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The Impact of Enterprise Architecture Strategy on Realizing End-to-End Condition Based Maintenance-Plus

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Abstract

Realizing End-to-End capabilities such as Condition Based Maintenance-Plus (CBM+) using the DoD's acquisition process presents significant challenges that need to be overcome. Acquisition of new capabilities, especially non-Programs of Records (PoR), has become more difficult to demonstrate and field based on a set of complex factors which include unique and special build requirements, more options for components, cost and schedule constraints, and quality risks of unprecedented systems. In this paper, we document the process on how Enterprise Architecture (EA) methodologies can be effectively used to incorporate critical structures within the Systems Engineering Process to streamline the requirements and architectures development for a non-PoRs. We then explore the dimensions of strategic planning, testing, and data collection that are needed to determine basis of issue requirements and Capability Set Architectures from EA methodologies. We conclude by presenting the results from the EA methodology integration into the Department of Defense Architecture Framework views for the CBM+ Communication Architectures.

Introduction

To many DoD Program Managers, the Systems Engineering (SE) process is perceived as a long, cumbersome, not well-understood, and sometimes unnecessary element of the DoD acquisition process that is usually the first program element to be marginalized. When Army programs do implement SE processes, they are usually hurried and incomplete, generating results that are anything but reliable and even less repeatable, if they are incorporated into the program at all. Desired capabilities are usually not supported by operational requirements from the user or program advocate leading to the system requirements to be fragmented, leaving their impact to other dependent systems to never be realized. Design architecture is usually neglected since the detailed expectations are not well documented nor is a program enforced to develop a "build-to" architecture. Most Program Managers bypass the development of these "design-to" architectures and expect "build-to", implementation, and Capability Set architectures to be developed before they are given a requirement list or Capability Document.

Changes and initiatives that have been implemented to a program cannot easily be verified, validated, or measured against capability requirements in order to determine if they are being implemented successfully and correctly. When technologies do make it through fabrication and to fielding, the new equipment frequently does not meet the soldiers' present needs nor does it integrate / interoperate with existing systems. DoD Program Managers must have the flexibility to succeed while complying to the DoD's acquisition process. The best way to do this is to supplement the current SE process with best practices and lessons learned from each of the major areas of the Systems Engineering VEE and through a more stringent use of EA methodologies of the DoDAF or Zachman Frameworks to achieve goals such as Agility through Design and Security through Data Governance.

Background

The Army's Conditions Based Maintenance-Plus (CBM+) program is now over ten years old and has been a critical initiative for DoD Programs of Record (PoRs) to incorporate with other maintenance constructs in an optimal maintenance approach. Program Managers and leadership for the CBM+ initiative understand the value of a comprehensive SE process, but also realize the constraints to resources and schedule for realization. The CBM+ Communication Systems Architecture (CCSA) provides a complete representation of how the Army systems takes a proactive approach to ensure equipment endures preventive maintenance techniques. In order to successfully achieve Warfighter missions, it is an Army priority to provide Warfighters with the most readily and sustainable equipment available. The CCSA lays out the communication systems, such as Combat Service Support (CSS) Automated Information Systems Interface/ Very Small Aperture Terminal (CAISI/VSAT), necessary to transmit logistics data from weapon systems, such as the Abram tanks and Stryker fleet, in the field to the enterprise. In addition, the CCSA illustrates the pathways of multiple maintenance data categories moving across the tactical network which will then be analyzed. Proactive and preventive maintenance techniques provide an accurate picture to the Warfighter of the operational status and an understanding of the lifecycle of the equipment. Since CBM+ is part of the Army Logistics Modernization effort, it is critical to fully utilize the CCSA capacity to upkeep the Army's overarching Logistics Architecture.

Many Army PoRs are being realigned to address Systems of Systems (SoS) concerns presented by an overarching capability such as CBM+. To provide the CBM+ stakeholders (i.e., LCMCs, PoRS) an initial set of capabilities or operational requirements, the CBM+ project has been developing Enterprise Architecture (EA) methodologies that address integration concerns. A new capability engineering process to upgrade SoS is necessary to realize the DoD SoS Engineering Process.

Systems of System Engineering recognizes key challenges to realize an overarching capability such as CBM+. Key changes in the traditional SE process identified by J. S. Dahmann, Rebovich, and Lane (2008) are viewing a system form a capability perspective, to orchestrate upgrades for multiple systems concurrently, and understanding the impact of emergent behavior on individual systems. To address the gaps in the traditional Systems Engineering (SE) process, the CBM+ project is developing requirements management process to enable the implementation of CBM+ solutions across Army platforms. Acquisition of new capabilities, especially non-PoRs has become more difficult to demonstrate and field based on a set of complex factors which include unique and special build requirements, more options for components, cost and schedule constraints, and quality risks of unprecedented systems.

Enterprise Architecture (EA) can provide many benefits to CBM+ such as: a holistic approach for the successful development and execution of strategy; best practices in organizational design, project portfolio management, requirements engineering, and systems design that are tailorable to the enterprise's needs; tools to integrate critical functionality across multiple programs of record. Most importantly, EA engages stakeholders to ask the necessary questions such as: "Why are we implementing this solution?" or "What are the potential consequences of these decisions?"

CBM+ Systems Engineering Processes

DoD PoRs must conform to the Joint Capabilities Integration and Development System (JCIDS) process, which includes the SE process, for the acquisition of a new capability, hence leaving PMs no choice but to undertake the cumbersome process. Under the JCIDS process, DoD PoRs require the development of Capability Documents. Capability Documents usually lay out the information for the Design Processes and a plan to implement the Realization Processes. Through the development of these Capability Documents, the SE process is usually undertaken to develop or derive the information necessary. The development of these Capability Documents usually takes a considerable amount of time (approx. 12-24 months for delivery). Non-PoRs usually aren't afforded this timeframe and are not mandated to have these Capability Documents, hence they are not usually incorporated into the schedule and development. Some non-PoRs may try to follow this process, but tend to burn out since they are not afforded the same resources and information as PoRs.

The SE Process has been traditionally represented using a VEE model. Figure 1 shows the Systems Engineering Process which is broken into Design (Blue) and Realization (Green) Processes. The SE Process usually is followed throughout the lifetime of a PoR.

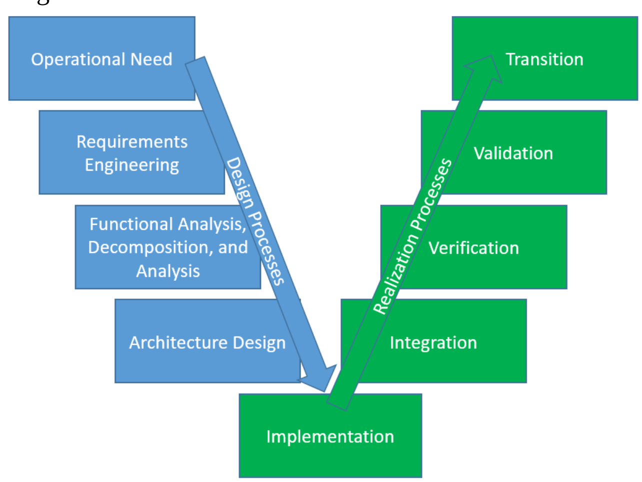

Figure 1: Systems Engineering Process (VEE Model). The VEE Model depicts the lifecycle of a single system.

Operational Needs and Requirements Development

An Operational Needs Statement (ONS, JUONS) is the usual driver for the development of requirements, Department of Defense Architecture Framework (DoDAF) architecture, and their respective Capability Documents. A Concept of Operations (CONOPS) is developed to determine the intent of the solution to be developed. While developing the CONOPS, a set of operational requirements begin to be developed to outline the user's needs in terms of thresholds. For example, a soldier may need to destroy a tank a mile away and doesn't have a current capability to handle the target. Operational architects then determine the necessary and mandatory Key Performance Parameters (KPP) (i.e. Net Ready, Sustainment, etc…) the system would consider to get a better understanding of the scrutiny behind the system that would be necessary. This is usually when the Capability Document writing portion is started such that the necessary information can be integrated in throughout the process.

Figure 2: Requirements Process

The Requirements Engineer would develop a System Requirement Specification based off the CONOPS and operational requirements. These system requirements will lay the foundation on the metrics that the systems must perform to determine if a solution is feasible. Key System Attributes (KSAs) are developed to better understand the system. For example, Transportability of the system to the field doesn't fall under a mandatory KPP (i.e. Net-Ready, Sustainment, etc.), but could be pivotal to the program if the solution cannot be delivered to a remote area. These are critical attributes that can be traded when choosing between alternatives, but not necessarily on the level of a program killer if a certain set of KPPs are not met.

The Requirements Engineer would assist with the development of the High-Level Design Requirements, the Detailed Design Requirements, and the Hardware and Software Requirements, if these are deemed necessary, but the responsibility of depicting this information would fall on the Operational and Systems Architects in the DoDAF products. The DoDAF products would still have to be described in the Capability Document and that responsibility will still fall on the Requirements Engineers writing the Document.

Enterprise Architecture Strategy to Realize CBM+

Operational Architects develop Use Cases based off the CONOPs on who would be involved with the systems and the appropriate tasks (i.e. Universal Joint Task List (UJTLs)) that the soldiers would have to perform to achieve the mission. For the CBM+ program, Use Cases were developed to represent the location of where the data would rest. For example, in Figure 3, the transmission of CBM+ data across DoD assets and networks, are categorized by their respective "swimlanes" of Platform, At-System, Tactical, and the Enterprise.

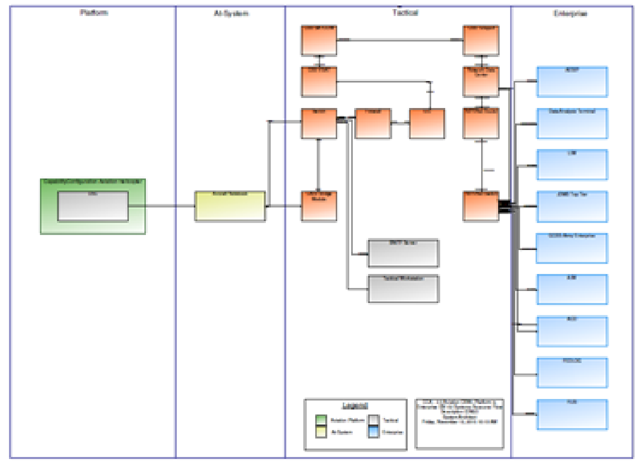

Figure 3: CBM+ Use Case for Parametric and Engineering Data from the Platform to the Enterprise Logistics Systems

Once these Use Cases are completed, the operational architects have the majority of the information necessary to build the corresponding Capability (CV) and Operational (OV) Viewpoints. Operational architects hand off the UONS/JUONS, CONOPS, Operational Requirements, CV and OV products, along with the written portion of the Capability Document to the System Architects for system determination and functionality to achieve the operations. The DoDAF Development Iterative Process is depicted in Figure 4.

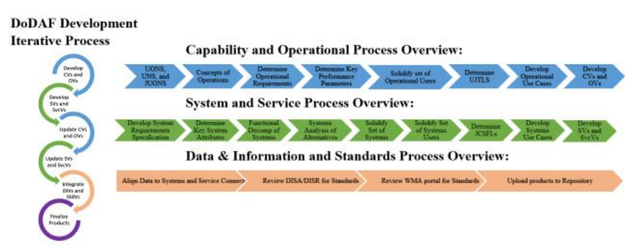

Figure 4: DoDAF Development Approach for CBM+

System Architects develop a Functional Decomposition of the Systems and its Systems Requirements Specification is performed to understand the real need when determining if a solution is meeting specific requirements. System Architects also develop an Analysis of Alternatives of

Systems to determine the appropriate solution based on production timeframe, costs, functionality, and expected thresholds and performance metrics to be achieved by the systems. Once a solution is chosen, system architects develop their system level use cases that will achieve the operational level use cases. These system level use cases require an understanding of the soldiers and units that will operate the system along with the functions (Joint Common System Function List (JCSFLs)) that these systems and soldiers or units could be expected to perform. The result should give systems architects all the information necessary to develop the System (SV) and Service (SvcV) Viewpoints. The System Architects work with the Operational Architects to review the entire set of architecture products to determine if the operational and system perspectives are in alignment. Data and Information views (DIV) and Standards Views (StdV) are incorporated if the Capability Document calls for it and the solution is at the advanced level for the incorporation of these products. An example of the CBM+ DIV-2 is shown in **Figure 5.**

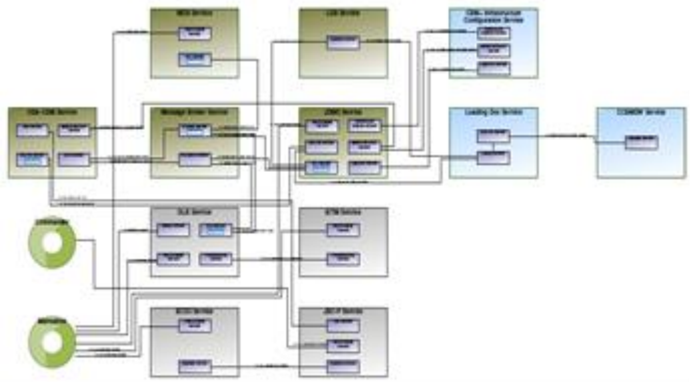

Figure 5: CBM+ Logical Model - DoDAF Data and Information View 2

DoDAF products, which support the program's information needs, along with the Capability Document are updated and then submitted to the Joint Requirements Oversight Council (JROC) for approval or changes. While the Capability Document is being reviewed, testing and verification and validation activities occurs on the system such that it can be ready for design and production once approval is met.

Traditionally, DoDAF products have been perceived as ancillary support to mandatory capability documents, such as the Initial Capability Document (ICD), Capability Development Document (CDD), Information Systems Capability Development Document (IS CDD), and the Capability Production Document (CPD). However, with DoDAF 2.0, the products must provide the core data necessary to define the capability requirements and to implement the capability. A key gap in DoDAF 2.0 has been the disconnect between specialty disciplines. The Unified Architecture Framework will associate results from specialty disciplines with the capability architecture.

A few variables go into the decision of determining which Capability Document to write such as ACAT-level, joint interest among the services, information system or standalone product, and the stage of production, to name just a few. DoDAF products should be developed with the knowledge of which stage and capability document that will be developed. DoDAF architecture should lay out the functional requirements and operational needs such that a portfolio of solutions could be selected to provide an acceptable solution to a user group. For example, if there exists a system requirement to provide a specific data transmission using a commercial satellite service, this function is mapped to a JCSFL function "Communicate Beyond Line-of-Sight (LOS) Wideband Commercial Satellite," a various set of potential solutions should be analyzed to determine if the solution can meet the set of requirements. It is critical to have a clear and thorough understanding of the JCIDS and/or Special Operations Forces Capabilities and Development System (SOFCIDS) processes.

Implementation, Testing, Verification, & Validation

Once the Project Managers deliver solutions to meet the soldier's requirements, these solutions must be formally tested within the field to see if they can deliver the capability and meet certain objectives and Use Case scenarios. The formal testing event within the Army is the Network Integration Evaluation (NIE) where soldiers can evaluate the technology solutions within the tactical communications network. "Beginning in fiscal 2016, NIEs will focus on testing and evaluation of network programs of record to continue to meet testing requirements and validate yearly capability sets for delivery, with other technologies assessed through annual Army Warfighter Assessment events." However, once a technology reaches the NIE testing stage, there is an expectation that the solution we will delivered in the following Capability Set. Many solutions are tested at NIEs each year, but most do not achieve the desired outcomes to be integrated into the field and have to wait for the following year's NIE to be tested again. In addition, "NIE is viewed as expensive, both to industry and to the defense budget, with no payoff." There has been a need for a pre-NIE type testing event where soldiers can use the technologies and give feedback to the developers to speed up the process of achieving the capability in the field while also reducing risk and cost. Further information on testing will be discussed in the CBM+ Architecture testing section.

Enterprise Architecture Methodologies and CBM+

Enterprise Architecture is based off the early works of John A. Zachman and his Zachman Architecture Framework (ZAF). The ZAF essentially addresses the questions of Who, What, Where, When, Why, and How of a problem from the perspectives from the varying stakeholders. The Department of Defense Architecture Framework (DoDAF) is similar to the Zachman Framework in that it has the same information within its views. However, the DoDAF organizes the core data for a capability according to a prescribed development sequence.

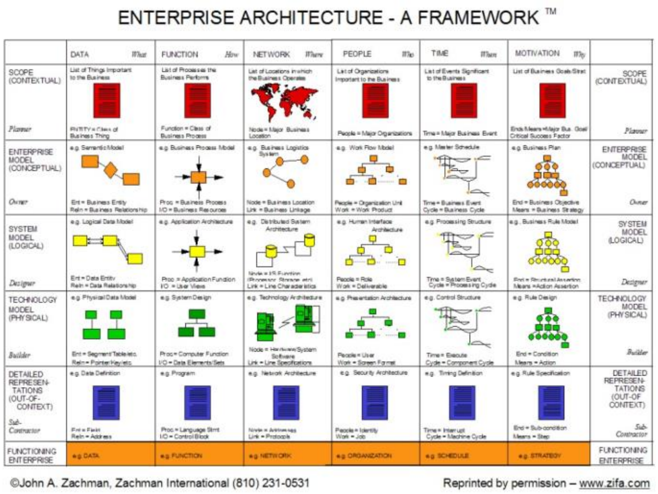

Figure 6: Zachman Framework

DoDAF Operational Views (OVs) answer the question of "Why", the System Views (SV) answer the question of "How", and the Data and Information Views (DIV) answer the question of "What." The left side of the matrix represents the key operational and system stakeholders involved the CBM+ Communications Architecture and CBM+ Communications System Architecture. A detailed trace between the information of the DoDAF view and Zachman Framework Matrix for the CBM+ program is shown below in Table 1.

	Condition Based Maintenance Plus (CBM+)					
	What	**How**	**Why**	**Where**	**Who**	**When**
	Data	**Function**	**Motivation**	**Network**	**People**	**Time**
Info	6 CBM+ Data Categories	Systems List & JCSFLs	Operational Needs Statement & AUTLs/UJTLs	Comms Network	Army Org Chart and Users	Use Case Sequence
Contextual Model	OV-1	SV-1, SV-2	OV-2	OV-1	OV-1	OV-1
Conceptual Model	DIV-1	SV-4	OV-3	SV-1, DIV-1	SV-2/OV-4	SV-1, OV-3
Logical Model	DIV-2	SV-5	OV-5, OV-7	SV-5, DIV-2	SV-5, OV-3	SV-5, OV-5
Physical Model	DIV-3	SV-6	OV-6	SV-6, DIV-3	SV-6, OV-6	SV-6, OV-6

Table 1: DoDAF & Zachman Framework Trace for CBM+ Program

In order to develop the Capability Documents, information from previous Capability Documents and Requirements must be investigated and integrated into a Requirements Repository software. Usually this is in the form of IBM Rational DOORs, but there are other software packages available such as Advance Concept Engineering's TestLink. The purpose of this is to trace related system requirements that have benchmarked in PoRs, such that they can be used as a baseline for non-PoRs that may not have a distinct set of operational or system-level requirements. These requirements will be critical for Testing, which will be discussed in the next section.

How Enterprise Architecture Drives CBM+ Testing

The CBM+ Communications Architecture (CCA) was initially tested using a Lab-Based Risk Reduction (LBRR) modeling and simulation (M&S) testing environment. The LBRR M&S testing environment allows for the generation of expected results without the high costs of live testing event. Once a solution achieves a certain expectation and threshold within the LBRR M&S testing environment, a Field-Based Risk Reduction (FBRR) event must occur for soldiers to use and evaluate the technology. The CCA utilizes C4ISR Ground Activity (CGA), a FBRR site, designed specifically for the assessment and validation of command, control, communications, computers, intelligence, surveillance and reconnaissance, or C4ISR, technologies on the network. CERDEC CGA differs fundamentally in purpose from the Network Integration Evaluation since engineers who helped build the network assist with the testing of technologies on the tactical network whereas NIE just gives a score at the end if objectives are met.

The CCA has been formally tested within the FBRR stage by soldiers in the Joint McGuire-Dix-Lakehurst CERDEC component. The CCA is currently being integrated into the Capability Sets since it will be critical to adapt the current practices of LBRR and FBRR testing environments to the CS NIE events. The design architectures (i.e. DoDAF) must be translated into implementation architectures within the Capability Set (C.S.) Architectures to be tested at NIE events. Each CS architecture is designed to be specific to a deployable Brigade Structure such as a Stryker Brigade Combat Team (SBCT) for a specific increment or year (i.e. CS FY 18 SBCT). Figure 7 illustrates how CBM+ Parametric and Engineering Data is transmitted from an Armored Brigade Combat Team (ABCT) battalion across DoD networks and Army assets at the Tactical and Enterprise-levels within the C.S. Architectures.

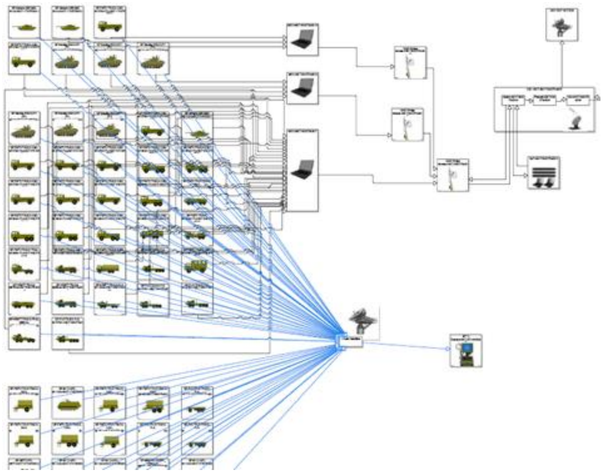

Figure 7: CBM+ Parametric and Engineering Data transmission from DoDAF views translated to Capability Set Architectures

Once these CS Architectures are finalized, the CCA and CS Architectures can be tested within NIE. Currently, by using current CCA testing events such as FBRR, technologies will be better prepared once they are integrated with other technologies to successfully complete a Use Case within the NIE event and can realize the soldiers needs in a significantly reduced testing timeframe. By using CGA, functionality can be tested and proven in a less harsh environment where data can be collected and to troubleshoot problems before a costly integrated NIE event. Through leveraging both CGA and NIE, technologies can be tested to achieve their critical KPPs (i.e. Net Ready, Sustainment, etc…) and Measures of Performance (MOP) by instilling a higher level of confidence in the results generated by both events. Aligning MOPs and Measures of Effectiveness (MOE) to KPPs and systems within the SV-7 will play a critical and effective role for the development of test use cases that will save time and money in the future stages in NIE or CGA.

Conclusion

This paper discusses a way to formalize a streamlined SE process that is guided by EA methodologies such that non-PoRs can achieve the same success as PoRs that are allocated resources and time to perform the SE studies. EA methodologies such as DoDAF and Zachman Frameworks ask the necessary questions and present the information in an organized and connected way. The use of DoDAF in DoD programs is currently used as a supplement to the development of the Capability Document where it goes to sit on the shelf, never to be looked at again for the systems lifecycle. By improving on these processes, the potential that Systems Engineering and Enterprise Architecture deliver can be realized when Program Managers follow a process that they can understand and support.

CBM+ has successfully demonstrated the use of this agile SE process that specifically improved on the requirements engineering and architecture design processes. By investigating the questions that the EA methodologies formulate, CBM+ was able to pre-emptively tackle problems such as bandwidth limitations on the transmission of CBM+ data over tactical networks and putting in Battalion servers (Store & Forward) to aggregate the CBM+ bulk data from the platforms and send back to CONUS via disks. Testing and integration processes for CBM+ were also streamlined to improve formal NIE events and fielding via C.S. Architecture sets.

Further investigation into the development of this process is necessary for other non-PoRs to be successful. The success and achievement that CBM+ has received is very much associated to the Program Manager’s understanding of potential of the SE process. Many non-PoRs don’t consider the SE process and are left with bigger problems during the end of the systems development process, which tends to be much costlier. Since CBM+ touches on most DoD ground and aviation platforms for reliability, programs that are as comprehensive as CBM+, should follow this revised SE process and EA methodologies to be successful throughout the program’s lifecycle.

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