order to compare architectures to one another for tradeoff purposes. It is this ability, to dynamically simulate a proposed architecture and evaluate the measures of effectiveness output, which provides the ultimate value to capability-based weapon systems acquisition efforts.

5.4 Recommendations for Further Study

During the course of this study, several additional areas of interest were identified, where further study could be of value to decision-makers. An obvious extension of this study is to evaluate the other Air Force product centers – and even investigate the state of architectural implementation within the other services acquisition programs. As previously mentioned, the success stories within ASC should be studied in greater detail in order to produce case studies that could serve as justification for the skeptical and a notional 'how-to' for those looking for an example to follow. Also a recurring theme throughout this study is the call for executable architectures. Efforts should be made in the engineering and research communities to develop techniques for the dynamic analysis of architectural products. Two additional recommended areas of study are capability management as a construct and the Air Force Materiel Command reorganization. Both areas are in their infancy, in that they are recent changes to the way of doing business, however careful study as these concepts mature would benefit Air Force acquisitions.

The first recommendation, in terms of additional study, is to reproduce this study at other product centers to determine if ASC is out front of the systems architecture implementation curve. How are the other centers, Air Armament Center (AAC), Electronic Systems Center (ESC), and Space and Missile Systems Center (SMC) coming along in their implementation of systems architectures within acquisition program management? It would seem notionally that ESC would be in front due to their exposure to the CAF since 1996, but is that the case? Also, SMC follows the space-specific guidance of the *NSS 03*-01, which calls for architecture products as part of process; but how are they doing?

The acquisition community would greatly benefit from case studies documenting successful lessons learned concerning system architectures. Specifically, an AEA Capability Management Case Study would have value no matter how successful this foray into capability management is. If it works and the capability is delivered to the warfighter in a timely and cost-effective manner, this could be a model for other "capability management" scenarios to follow. If it doesn't work, then the focus of the case study could be "how could such a seemingly good idea fail?" In either case, the DoD is moving towards a capability-based development system, and as the Air Force's first true capability management effort, AEA bears close study.

The need to evaluate methods to make the DoDAF views executable has been identified repeatedly in this study. There are tools, such as VITECH's CORE that allow the system engineer to "run" the architecture. However, at this point, this analysis only provides the answer to the question, "does the architecture modeled work"? This is truly an important question, as it is much better to find that the design is missing key interactions in a modeling arena as opposed to when you have built hardware and are testing. The next step, however is the ability to measure how well each architecture performs, not just that it works.

Closely related to the study of the AEA capability management effort would be to further explore the idea of Capability Management altogether. For instance, what exactly constitutes capability management? What differentiates between program management and capability management competencies? Further, who are capability managers; what training/experience/knowledge are required? Where do they fit organizationally (product center, AFMC headquarters, MAJCOMs, USAF CONOPs)? What about funding and control of schedules to synchronize capability releases? This is an area ripe for study. Perhaps investigating how similar efforts are done in industry.

– The final recommendation for additional study would be to evaluate the effectiveness of AFMC reorganization. This is a recent change to how AFMC does business and was done to accomplish specific goals. The study could be a case study investigating the pros and cons of Wing/Group/Squadron organization, measuring progress against the stated goals of the reorganization effort. Does this structure really make it easier to relate to customer? Does the new structure increase cross-enterprise integration? ASC is the first product center to implement this reorganization, but the other AFMC product centers are also reorganizing this way.

ASC is, as part of the overall DoD acquisition transformation effort, in a period of change. The aim is for a more top-down, capabilities-based weapon system process where all services developed by each service interact to produce the effects combatant commanders require to meet the national security objectives. The DoDAF provides a proposed framework for the development of architectural products in support of the kind of analysis required to make this vision happen. However, at least at this point in ASC, the architectures have not been integrated into the everyday operations of the acquisition program office personnel charged with managing the development of new capabilities.

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Vita

Captain Chad Millette graduated from the University of Arizona with a B.S. in Mathematics and was commissioned an officer in the United States Air Force in August 1995. Following an operational experience tour as an intelligence officer, Captain Millette became an acquisitions officer assigned to the Headquarters Air Force Office of Special Investigations (HQ AFOSI). During this assignment, he completed Squadron Officer School. His next assignment was as the Program Manager for the Advanced Strategic and Tactical Infrared Expendables, or ASTE, program at the Aeronautical Systems Center (ASC). His performance in this assignment led the program director to select him as her Executive Officer. It is from this assignment Captain Millette arrived at AFIT. After graduation, Captain Millette will be heading to Los Angeles Air Force Base to work in the Software Integration Division of the Space-Based Infrared Radar System (SBIRS) Program Office.

Captain Millette is married and the father of twin boys. He is also a diehard Red Sox and Patriots fan – facts that made studying during the 2003 – 2005 timeframe problematic (2 Patriots Super Bowl wins and the 2004 Red Sox World Series victory).

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14. ABSTRACT
The purpose of this research was to identify the current status of the use of the Department of Defense Architecture Framework (DoDAF) systems architecture products within the Aeronautical Systems Center (ASC) program offices. There are regulatory requirements dictating the creation of DoDAF products as annexes to programmatic documentation, such as the Joint Capabilities Integration Development System (JCIDS) requirement for systems architectures as annexes for acquisition milestone decision documentation. In addition, the DoDAF itself identifies several products as being highly applicable for the development of acquisition strategies. The research issue was to investigate the use or systems architectures, and particularly the DoDAF products, within the context of Air Force weapon systems acquisitions, as represented by ASC.

The research indicated two conclusions: while programs required to follow the new acquisition processes are doing so, very few are employing systems architectures systematically, and at this point, at least within ASC, the benefits to acquisition program management personnel derived from an architectural context are not yet being realized. These conclusions result in several recommendations to ASC, the DoDAF Working Group, and the systems engineering community in general as to how to make systems architectures more a way of doing business within Air Force weapon system acquisitions efforts.

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