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The Utility of Modeling an Enterprise Architecture for Air Force Digital Transformation

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THE UTILITY OF MODELING AN ENTERPRISE ARCHITECTURE FOR AIR FORCE DIGITAL TRANSFORMATION

THESIS

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Abstract

The Air Force Materiel Command is undergoing a digital transformation to increase the speed of delivering new warfighter capabilities. This Digital Campaign consists of six Lines of Effort (LOEs) formed with diverse goals to transform the enterprise. This research investigated using the Zachman Framework and Systems Modeling Language to analyze this transformation. Extensive modeling captured the as-is Preliminary Design Review (PDR) process, and mapped LOE goals as primary impacts to Zachman cells. This led to an identification of a to-be digital PDR process. Secondary affected cells were then traced following a relationship analysis. Four discoveries were made. (1) Enterprise modeling in Zachman is analogous to a system decomposition under typical systems engineering approaches. (2) As long as the transformation goals do not change, the Zachman cells, and those entities mapped into those cells, will be directly affected by the new digital enterprise. (3) Different from past process transformation efforts, the Digital Campaign has focused on technology upgrades to drive process change. (4) Lastly, model analysis revealed transformation gaps within certain cells that should be covered with new goals. This research provides a formal, model-based methodology for guiding improvements in pursuit of Air Force digital transformation.

Acknowledgments

I would like to express sincere appreciation to my thesis advisor, Dr. John Colombi, for his guidance, engagement and support throughout this thesis research effort. I would also like to thank my wife for her love and support in this endeavor. When someone takes on an activity that consumes so much individual time and energy, loved ones are also challenged.

Mark W. Kassan

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I. Introduction

General Issue

Pressure is being put on the United States Air Force to maintain its dominance over potential adversaries as the speed of technology is increasing (Brown, 2020). In addition, the Air Force's time to field its most advanced and complex weapon systems has been increasing over the past fifty years. This is allowing these potential adversaries to develop and field new capabilities faster than the Air Force. For example, back in the 1970s, the F-16's concept to field averaged about six years, whereas the latest aircraft developed, the F-35, will exceed twenty years from concept to full operational capability. It is believed that this fielding time will only continue to increase unless the Air Force makes a paradigm shift in the way it acquires new capabilities (Alia-Novobilski, 2020).

To address this increasing time to field new capabilities, the Air Force must undergo a strategic, enterprise-wide transformation. This need for change has been realized by senior Air Force leadership including the Assistant Secretary of the Air Force for Acquisition, Technology, and Logistics, Dr. Will Roper, and the commander of the Air Force Material Command (AFMC), General Arnold Bunch. The primary focus of this transformation is the use of digital models and artifacts integrated across the lifecycle. General Bunch, has stated, "Transitioning to a digital AFMC enterprise is a priority for our command and is foundational to our success in today's adversarial environment." He further stated, "To continue to be the critical enabler for our Air Force

and deliver capability at the speed of relevance, we need to leverage digital technologies to better enable a fully interconnected Air Force research, acquisition, test, and sustainment enterprise" (Alia-Novobilski, 2020) (Roper, 2020).

To address this digital transformation, Gen. Bunch in Feb 2020 established a Digital Campaign to drive the whole enterprise to move towards transforming and create an environment to promote change in six lines of efforts (See Figure 1). These six lines of efforts address the (1) Information Technology Infrastructure, (2) Models and Tools, (3) Standards, Data, and Architectures, (4) Lifecycle Strategies and Processes, (5) Policy and Guidance, and (6) Workforce and Culture.

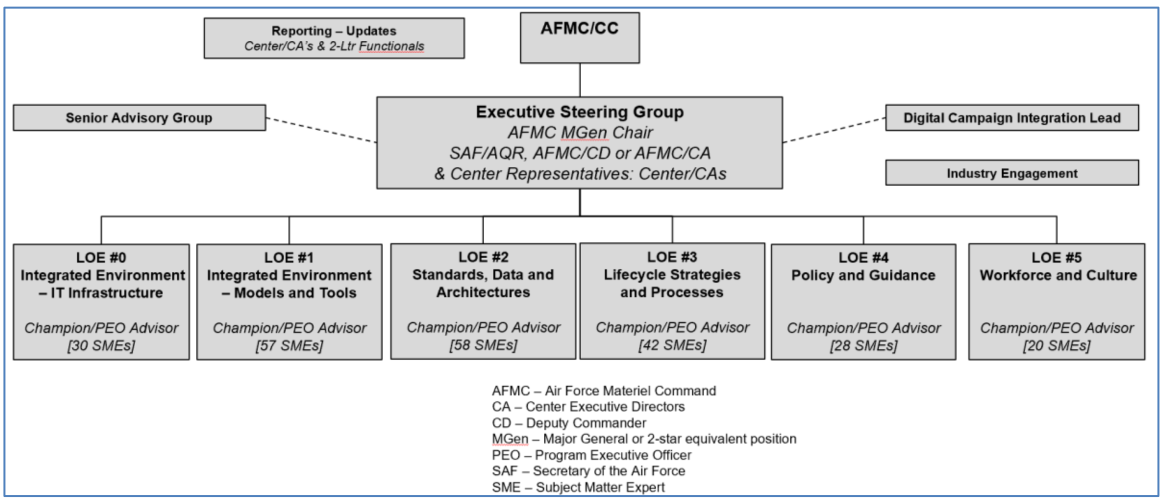


Figure 1: AFMC Digital Campaign

These six lines of effort are attacking all aspects of the digital transformation from an enterprise perspective by mostly leveraging the efforts of a handful of big programs. The lines of effort are comprised of many of the Subject Matter Experts (SME) in the very areas related to the work they perform everyday as part of the organizations within the Air Force Acquisition Enterprise. The general consensus is that this is the right thing at the right time for the United States Air Force.

Problem Statement

While there is a lot of activity and motivation across the Digital Campaign, it is still a “coalition of the willing.” These teams are trying to understand and improve a very large and complex enterprise comprised of many distributed organizations, people and processes that are highly intertwined. In addition, the processes have been continuously evolving since the 1960s (Fox, 2011). In a sense, the Digital Campaign, led by Maj Gen Bill Cooley, is getting things done by grit, experience, and instinct to overcome complexity in transforming a very large enterprise. As a result, without a rigorous and structured effort to break down the complexity, identify, map and unravel the interactions, and transcribe individual processes and digital flows, the Digital Campaign is bound to miss critical aspects. This is where an effort to model an Enterprise Architecture (EA) can introduce a formal methodology to provide the insight needed to complete the digital transformation. This thesis will study the utility of modeling the architecture of the Air Force acquisition enterprise to visualize and gain insight through views and viewpoints to complete the digital transformation.

Research Objective

The main objective of this thesis is to determine the utility of modeling the AFMC digital transformation by assessing the ability to visualize and analyze the data and process changes to improve acquisition of USAF weapon systems.

Investigative Questions

This research centers around the usefulness of enterprise architecture for the purpose of studying the digital transformation holistically. The thesis will address three questions:

1. How can the digital transformation of the AFMC acquisition enterprise be modeled to visualize the primary impacts?
2. How does modeling the digital transformation of the AFMC Acquisition Enterprise identify secondary impacts?
3. What, if any, are the Digital Campaign gaps in pursuing change?

Methodology

This research will use the Object-Oriented Systems Engineering Method (OOSEM) to build a System Modeling Language (SysML) model within the Zachman Framework for a portion of the current AFMC Acquisition Enterprise. Once that is done, the Digital Campaign goals will be entered as requirement changes into the model. The primary effects of these changes on the enterprise's people, products and processes will be studied and documented. These documented results will answer how does modeling the enterprise in this manner result in the visualization of the current enterprise, how does it simplify the current enterprise and what are the primary changes that happen as a result.

The research will then use the inherent structure found in the Zachman Framework of the AFMC enterprise architecture to identify how secondary impacts can be identified. The process and results that are discovered will answer the second research question.

The final step of the research will model the known activities of the ongoing Digital Campaign and perform a relationship analysis with the changes reflected in the enterprise model. This should determine what changes are missing. Modern systems engineering tools provide analysis capabilities including entity tracing, meta-chain

navigation, relation map diagrams and dependency matrices. These capabilities will be used to identify any gaps with implementing permanent digital change to the AFMC Acquisition Enterprise.

Assumptions/Limitations

This research is designed to support the digital transformation of the AFMC acquisition community, which in the current timeframe, consists of an AFMC Digital Campaign, a United States Space Force Digital Engineering effort, and SAF/AQ focus areas. The SAF/AQ focus areas include Agile Software, Open System Architectures and Digital Engineering. This research directly supports and refines the AFMC Digital Campaign, its goals and activities.

The AFMC Acquisition Enterprise is a large and complex enterprise and modeling all of it to the appropriate fidelity would take considerable amount of time beyond the scope of a single thesis. Therefore, this research scopes down on a particular event of the enterprise that is pertinent to most acquisitions. The event is the Preliminary Design Review (PDR) within the Technology Maturation and Risk Reduction (TMRR) phase of a defense acquisition. The PDR process involves sufficient personnel, resources and data artifacts within an acquisition program to provide enough model elements to permit adequate research analysis.

Department of Defense acquisition instructions (5000 series) are changing as this thesis is being completed. This research assumed that the enterprise is acquiring a major capability, either a new program or a major modification to an existing weapon system

that would require a PDR. As always, both traditionally and under new policy, there are always shortcuts and tailoring activities available to a program manager.

Implications

This thesis has direct bearing on the current AFMC Acquisition Enterprise digital transformation. As of the start of this thesis the AFMC Digital Campaign is only seven months into a multiyear effort to transform the acquisition enterprise into a digital acquisition enterprise. If it is shown that this thesis modeling effort can provide easy to visualize views of this complex transformation and uncover important disconnects and relationships not realized during the current AFMC Digital Campaign, then perhaps a larger effort can be commissioned. Then more issues can be identified and resolved before a situation results in the need for a large and unaffordable mitigation activity.

Preview

This thesis is organized to provide a full understanding to the reader of the research activities undertaken to answer the thesis research questions. Chapter I describes the background and urgency that has led to the problem statement that the Digital Campaign is not following a formal problem and solution process. This has led to the focus of this research being encapsulated in the three research questions which revolve around the usefulness of modeling the acquisition enterprise to aid in the digital transformation. Chapter II provides a review of literature that addresses research on the urgency of digital transformation, the development, modeling and use of enterprise architecture frameworks, current acquisition processes and model-based systems engineering needed for this research. Chapter III describes how a methodology was

decided and pursued to build an enterprise architecture model that represents the current AFMC Acquisition Enterprise, the impact of Digital Campaign goals upon that enterprise, and the resulting future digital AFMC Acquisition Enterprise. Chapter IV analyzes using relationship analyses to determine secondary impacts to the enterprise. The chapter also addresses the resulting modeling effort to determine how well the enterprise architecture model answers the research questions and draws resulting conclusions from the observations. Chapter V summarizes the research by presenting the researcher’s final conclusions, and recommendations for future research.

II. Literature Review

Chapter Overview

The purpose of this chapter is to provide the reader with the basic concepts necessary to understand this thesis research. This thesis research addresses the major concepts of digital transformation, enterprise architecture frameworks, the Defense Acquisition System, and the systems engineering method used for modeling the enterprise architecture.

Digital Transformation

The rapid pace of changes in the commercial marketplace is driving the need for companies to make better informed and faster business decisions. Businesses have sought out digital transformation in order to achieve agile capabilities using the latest available technology to position themselves to take full advantage of the ever-changing environment, improve business agility and growth, and promote innovation within their companies. One such company is Intel Corporation who has framed their digital transformation around enterprise architecture to simplify and map people, processes and tools providing insight into ways to be agile, reduce technical debt, update bureaucratic processes, and increase automation (Singh, 2019). Digital transformation claims within Intel’s 2018-2019 Information Technology (IT) Annual Performance Review include saving 933,000 productivity hours per quarter and improving time to market by approximately 52 weeks (Intel Corporation, 2019).

The need to digitally transform is no different for the Department of Defense (DoD) and the Air Force where near peer competition is changing the dynamics of the

threat through rapidly changing technology becoming more readily available. In 2018, the DoD published a digital engineering strategy, expressing digital transformation as mostly an engineering function requiring "new methods, processes, and tools, which will change the way the engineering community operates" yet acknowledged that the "shift extends beyond the engineering community with an impact on the research, requirements, acquisition, test, cost, sustainment, and intelligence communities." This strategy laid out five goals and fourteen focus areas for the services to transform their enterprises to provide capabilities to the warfighter faster than potential adversaries. This strategy was established at a high level leaving it up to the military services to develop implementation plans (Deputy Assistant Secretary of Defense, 2018). Since that time, the Air Force has struggled to gain traction for digital engineering in all except a few new programs.

Digital transformation for a large organization like the Air Force is an enormous undertaking. It is a complex, time-consuming journey requiring vision, strategy, and implementation planning, with considerations of the appropriate mix of technologies and processes to achieve the vision of speed and agility. An Accenture report states that only 19 percent of aerospace and defense companies successfully transform operations such that they see significant returns on their investments (Schmidt, Gelle, Addino, & Ghosh, 2019). The idea of what it means to be digital is very broad and disperse within the literature. Most of the literature addresses digital transformation as either updating business processes as a result of updating IT infrastructures, while others focus on operations, capabilities, and mission sets; all have in mind the ability to improve data-based decision making and increase speed and agility. Digital transformation has also been framed as simply using a 3D model using Computer Numerical Control (CNC)

manufacturing techniques. Another example of transformation involves performing analytics to a large set of related data using artificial intelligence for decision making, predicting and forecasting. A third example of transformation is having an organization socialize and share ideas within a collaborative digital environment. And lastly, digital transformation can mean model and data integration within a digital environment for data-driven real-time decision making. For the Air Force, the current Digital Campaign is trying to tackle all of these, the integration of these and even more. The Air Force must be careful, because it has tried to transform before with massive failed programs like the Expeditionary Combat Support System (ECSS). ECSS expended nearly a $1B dollars over ten years before being cancelled, as the Air Force tried to implement data-based decision making and solve data integration issues across a large cross section of engineering, logistics, program management and contracting (Kanaracus, 2012). This research addresses a potential weakness in the current digital transformation approach of the Digital Campaign: not understanding and not modeling all of the intricacies and relationships between the products, processes and people of the Air Force acquisition enterprise. This next topic will provide background on why an enterprise architecture framework should be considered as a primary tool for modeling the Air Force digital transformation.

Enterprise Architecture Frameworks

An architecture framework is a tool for describing an architecture using "conventions, principles and practices established within an application-specific domain and/or stakeholder community" (IEEE, 2011). It presents unique stakeholder

perspectives in views that communicate information of concern to that stakeholder about the system. A system described by an architecture framework usually is expressed in terms of operational concepts and capabilities. An enterprise architecture framework presents unique stakeholder perspectives for connecting organizational goals to business objectives. A system (and an enterprise) with a high level of complexity generally is a system that has a very large number of relationships, rules, and cascading effects that exhibit traits that the original system designers never intended (emergent behaviors) (Bondar, Hsu, Pfouga, & Stjepandic, 2017).

The earliest beginnings of EAs can be traced to an IBM methodology in the late 1960’s called Business Systems Planning (BSP). The purpose of which was to deliberately plan information systems by collecting data through interviewing managers and then developing a top-down plan involving models representing a logical structure that could be implemented. This modeling considered the relationships between business processes, network systems and data (Kotusev, 2016). There were several versions and improvements of the BSP through to the 80s when John Zachman would introduce his framework internally to IBM.

John Zachman published his original framework in 1987. The framework was similar to the 1986 PRISM EA framework published by the PRISM research service of Index Systems and Hammer and Company. The PRISM framework introduced the concept of principles to bridge the gap between top management and technical experts and was instrumental in guiding the definition and evolution of architectures (Greefhorst & Proper, 2010).

It was not until 1992, when the Zachman Framework was extended into thirty categories in a matrix where there were five perspectives (planner, owner, designer, builder, and subcontractor) in rows and six interrogatives (*what*, *how*, *where*, *who*, *when* and *why*) along the columns. Each of the thirty cells in this matrix contain a unique entity suggesting that it serves as a "periodic table" for entities. This resulted in a different diagram representing a different abstraction and different perspective of the EA (Sowa & Zachman, 1992).

In 2011, Zachman updated his framework matrix to a version 3.0 and titled it *The Zachman Framework for Enterprise Architecture*. This version as shown in Figure 2 is a six-by-six matrix with the names of the perspectives being the executive, business management, architect, engineer, technician and the enterprise and the same six interrogatives.

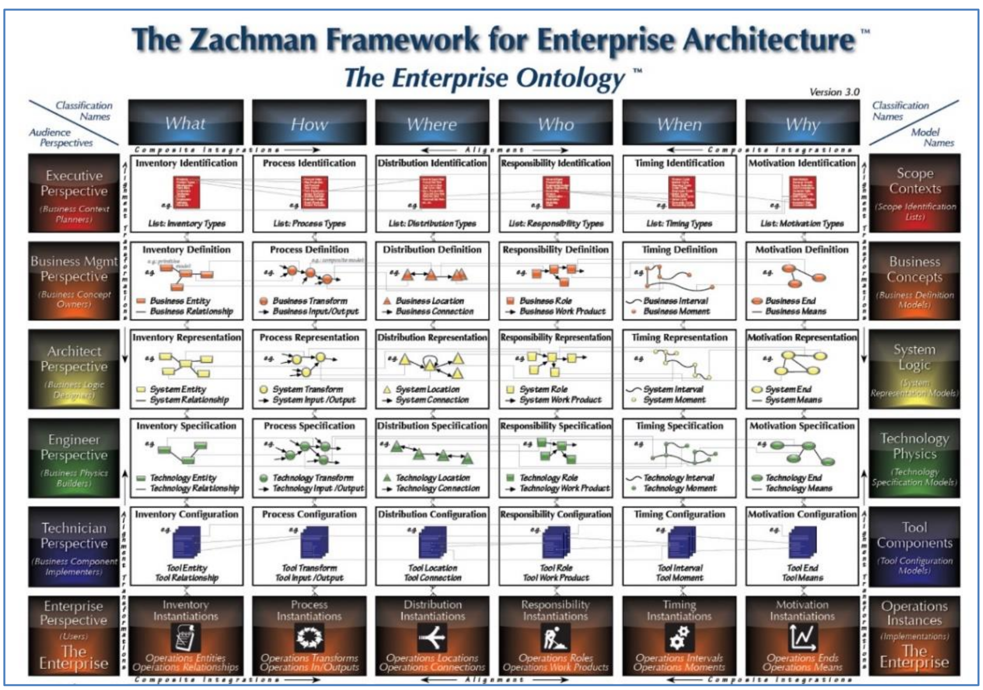


Figure 2: Zachman Framework for Enterprise Architecture

In 1996, the US Congress passed the Clinger-Cohen Act requiring a process be designed and implemented within a Government agency that would maximize the value of information technology acquisitions, and managing the risks involved. The Federal Enterprise Architecture Framework (FEAF) was developed in 1999 to address this Clinger-Cohen Act requirement and was focused on enterprise engineering, and program and capital management (Richards, Hastings, Shah, & Rhodes, 2007). The first architecture framework to come along in the DoD, addressed in a 1995 Deputy Secretary of Defense directive, was the Command, Control, Communications, Computers, and Intelligence, Surveillance, and Reconnaissance (C4ISR) Architecture Framework v1.0 as a result of lessons learned from the 1991 Gulf War, that defined a DoD-wide effort to helped define and develop a better means and process for ensuring that C4ISR capabilities were interoperable and met the needs of the warfighter (DoD, 2007). The C4ISR architecture framework became the basis for the Department of Defense Architecture Framework (DoDAF) Version 1.0, released in 2003 which standardized architectures across the DoD in an attempt to achieve interoperability and a System-of-Systems (SoS) approach. And finally, the DoDAF has evolved into the present-day version 2.02 as of August 2010 and "serves as one of the principal pillars supporting the DoD Chief Information Officer (CIO) in his responsibilities for development and maintenance of architectures required under the Clinger-Cohen Act" (DoD CIO, 2020). DoDAF has seen shared updates and development from UK Ministry of Defense Architecture Framework (MODAF) efforts. However, since 2010, updates and refinement of the DoDAF meta-model (DM2) have stagnated.

There are a few other EA frameworks that have evolved and are available presently. These include The Open Group Architecture Framework (TOGAF) and the Unified Architecture Framework (UAF). The TOGAF is an enterprise architecture framework and methodology first published in 1995 and contains a methodology and a framework for architecting a technical enterprise architecture. The Open Group claims to be a very diverse global consortium with over 790 member organizations. The Open Group maintains standards, frameworks, reference architectures, tools, models, and guides for enterprise architects. The group has also created a set of principles “describing how digital standards can be best used together to accelerate the adoption of digital practices across an organization, facilitating sustainable and enduring change” (The Open Group, 2020).

The Unified Architecture Framework (UAF) maintained by the Object Management Group (OMG) is based on the Unified Profile for DoDAF/MODAF (UPDM). The OMG founded in 1989 is a not-for-profit computer industry standards consortium of international representation from government, industry and academia. UAF “enables stakeholders to focus on specific areas of interest in the enterprise while retaining sight of the big picture. UAF meets the specific business, operational and systems-of-systems integration needs of commercial and industrial enterprises” (Open Management Group, 2020).

There are many different definitions of an enterprise in the literature. The major theme in many of these documents is that an enterprise is an organization or activity whose boundary is defined by a common mission and who uses technology, processes, and resources to perform that mission (Bernard, 2012). In the Air Force, as in any

complex large organization, there are numerous enterprises. The Air Force has enterprises consisting of a single formal organization (purposefully structured with top-down authorities, accountabilities and responsibilities), and enterprises that consist of a collection of formal organizations and enterprises that consist of pieces of formal organizations; all with a consideration of achieving a common goal. One of the first activities for this research was to define the boundary of this acquisition enterprise to use as a basis for the enterprise architecture modeling. It was decided that the research would focus on AFMC as an organization who performs an acquisition mission of delivering capability to warfighters. This includes the executing programs and the command and center support organizations that can provide enterprise-level processes, technologies and resources to program offices where achievement of the goal is focused.

Enterprise architecture is an approach to resolve enterprise-wide concerns and gives the systems engineer a way to formally model and address the concerns. This implies that the enterprise architecture is built for a specific purpose to address concerns of the enterprise. One such effort in 2011 by Williams and Stracener (2013) attempted to use enterprise architecture for optimizing organizational program design for the purpose of developing complex aerospace and defense products. While this research was focused on exposing the activities between a to-be architecture and an as-is architecture, both are related to providing products (or capabilities) to the defense warfighter. Their work first considered the organization as a system (or a machine) built for that purpose.

There are several instances in the literature that address enterprise architecture frameworks and their power to be a useful tool to support complex enterprises and digital transformation. There has been recent popularity in modeling SoS architectures. A

recent study in the *Journal of Industrial Information Integration* concludes that the Zachman Framework is appropriate to use to model a complex SoS with emergent behavior. SoS complexity is apparent because of the interoperability and interactions required of independent functions that are not necessarily hierarchal and centrally controlled. By modeling the SoS architectures in a modular way, the models can be easily modified and expose new or changed emergent behaviors (Bondar, Hsu, Pfouga, & Stjepandic, 2017). Another instance of modeling a complex warship using digital and enterprise architecture modeling principles demonstrated that the modeling of the enterprise system could be more efficiently completed and validated through the use of the model-based systems engineering process. The effort used the DoDAF and mapped to the interrogatives of the Zachman framework as an integrity check (Tsui, Davis, & Sahlin, 2018). The literature has many examples of successfully using enterprise architecture frameworks. Next, this paper will describe two other important concepts used for this research: DoD acquisition process, and model-base systems engineering.

Defense Acquisition System

The Defense Acquisition System (DAS) will be explained briefly. The DAS consists of three business processes; Acquisition process, Joint Capabilities Integration and Development System (JCIDS) process and the Planning, Programming and Budgeting and Execution (PPBE) process. The Acquisition process is a system lifecycle framework defined by DoD Instruction 5000.02, *Operation of the Adaptive Acquisition Framework* (DoD, 2020). The instruction calls out responsibilities, roles, and authorities for six acquisition pathways; Urgent Capability Acquisitions, Middle Tier of Acquisitions,

Major Capability Acquisitions, Software Acquisitions, Business Systems Acquisitions, and Acquisitions of Services. This research constrained to the Major Capability Acquisitions process which is further explained in DoDI 5000.85 and is illustrated in Figure 3. This instruction describes the Acquisition process as an "event-based process where a program goes thru a series of processes, milestones and reviews from beginning to end" (DoD, 2020).

The Materiel Solution Analysis phase is where multiple concepts are considered for the product as expressed through the capability gaps, and system requirements. These concepts help support the acquisition strategy decision for the product at Milestone A.

Milestone A is the entry into the Technology Maturation and Risk Reduction (TMRR) phase. Milestone A approves the program acquisition strategy and the request for proposal for TMRR support activities.

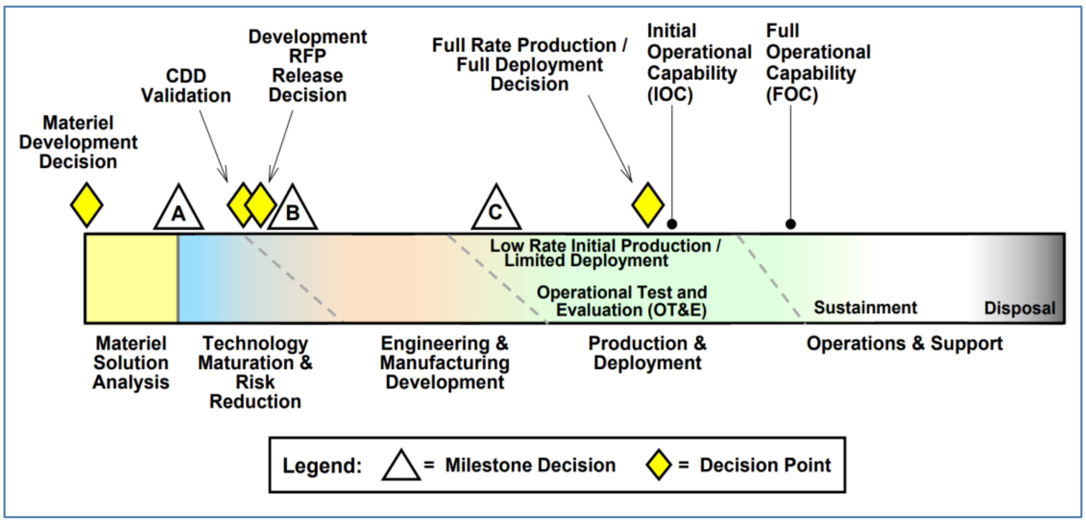


Figure 3: DoD Acquisition Process for Major Capability Acquisitions

The purpose of the TMRR phase is to reduce program risk by reducing technology, engineering, integration and lifecycle cost risk so that the program can move

into an Engineering and Manufacturing Development (EMD) contract for the product development which will also heavily impact production and sustainment of the product.

Milestone B is the entry into the EMD phase. All sources of risks must be demonstrated as adequately mitigated to support a commitment to complete design, development and production. This includes cost, technology and engineering risks and requires validated capability requirements before moving into EMD. The program must also be fully funded in the Future Year Defense Program (FYDP).

There is a lot that goes into the EMD phase. It is this phase that the materiel solution is developed, built, tested and evaluated to verify that all operational and implied requirements have been met, and data is provided to support production, deployment and sustainment decisions.

Milestone C is the decision point for transitioning into the Production and Deployment (P&D) phase. This milestone review requires a full review of test and evaluation results, needing to show evidence that the production design is stable, that there are no significant manufacturing risks and that any software is mature enough for production.

The P&D phase is when the requirements-compliant materiel solution is produced and deployed to the operational organizations. Within the P&D phase, a full-rate production decision review will be conducted to assess the results of initial operational test and evaluation to evaluate acceptable reliability and performance, and manufacturing readiness to ramp up to full manufacturing speed. The review will also evaluate whether the sustainment and support systems are adequate.

And finally, once the materiel solution is deployed to the operational organization, the product will enter the Operations and Sustainment phase. This phase executes the product support activities which includes personnel training, and system sustainment over the rest of the lifecycle, including disposal.

Model Based Systems Engineering

One of the iterative processes conducted throughout the lifecycle of the materiel solution is the systems engineering process as expressed and accepted by most of the Department of Defense as the “Vee” model illustrated in Figure 4. The “Vee” model starts with user needs in the upper left corner and ends with a user-validated system in the upper right. On the left side, the requirements are decomposed and allocated to functions that meet the user’s need. The right side builds the system up from its basic components into an integrated fully-functional system, validated through verification and validation and the components are built into assemblies and assemblies are built into subsystems and finally as a complete system (Forsberg & Mooz, 1991).

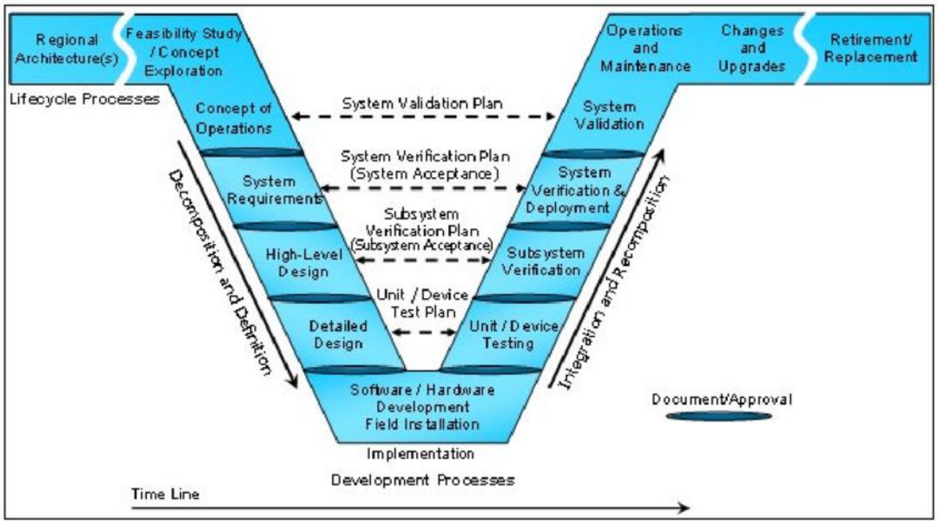


Figure 4: The "Vee" Model

The reason for the above discussion on the systems engineering process is because this same iterative process is used when referring to Model-Based Systems Engineering (MBSE) processes. The OOSEM is a MBSE method using SysML, that starts with stakeholder's requirements and ends with a model of the enterprise (i.e., system) architecture. The next paragraph discusses the OOSEM.

Originally developed by engineers in the mid-1990s at Lockheed Martin, OOSEM methodology was based on the Unified Modeling Language (UML) and later adapted to use the SysML. OOSEM is described as a top-down model-based approach that is consistent with the systems engineering process using SysML to visualize the analysis, specification, design, and verification of systems. The method results in the modeling artifacts that make up a system model defined by the stakeholder needs, system requirements, and the synthesized solution. "The process leverages object-oriented concepts and other modeling techniques to help architect flexible and extensible systems that can accommodate evolving technology and changing requirements" as stated by

Friedenthal, Moore, & Steiner (2015). Each of the system components are traced back to the system requirements. The design is optimized and alternatives are considered, and the system is validated and verified against the system requirements and the stakeholders needs. See Figure 5 below (Estefan, 2008).

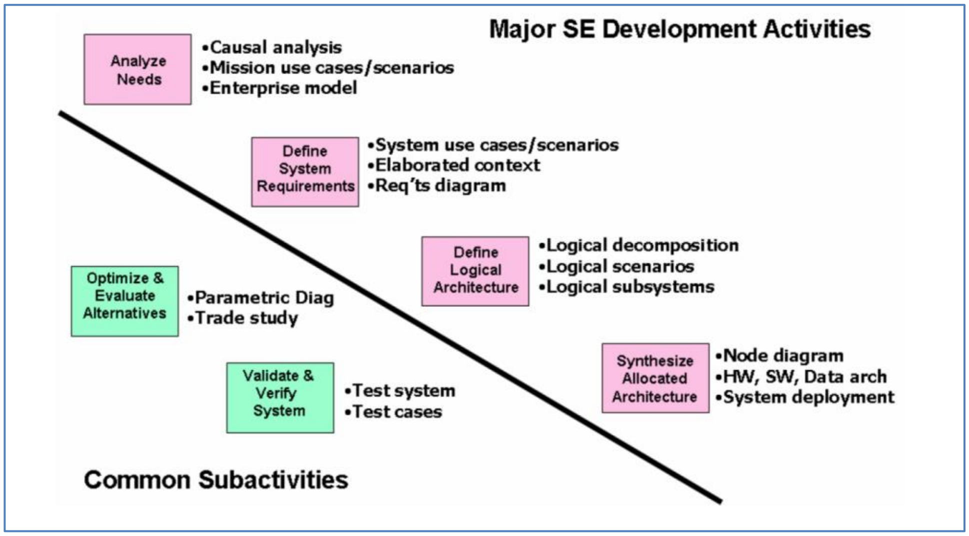


Figure 5: OOSEM Activities & Modeling Artifacts (Estefan, 2008)

Summary

This chapter delved into concepts in the literature necessary to understand this thesis research. This chapter addressed the concept of digital transformation, why it is being pursued by today's businesses and why the Air Force has an urgency to digitally transform its acquisition enterprise. Also addressed was the history of enterprise architecture frameworks, what is currently being used, and what the Zachman Framework allows a user to do. And finally, this chapter addresses the acquisition process, systems engineering and the use of OOSEM to model an enterprise architecture. A basic understanding of all these concepts are necessary for this thesis research.

III. Methodology

Chapter Overview

The purpose of this chapter is to discuss the methodology followed in this research. It will describe the use of OOSEM and SysML for modeling the PDR process of the AFMC Acquisition Enterprise using the Zachman Framework for Enterprise Architecture (or Zachman Framework). The top-down steps of the OOSEM were followed to model the as-is AFMC Acquisition Enterprise architecture. This method started at the top of the Zachman Framework which represents the executive or contextual perspective of the acquisition enterprise. Each cell was modeled taking into account the perspective and the interrogative. The research continued to build down the perspectives, building in more model details for the PDR process. For each perspective, the interrogative columns were addressed.

Once completed, the AFMC Digital Campaign goals were mapped to the Zachman Framework and primary impacts to the PDR process were assessed and documented in terms of an expected to-be architecture. The to-be models were built and secondary impacts within other cells were traced.

Methodology Details

Dassault No Magic CAMEO Systems Modeler V19 was used for this research because it was available in the AFIT research environment. It is also one of the SysML modeling tools used by a large portion of the Air Force acquisition community. There are other tools also used within the Air Force enterprise. These include Sparx Systems

Enterprise Architect, IBM Rational Rhapsody, SPEC Innovations Innoslate, and Siemens' Systems Modeling Workbench.

The Zachman enterprise architecture is a framework for visualizing a complex enterprise. John Zachman is clear that he does not prescribe a method for his framework, so it is left up to the user to determine the method. This research effort chose to use the OOSEM process as outlined in Figure 6, which starts with organizing the model.

This research focused on one part of the acquisition process in order to answer the research questions. The PDR was picked because it is a prominent technical review within an acquisition process that the majority of major and minor programs must go through. The PDR event should be considered a thing (i.e., not an activity), because an "event" is defined as a "thing that happens" (Oxford University Press, 2020). To be clear, at times, this research will refer to the PDR as a PDR process, but in actuality, the PDR processes described are activities that happen around and in support of the PDR event. The PDR is also relatively universal in that there are similar documents needed for the review across different programs. The review generally takes place between an external entity (vendor/ contractor) and a program office, where the vendor takes the time to prove to the program office and other stakeholders that it has met the system requirements in allocating the requirements down to subsystems, software and components of the needed system. In addition, risk and affordability is looked at during a PDR. The research expectation is that the PDR process has many, if not all, of the ingredients necessary to show digital transformation impact from the Digital Campaign goals and thus provides enough evidence to answer the three research questions.

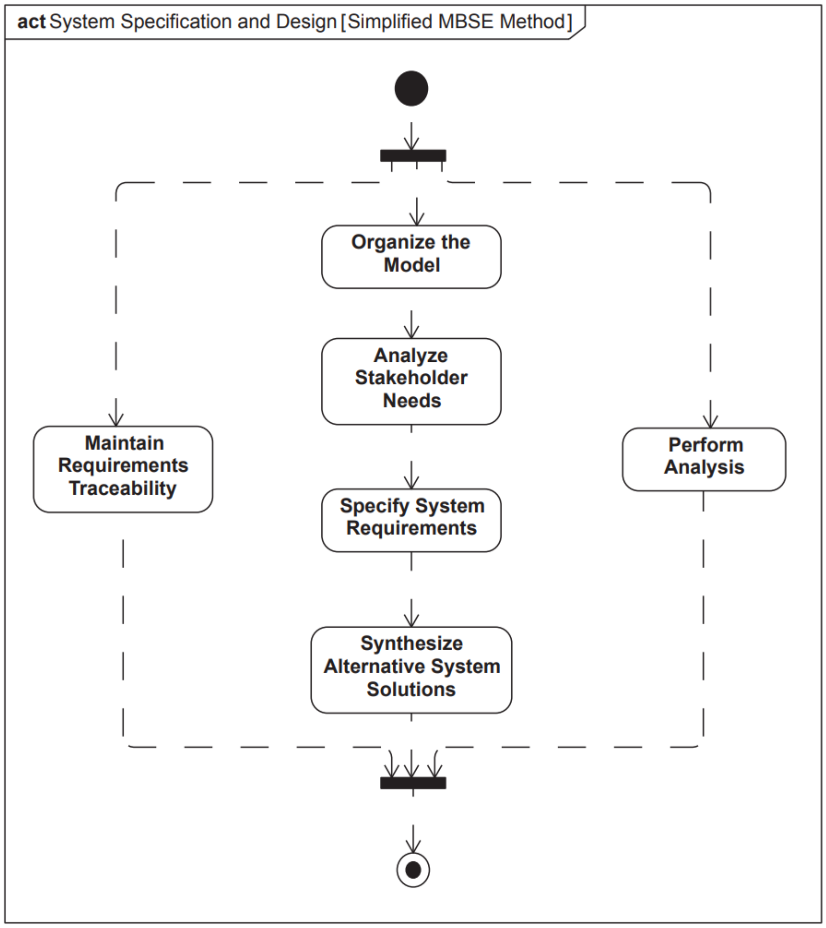


Figure 6: Simplified OOSEM for Specify and Design Process Flow (Friedenthal, Moore, & Steiner, 2015)

Organizing the Acquisition Enterprise Architecture Model

The first step of OOSEM is to "organize the model" as shown in Figure 6. To accomplish this step within CAMEO, a package model as shown in Figure 8 was built that represents the Zachman Framework Version 3.0 of Figure 7. A top-level package is created for each perspective. A package is a folder that establishes a way to contain and organize related information within a model.

The perspectives represent the stakeholders within the enterprise and who participate in the overall enterprise outcome. For this exercise, only four perspectives

(Executive, Business Management, Architect, Engineer) were addressed. The other two perspectives are the Technician (contractor) and the Enterprise (instantiations of the enterprise). Both of these perspectives for this research were considered outside the scope of this effort. Within each of the perspective packages were packages representing the Classification Names (or Interrogatives) of the Zachman Framework as shown in Figure 8. These sub-packages represent the intersection of the perspectives and the interrogatives and will be referred to as a cell within this research. It is within each cell that the modeling artifacts will reside in the form of diagrams, entities and relationships. To understand what diagram will go in each cell, research was done to define each of the four perspectives. These perspectives are from the point of view of the Executive, Business Management, Architect, and Engineer.

The Executive perspective is also known as a contextual perspective. This is the person who is setting the strategy for the enterprise. This person is concerned with depicting in broad terms, the basic scope of the enterprise (Sowa & Zachman, 1992). This research defines this person as an AFMC executive with duties to understand and provide the overall resources and data needed to meet many customers' materiel requirements within the DoD acquisition process.

The Business Management (or business manager) perspective is also known as a conceptual perspective. This is the person who runs the execution organization. This person's perspective is from someone who has to work within the enterprise business and cares about the business products and processes and how they interact

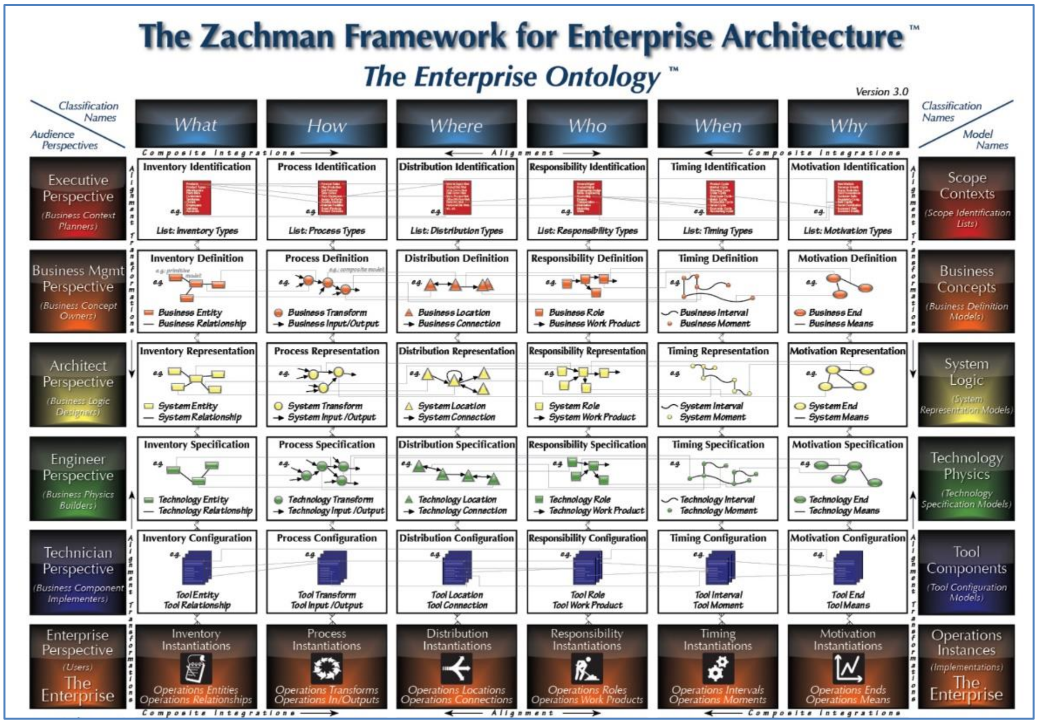


Figure 7: Zachman Framework Version 3.0

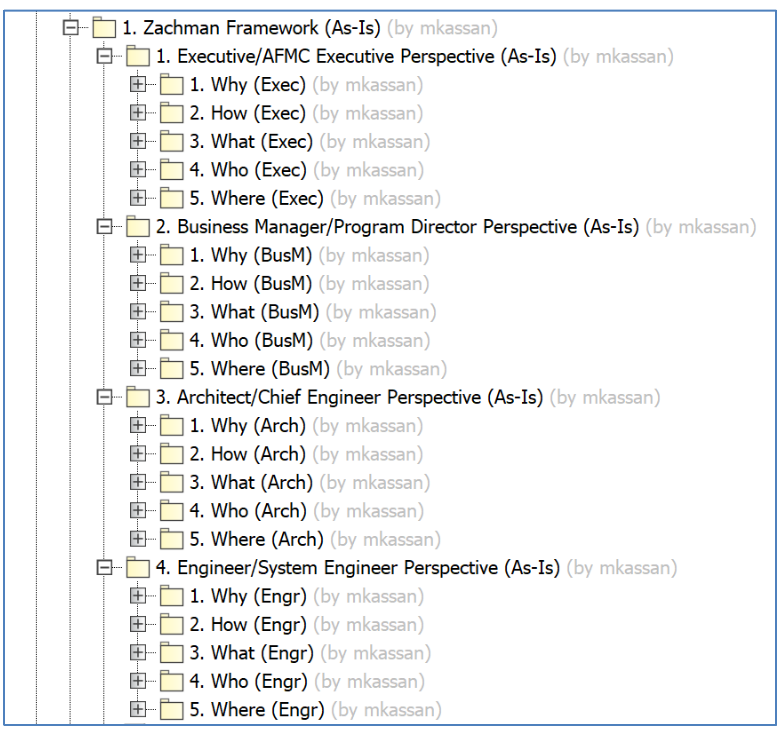


Figure 8: CAMEO package structure representing Zachman Framework matrix

(Sowa & Zachman, 1992). This research defines this person as an program office director responsible to produce a product and related data that meets a customer's materiel requirement.

The Architect perspective is also known as a logical perspective. This is the person who designs discipline into the organization. This person is concerned with the details of the materiel solution, data products and the business processes that produce those data products (Sowa & Zachman, 1992). This research defines this person as a chief engineer responsible for the detailed processes that produce the materiel solution, and the data products required to meet a customer's materiel requirement.

The Engineer perspective is also known as a physical perspective. This is the person who is responsible for applying specific technologies to solve the problems of the organization. This person is concerned with the constraints of the technology and processes used to produce the data products and must adapt the information technology to meet the enterprise requirements (Sowa & Zachman, 1992). This research defines this person as a systems engineer responsible for applying available information technology and support personnel to the program office business processes that produce the materiel solution and data products.

The perspective definitions are the rows of the Zachman Framework. The five columns for this research are represented as the interrogatives: *why*, *how*, *what*, *who* and *where*. The sixth column, the *when* interrogative, was not considered. Definitions of these columns are described in the following paragraphs.

The *why* column describes the motivation of the enterprise. These are typically described in terms of goals and objectives. Within a model these are best represented as

requirements diagrams depicting relationships of goals to sub-goals (or objectives) of the enterprise (Sowa & Zachman, 1992). This research uses requirements diagrams that link the executive's stakeholder requirements (those of the customers' having a materiel solution need) down to the engineer's IT requirements used to meet the requirements flowing back up to the stakeholder's requirements.

The *what* column can be described as the data artifact. Generally speaking, this is the "things" of the enterprise (Zachman, 1987). For this research, the things are the data products being produced, shared, consumed, used and stored by the enterprise. These are represented by blocks, Block Definition Diagrams (BDD) and their relationships.

The *how* column can be described as the function artifact and is the column where business processes of the enterprise would be described for creating and transforming the enterprise products (Zachman, 1987). This research used activity diagrams to describe the processes of concern for each perspective. These perspectives included the executive's scope of the overall acquisition process to the more detailed processes of the architect and engineer, who are involved in preparing and conducting a PDR event.

The *who* column is the people and organization artifact. This column depicts organizational structure as well as the roles of people within the organization. Organizational structure usually shows hierarchal lines of authority or links to who is providing the work product or work service (Sowa & Zachman, 1992). This research used block definition diagrams to represent parts of the acquisition enterprise involved in and concerned with the PDR technical event.

The *where* column is the location artifact. This column depicts where the business is occurring or flowing between the enterprise network and sites, depending on

the perspective. (Sowa & Zachman, 1992) (Zachman, 1987) This research used block definition diagrams, blocks and relationships to represent locations, where locations are defined as a place for organizations or IT systems within the acquisition enterprise.

This thesis will use the nomenclature of Figure 9 to refer to each cell of the Zachman Framework. As one can see, each cell is the intersection of an interrogative column and a perspective row. For instance, the *what* interrogative column intersects with the engineer perspective and is referred to as the cell of "What (Engr)," where engineer is abbreviated as "Engr". Other abbreviations include "Exec" for executive, "BusM" for business manager, and "Arch" for architect.

	WHY	HOW	WHAT	WHO	WHERE
EXECUTIVE (AFMC Executive Leader)	Why (Exec)	How (Exec)	What (Exec)	Who (Exec)	Where (Exec)
BUSINESS MANAGER (Program Director)	Why (BusM)	How (BusM)	What (BusM)	Who (BusM)	Where (BusM)
ARCHITECT (Chief Engineer)	Why (Arch)	How (Arch)	What (Arch)	Who (Arch)	Where (Arch)
ENGINEER (Systems Engineer)	Why (Engr)	How (Engr)	What (Engr)	Who (Engr)	Where (Engr)

Figure 9**:** Zachman Framework Cell Definitions used in this research

Developing the As-Is Acquisition Enterprise Architecture Model

Once the Zachman Framework is set up and understood within the CAMEO tool, the next OOSEM step is to start with modeling the contextual level (executive perspective) and

conceptual level (business manager) as the “analyze stakeholder needs”. This work is demonstrated in Figure 11 through Figure 15 for the executive perspective and Figure 16 through Figure 20 for the business manager perspective. Once complete with these two perspectives, the research moved to the next step within OOSEM which is “Specify System Requirements”. This step is accomplished by modeling the logical level cells of the architect. This work is demonstrated in Figure 21 through Figure 25. And finally, the last step of the OOSEM is to model the “Synthesize Alternative Systems Solutions” for the physical level cells of the engineer’s perspective as demonstrated in Figure 26 through Figure 30. The resulting completed set of models is a metamodel of the PDR process for the four enterprise perspectives and is represented by cell models in Figure 10.

The following paragraphs step through the research activity that resulted in the data artifacts produced for each cell within the as-is enterprise architecture. The as-is enterprise architecture is a representation of the actual acquisition enterprise for the PDR and related data, organizations, personnel and processes as viewed by each perspective.

	WHY	HOW	WHAT	WHO	WHERE	WHEN
EXECUTIVE (AFMC Executive Leader)	Stakeholder Requirements	Conduct Acquisition Process	Enterprise Data	Acquisition Enterprise	Acquisition Enterprise Locations	X
BUSINESS MANAGER (Program Director)	Technical Review Requirements	Conduct Technical Review Process	PDR Data	Program Office	Technology Maturation and Risk Reduction Phase	X
ARCHITECT (Chief Engineer)	PDR Data Requirements	Conduct PDR Process	PDR Data Products	PDR Participants	PDR Location	X
ENGINEER (Systems Engineer)	PDR Technology Requirements	Prepare/Maintain PDR Technologies	PDR Technology	PDR Technology Personnel	PDR Technology Location	X
TECHNICIAN (CONTRACTOR)	X	X	X	X	X	X

PDR - Preliminary Design Review

Figure 10: Preliminary Design Review of the AFMC Acquisition Enterprise within the Zachman Framework (As-Is Representation)

Executive Perspective

Starting with the executive and *why* cell (i.e., “Why (Exec)”), the stakeholder requirements results in a requirements diagram that represents the overall purpose of the acquisition enterprise (see Figure 11). This purpose is to deliver a materiel solution and the data artifacts which prove that solution meets the requirements of being sustainable, effective, suitable, timely, affordable and survivable. These requirements are stated in DoDI 5000.02 (23 Jan 2020) paragraph 1.3 and are the basis for what the AFMC executive believes are his requirements for any materiel solution that a customer needs.

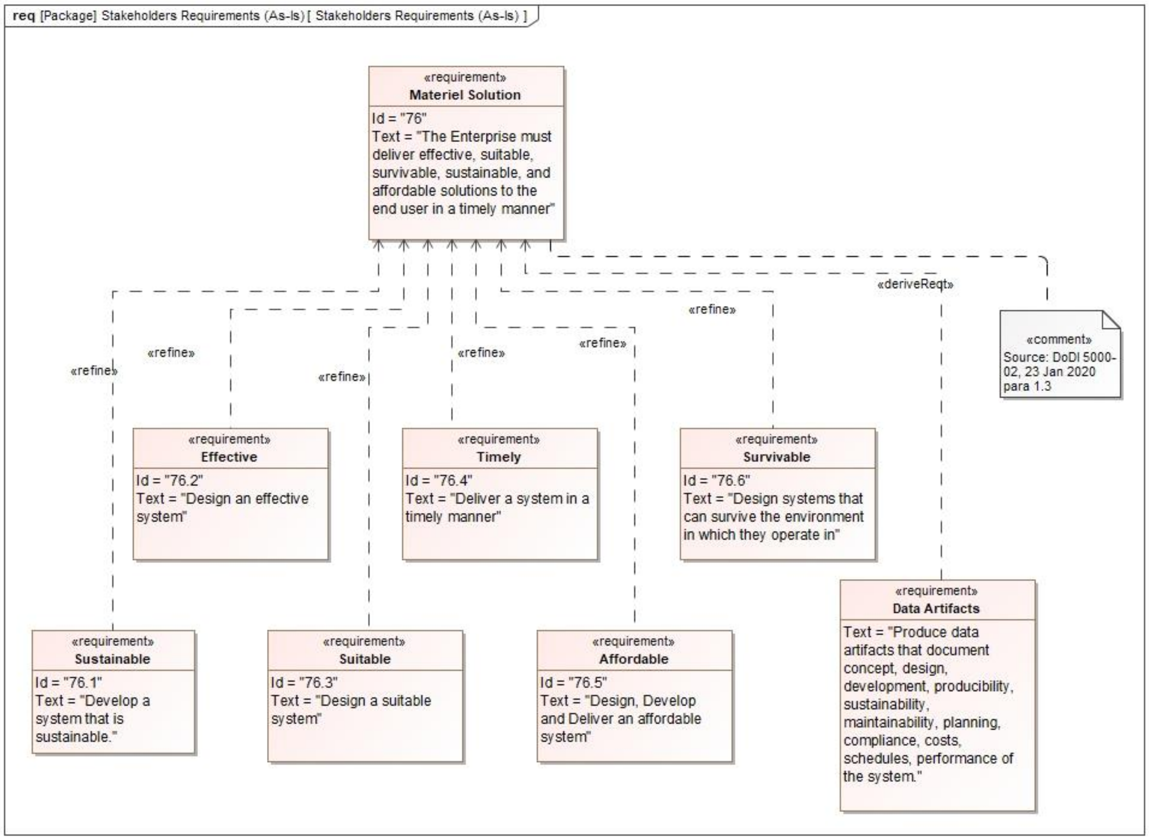


Figure 11: Stakeholders Requirements (Cell: Why (Exec))

Referring to Figure 12, the AFMC Executive sees how acquisition is done through the DoD acquisition process as defined in DoDI 5000.85 for a Major Capability Acquisition. This model reflects the phases of the acquisition lifecycle which are what the AFMC Executive cares about. It is modeled as a state machine because the materiel solution will be in only one condition (phase) at any single time. The AFMC Executive also cares about the milestones (Materiel Development Decision, A, B, C) denoted by diamonds in the figure because these are the major review opportunities to impact this materiel solution.

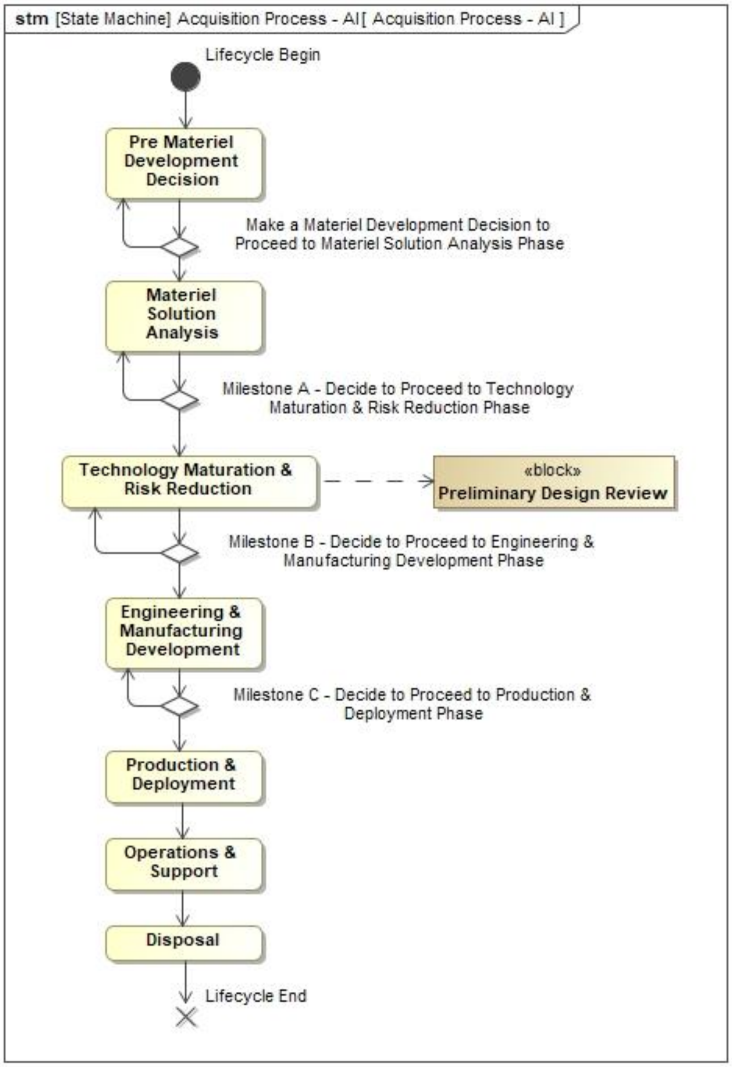


Figure 12: State Machine Diagram of the Acquisition Process (Cell: How (Exec))

The things that the AFMC Executive is concerned about are represented in the block definition diagram of Figure 13. These are the top-level data needed to manage and provide a materiel solution to the customer of the materiel solution. These data include the design, performance, cost, risk, requirement, maintenance, operational, logistics, security, test, interface and schedule data of the materiel solution.

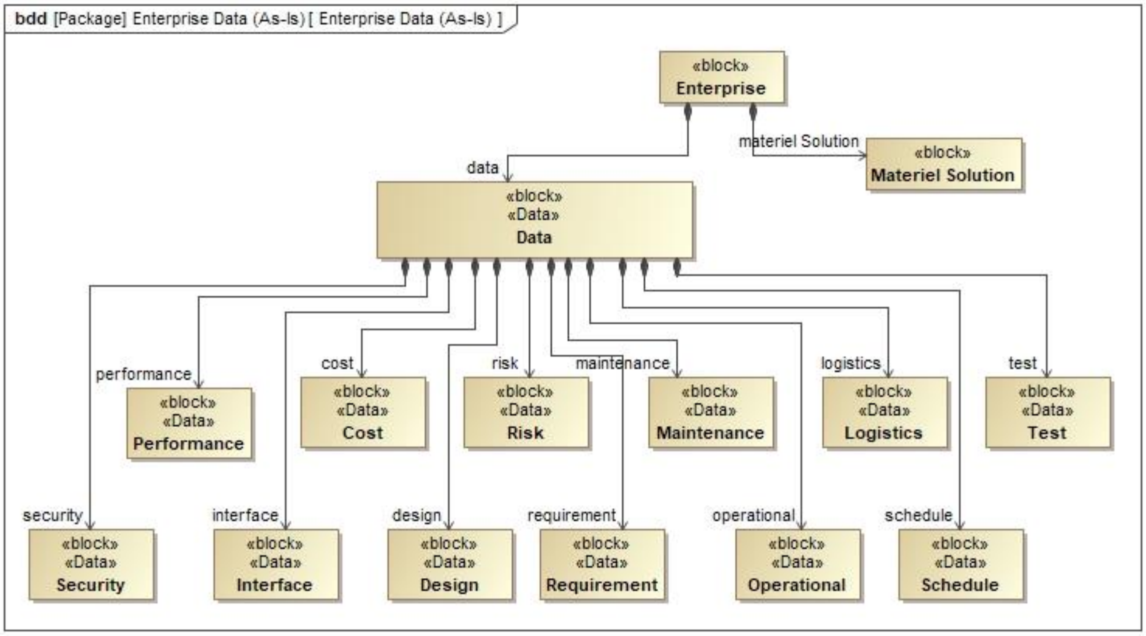


Figure 13: Enterprise Data for the AFMC Executive (Cell: What (Exec))

The AFMC Executive sees the *who* of the AFMC Acquisition Enterprise as the organizations shown in Figure 14. The executive cares about the organizational actors within and outside the enterprise. The actors outside the enterprise include the Air Force headquarters leaders and staff who are responsible for overall management of Air Force acquisition, and the Major Command (MAJCOM) leaders, users and staff, as well as the contractor/vendor team. The actors within the enterprise include the program office team, the command support directorate leaders and staff, the program executive officers who execute materiel solution portfolios through the program offices, and various support staffs within the six centers within AFMC (Command).

The executive's perspective on the *where* of the AFMC Acquisition Enterprise is concerned with the physical locations of the enterprise. This is represented by the block definition diagram of Figure 15 where a logical block "Location" is associated with the

enterprise organizations. Several Air Force bases are identified in comment as location instances for portions of the acquisition organizations.

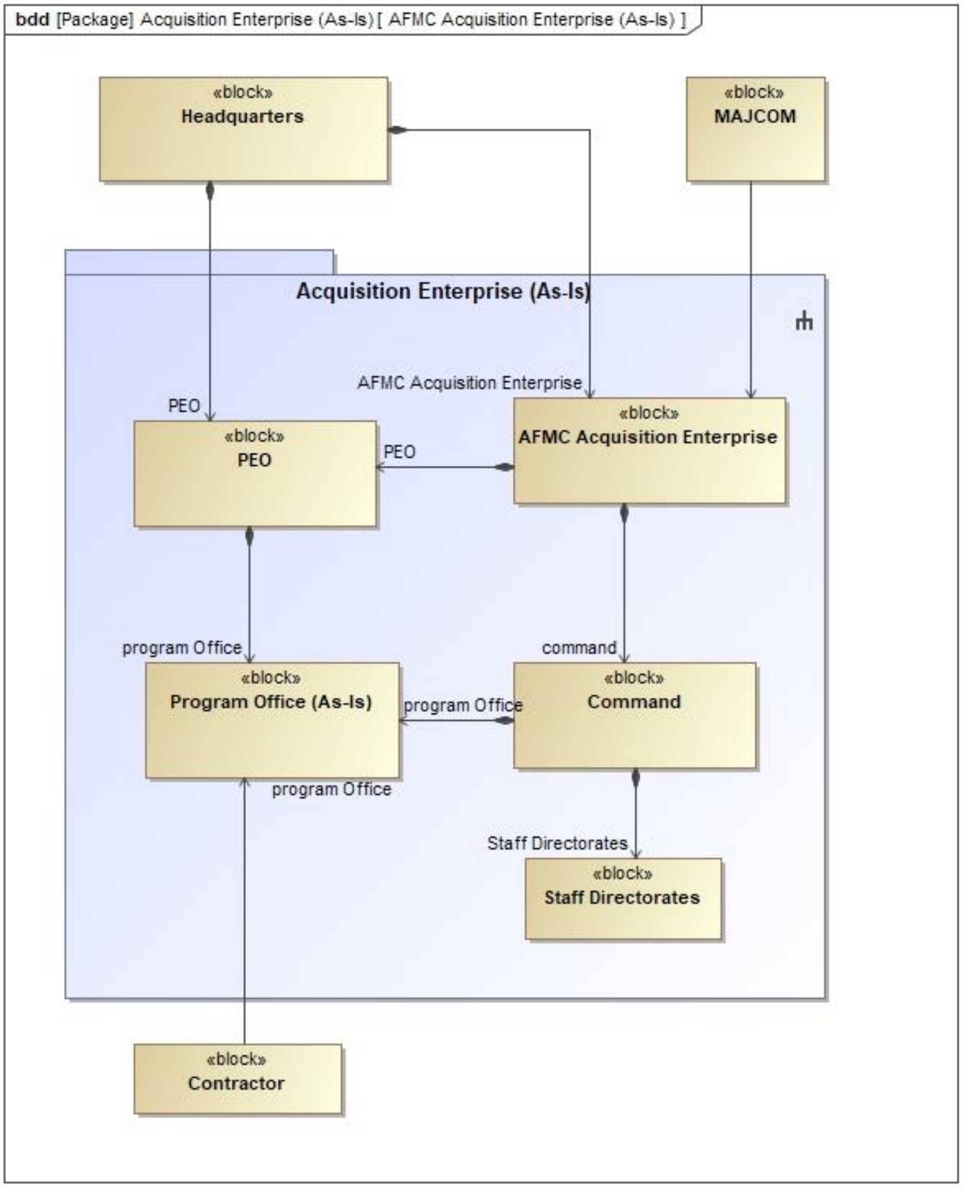


Figure 14: Organizations of the AFMC Acquisition Enterprise (Cell: Who (Exec))

The creation of the diagrams of each of the cells of the executive perspective sets the context of the AFMC Acquisition Enterprise and the PDR process that this research

continues to break down through the modeling of the other framework perspectives. The next perspective is the business manager or program office director perspective.

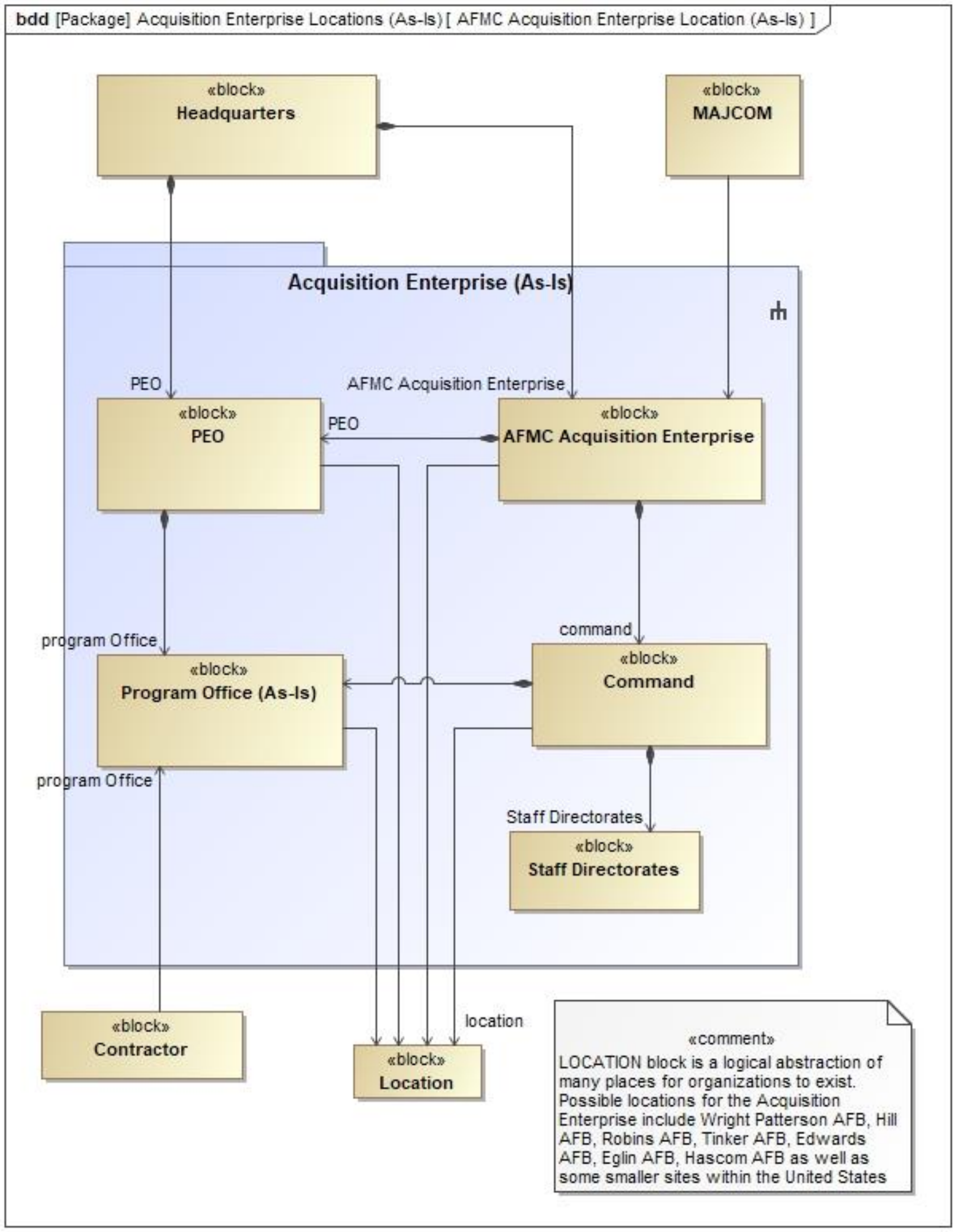


Figure 15: Acquisition Enterprise Locations of the Executive (Cell: Where (Exec))

Business Manager/Program Director Perspective

The program office director (or program director) is concerned with all of the technical and business processes within the AFMC Acquisition Enterprise. There are specific requirements to generate data to validate that the materiel solution is being built correctly and will meet the requirements of the customer. The requirements diagram within this *why* cell shows relationships between the top requirement to produce data, the systems engineering process and the requirement to conduct technical reviews of the system and data. The requirement for technical reviews, including the PDR, are the reviews that will confirm the customer's requirements are being met. This is represented by the requirements diagram of Figure 16.

As shown in Figure 17, the program director is concerned with the overall PDR process and the data products needed for that process. As illustrated in the activity model, there are specific documents that are delivered into the process. IEEE 15288.2 *Standard for Technical Reviews and Audits on Defense Programs* was used as the basis for defining these documents. They are reviewed within the process and come out of the process to move to the next step in the systems engineering process. There is also a concern with ensuring that the Systems Functional Review is completed prior to starting the PDR and that the Critical Design does not start until all the relevant PDR actions are completed. There are activities within the "Conduct PDR process" that are the concern of the architect in the next lower level of the framework and are reflected in the "How (Arch)" cell.

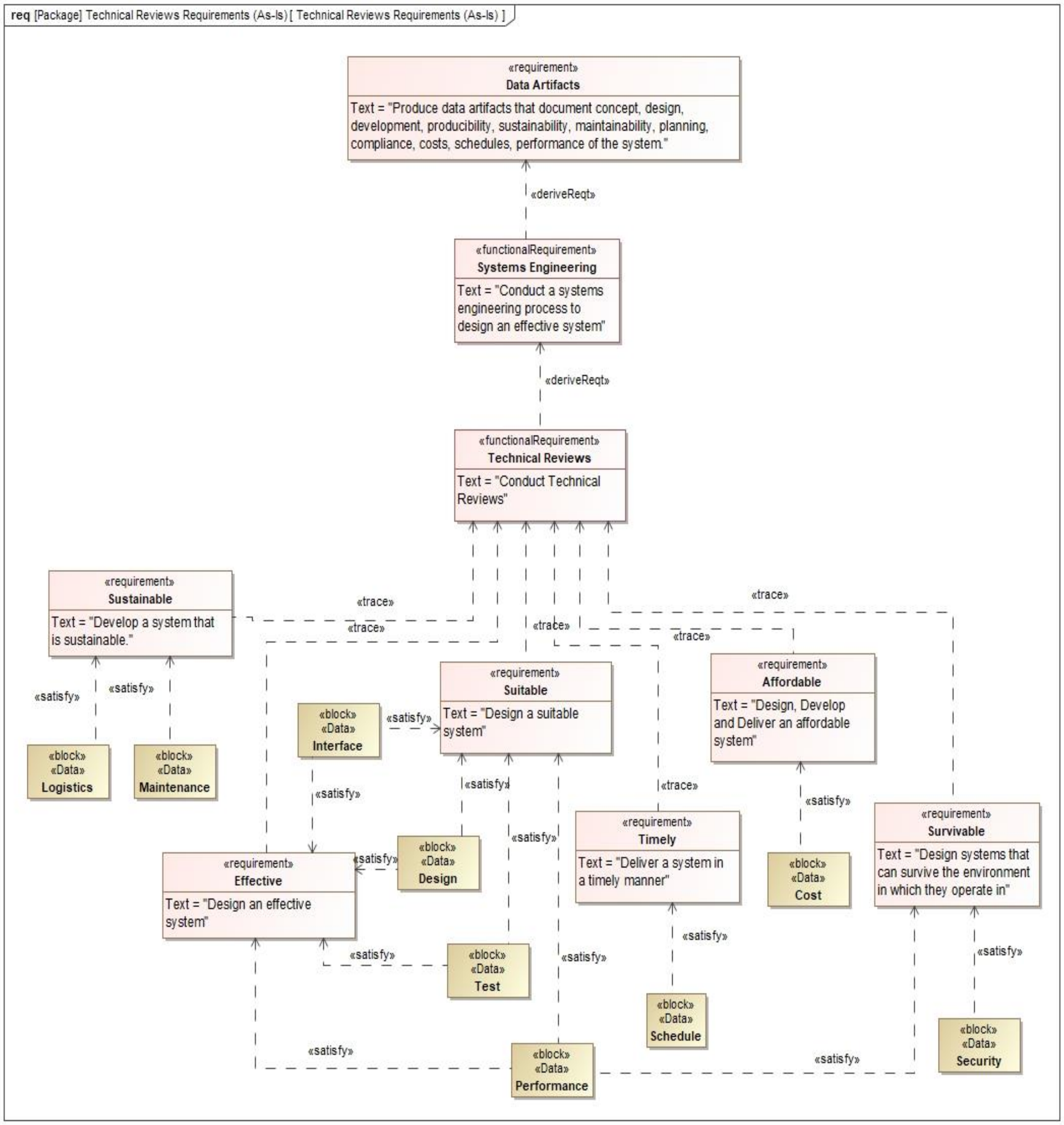


Figure 16: Requirements view of the Program Director (Cell: Why (BusM))

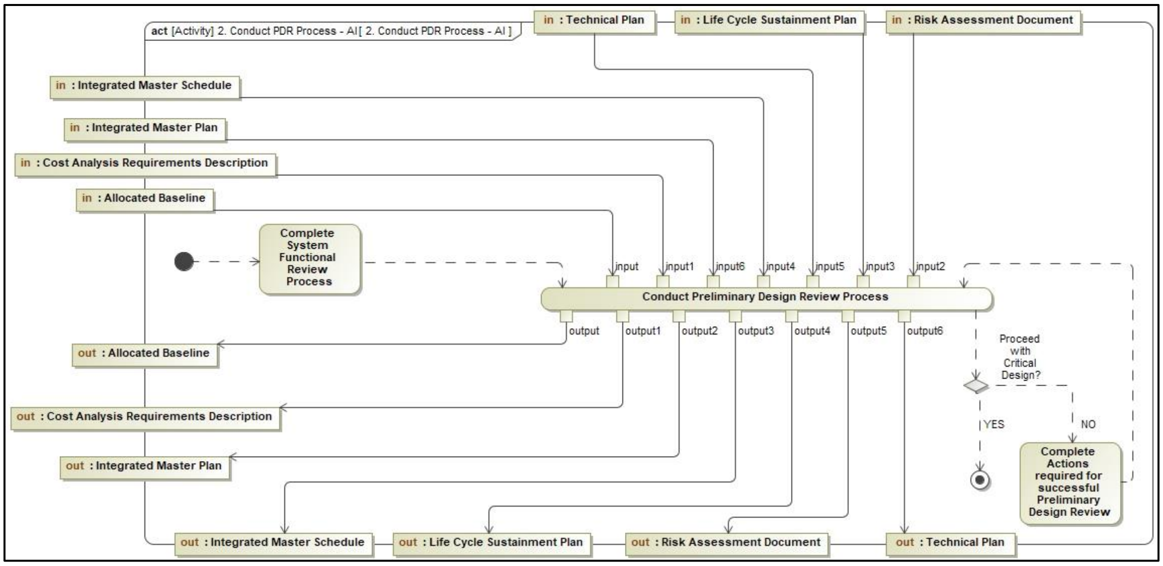


Figure 17: Conduct PDR process for the Program Director (Cell: How (BusM))

The things that the program director are concerned with as mentioned in the last paragraph include the data products that are related to the data that validate the materiel solution. These are represented by the model in Figure 18. As the model shows, the data needed for the materiel solution are contained in the documents developed by other processes of the enterprise. These documents are reviewed and approved by the PDR process.

The program director is concerned with the program office and the program office personnel as well as stakeholders who interface with the program office. Figure 19 shows the representation of the program office and its staff who are pertinent to the conduct of the PDR process.

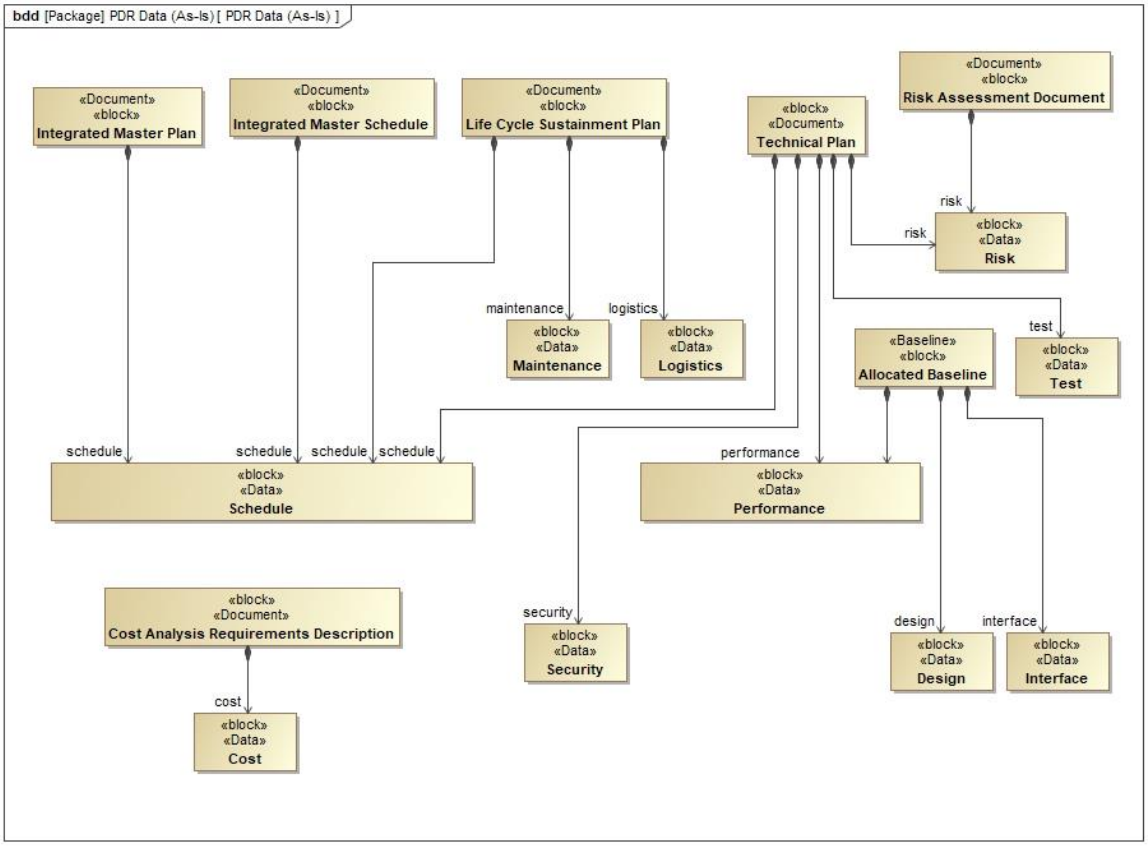


Figure 18: PDR Data for the Program Director (Cell: What (BusM))

The program director is concerned with where technical reviews are going to be conducted for his program. There are two choices within the as-is enterprise: on-premise or off-premise conference rooms. Sometimes there might be a combination of on-premise and off-premise meetings depending on circumstances. Figure 20 represents this entity relationship.

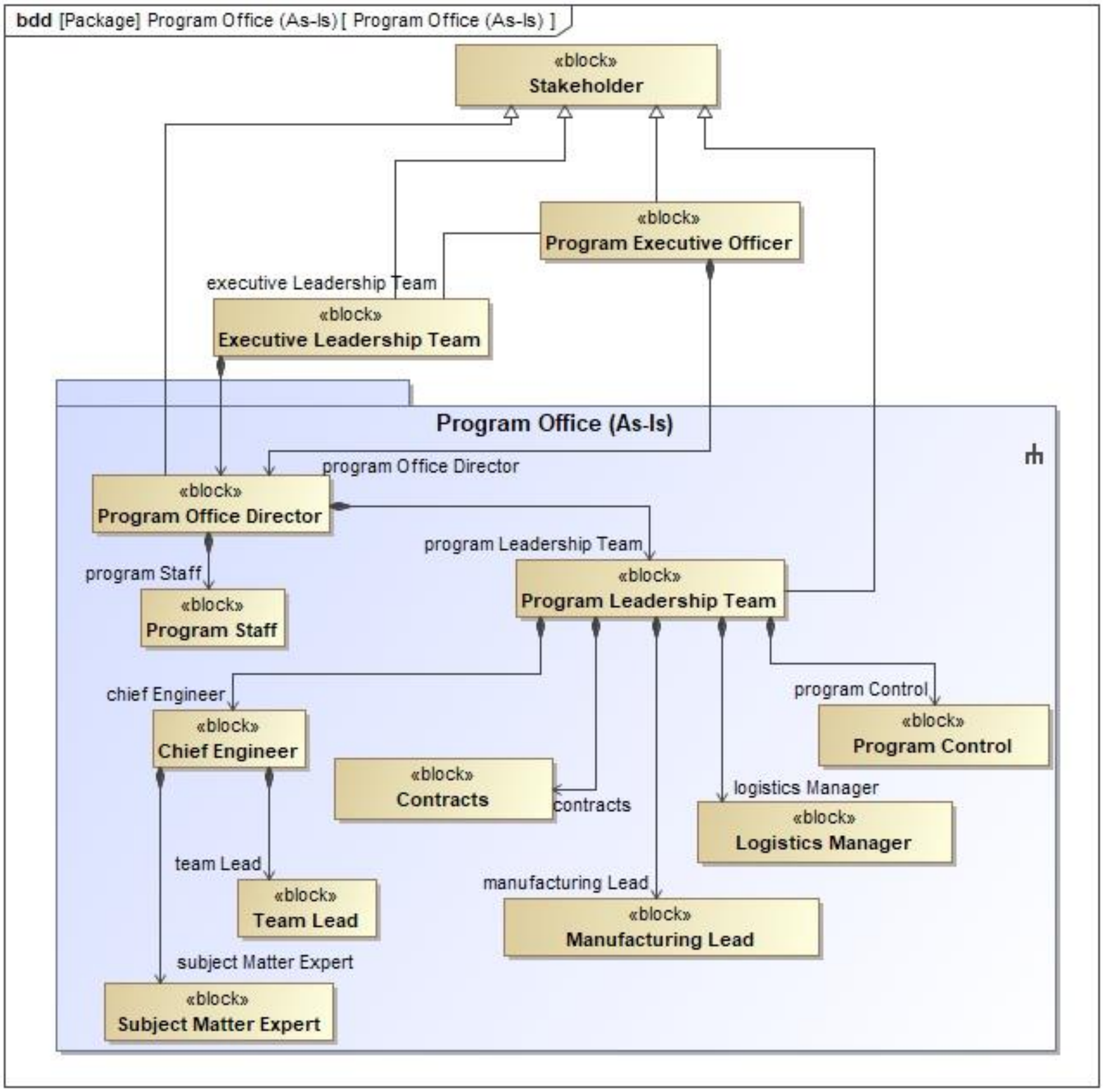


Figure 19: Program Office for the Program Director (Cell: Who (BusM))

Architect/Chief Engineer Perspective

The architect for the AFMC Acquisition Enterprise is the chief engineer. They are responsible for setting up, complying with, managing and executing the PDR process.

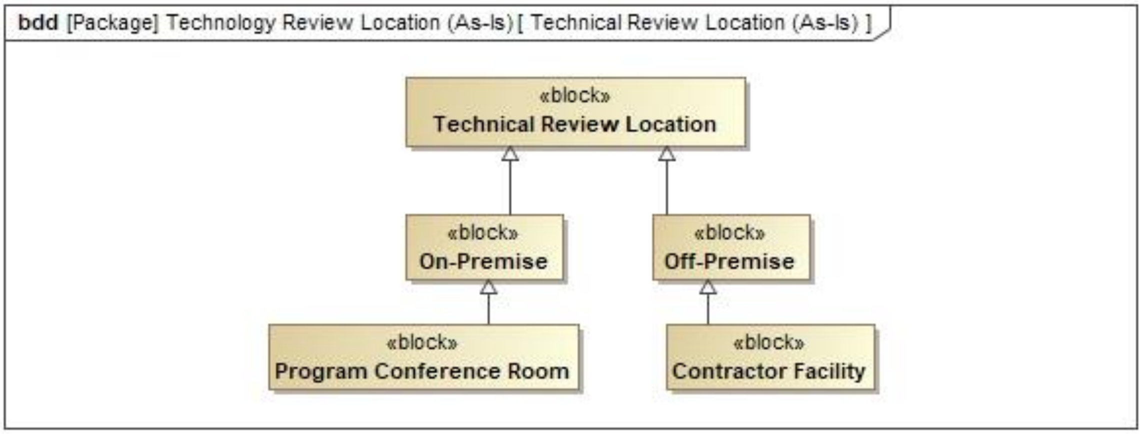


Figure 20: TMRR Technical Reviews for the Program Office Director (Cell: Where (BusM))

As shown in Figure 21, the architect has a need to deliver necessary documents for the PDR. These documents are the Cost Analysis Requirements Document, the Life Cycle Sustainment Plan, the Integrated Master Schedule, the Integrated Master Plan, the Risk Assessment, the documents that represent the Allocated Baseline, and Technical Plans. The Technical Plans include documents such as the Test and Evaluation Plan, the Systems Engineering Plan, several different levels of verification and validation plans, and modeling and simulation plans. Also shown are the documents (represented by blocks) satisfying the physical requirements for the documents. In addition, the chief engineer is concerned with ensuring that PDR participants gain the training they need to participate in a PDR.

As shown in Figure 22, the architect is concerned about the PDR process. This PDR process shows the chief engineer has a major role in preparing for, conducting and closing out the PDR. Their perspective is to ensure that these activities are completed by the correct personnel (which also includes a PDR chair, program manager, subject matter experts and a PDR recorder). The subject matter experts are mostly engineers performing

review and analysis of the data products that will be formally approved at the PDR. There is a lot of activity within this part of the process not shown as part of this perspective. This process also includes an activity block of personnel attending a PDR presentation which requires production of additional data products in the form of a PDR membership list, PDR agenda, PDR presentation briefing, PDR minutes/action items and PDR summary report (IEEE, 2015).

When considering the PDR requirements, the chief engineer is mainly concerned with the delivery and review of data products that represent the system under development, through the PDR process. This takes the form of entry products that will contain the data required by the materiel solution as shown in Figure 23. In addition, they are concerned for other entry documents needed to conduct a PDR which include the presentation document (usually a Microsoft (MS) PowerPoint document), the PDR membership list, and the PDR agenda. The other consideration is the PDR closure products also as shown in Figure 23 which include products such as the PDR minutes, action items and PDR summary report.

The chief engineer is also concerned with the PDR participants needed to conduct the PDR process as illustrated in the block definition diagram of Figure 24. This includes subject matter experts, the program manager, the chief engineer, the PDR chair and the PDR recorder. Also included as a participant is the contractor (vendor) who is usually the primary presenter during a PDR. The contractor though is still considered outside the AFMC Acquisition Enterprise.

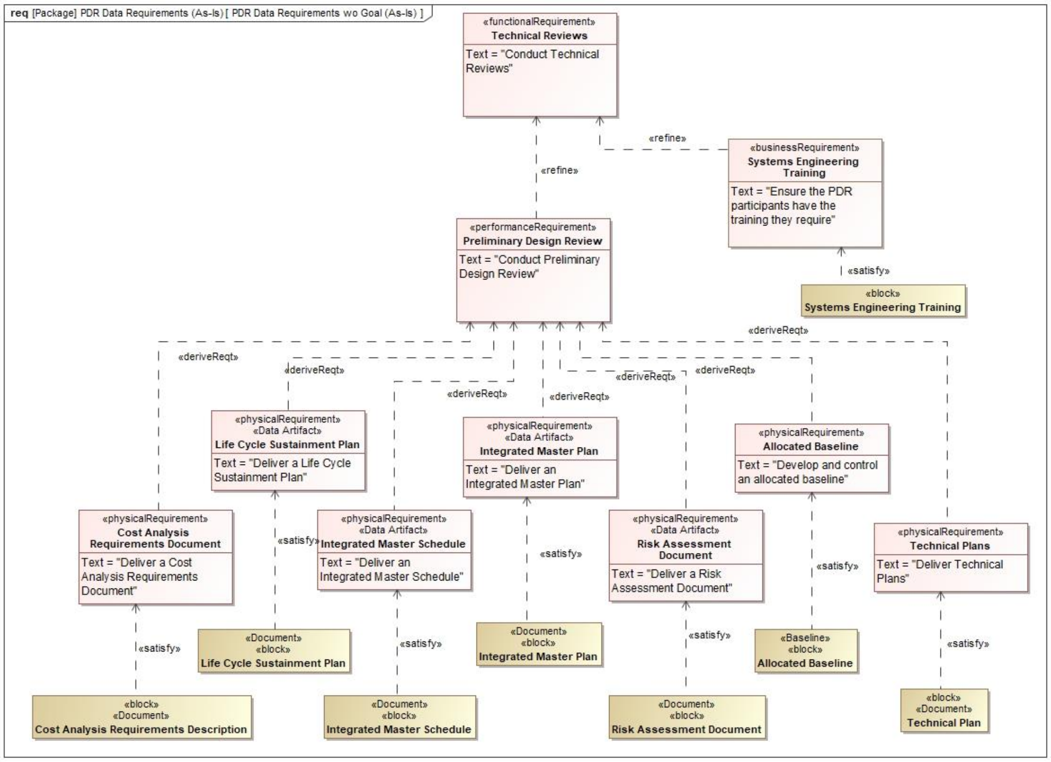


Figure 21: PDR Data Requirements for the Chief Engineer (Cell: Why (Arch))

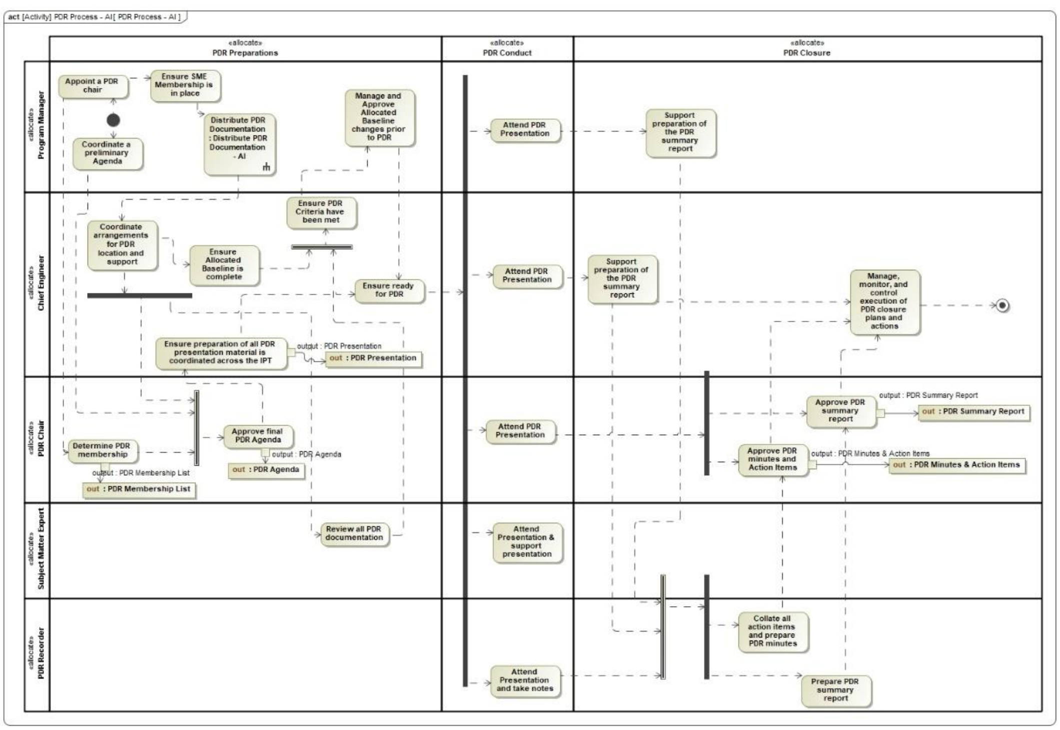


Figure 22: PDR Process for Chief Engineer (Cell: How (Arch))

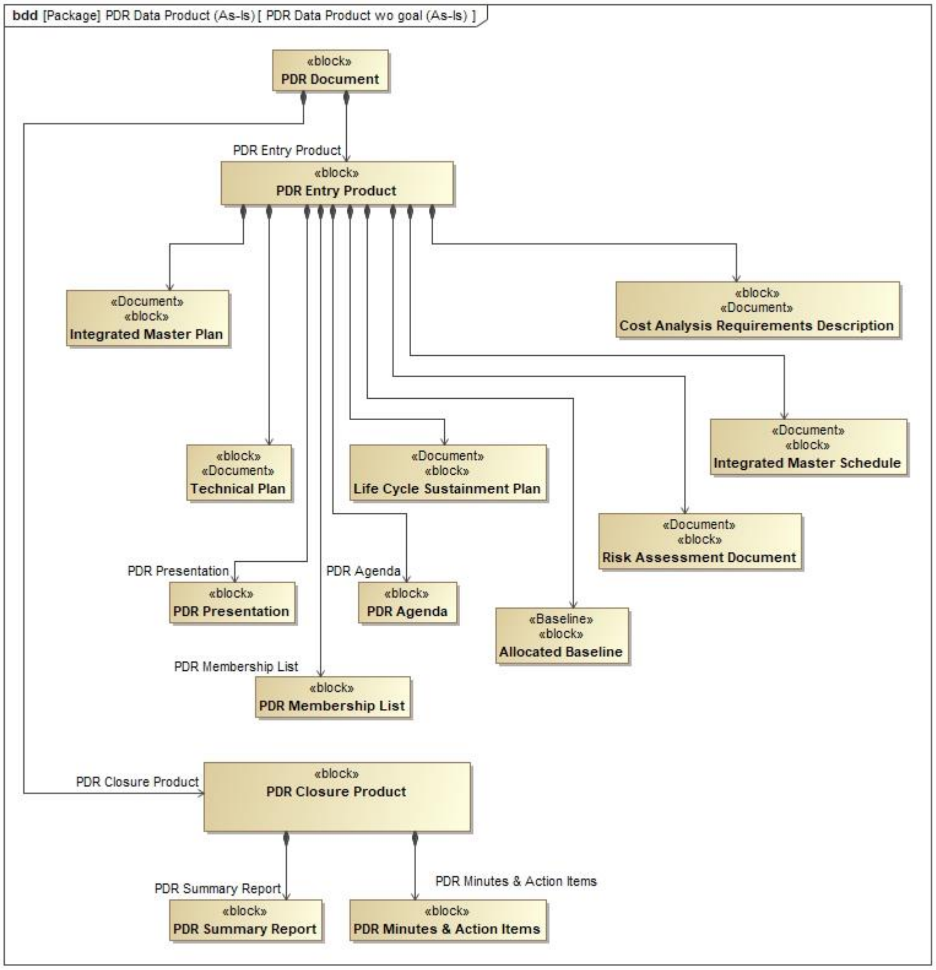


Figure 23: PDR Entry and Closure Products for the Chief Engineer (Cell: What (Arch))

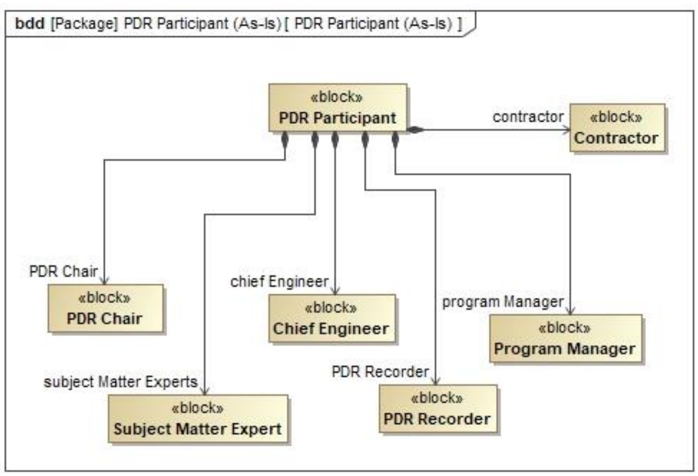


Figure 24: PDR Participants for Chief Engineer Perspective (Cell: Who (Arch))

The chief engineer cares about the details of where a PDR will take place within the AFMC Acquisition Enterprise. As shown in Figure 25, the PDR is an in-person event that is conducted either on-premise (i.e. within a conference room located on an Air Force base) or off-premise (i.e. at the contractor facility). The figure also points out that there are some constraints that need to be considered when the architect chooses the location. These include, as example, program classification security level, the size of the room needed to accommodate the PDR participants, and the technology needed in the room for the presentation (e.g., projectors, computers, internet, cybersecurity software). In addition, the location of data products during the PDR process is a concern. In the as-is enterprise, data products will be typically located on a share drive or on a participant's desktop hard drive.

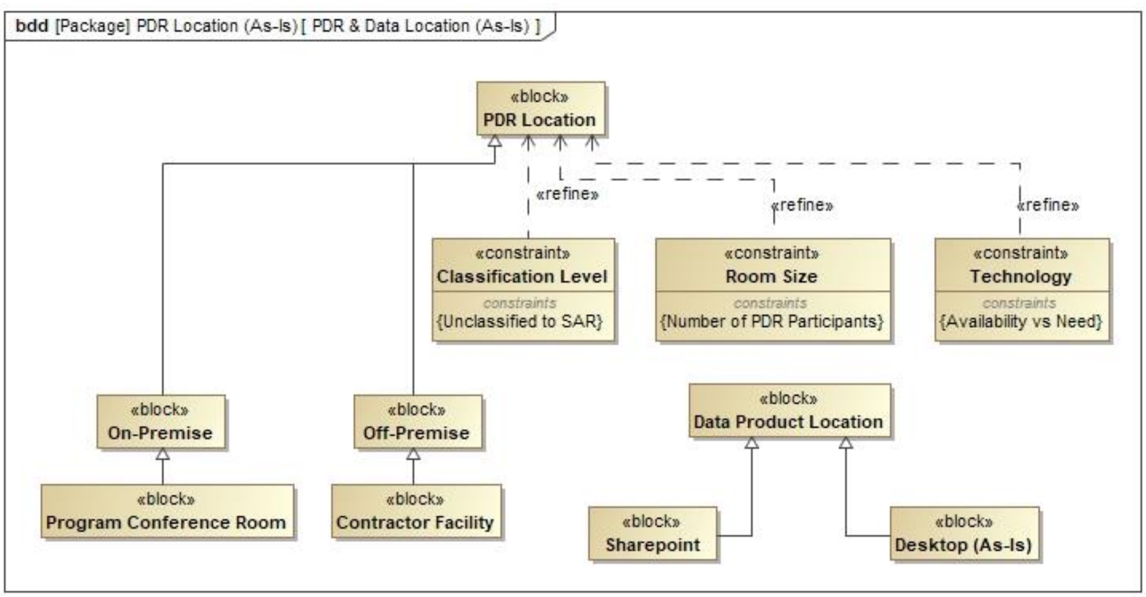


Figure 25: PDR & Data Product Location for the Chief Engineer (Cell: Where (Arch))

Engineer/Systems Engineer Perspective

Figure 26 shows that the systems engineer is concerned about the three types of technology needed for a PDR. These are Desktop Tools, Collaboration tools, and the Information Access and Management Technology items. These three broad requirements are further broken down into more specific requirements. Also included in this diagram are the items/things that satisfy those requirements for a PDR. As can be expected within the Air Force, a PDR requires data products. These data products will need to be developed using tools such as MS Word, MS PowerPoint, and MS Project. These products will need to be shared and reviewed and are usually done using tools such as MS SharePoint. In addition, every actor within the AFMC Acquisition Enterprise will have access to a laptop or desktop computer that is connected to the network (Air Force Network) which provides access to internet sites and SharePoint sites.

The systems engineer is concerned with the process of preparing and maintaining the technology needed for a PDR. It is important that the IT infrastructure is in place for the development, review and delivery of the data products as well as being available for the PDR conduct and post PDR activities. The IT preparation and maintenance activities are represented by the activity diagram in Figure 27 where there are actors that are assigned responsibilities within these activities. As example, these actors include security specialists, cybersecurity specialists, IT specialists and data managers.

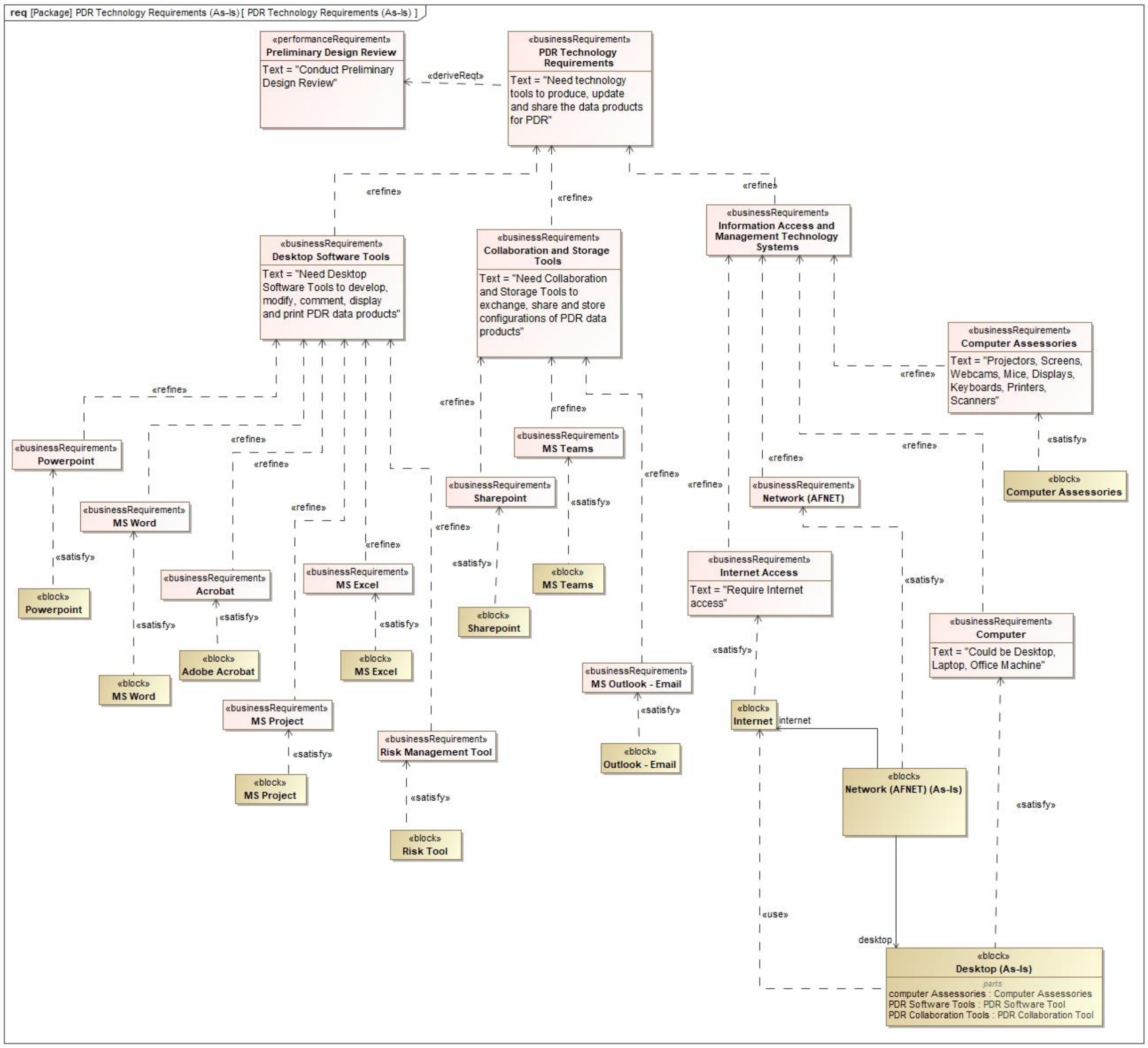


Figure 26: PDR Technology Requirements for the Systems Engineer (Cell: Why (Engr))

As shown in Figure 28, the engineer cares about the relationship between the documents required for the PDR, and the IT and software tools needed to produce, review, comment on, and approve the documentation, as well as the IT and software needed to conduct the PDR meeting. The documents also include the PDR presentation which is normally a MS PowerPoint-created document which is projected on a screen in the room and shared during the meeting for all participants to see. There are also several block definition diagrams in this cell, not shown, such as a BDD to represent the

composition of the Allocated Baseline, a BDD to represent the composition of the PDR Entry Products and a BDD to represent the composition of the PDR Closure Products. These are all considered the "things" that the engineer is concerned with.

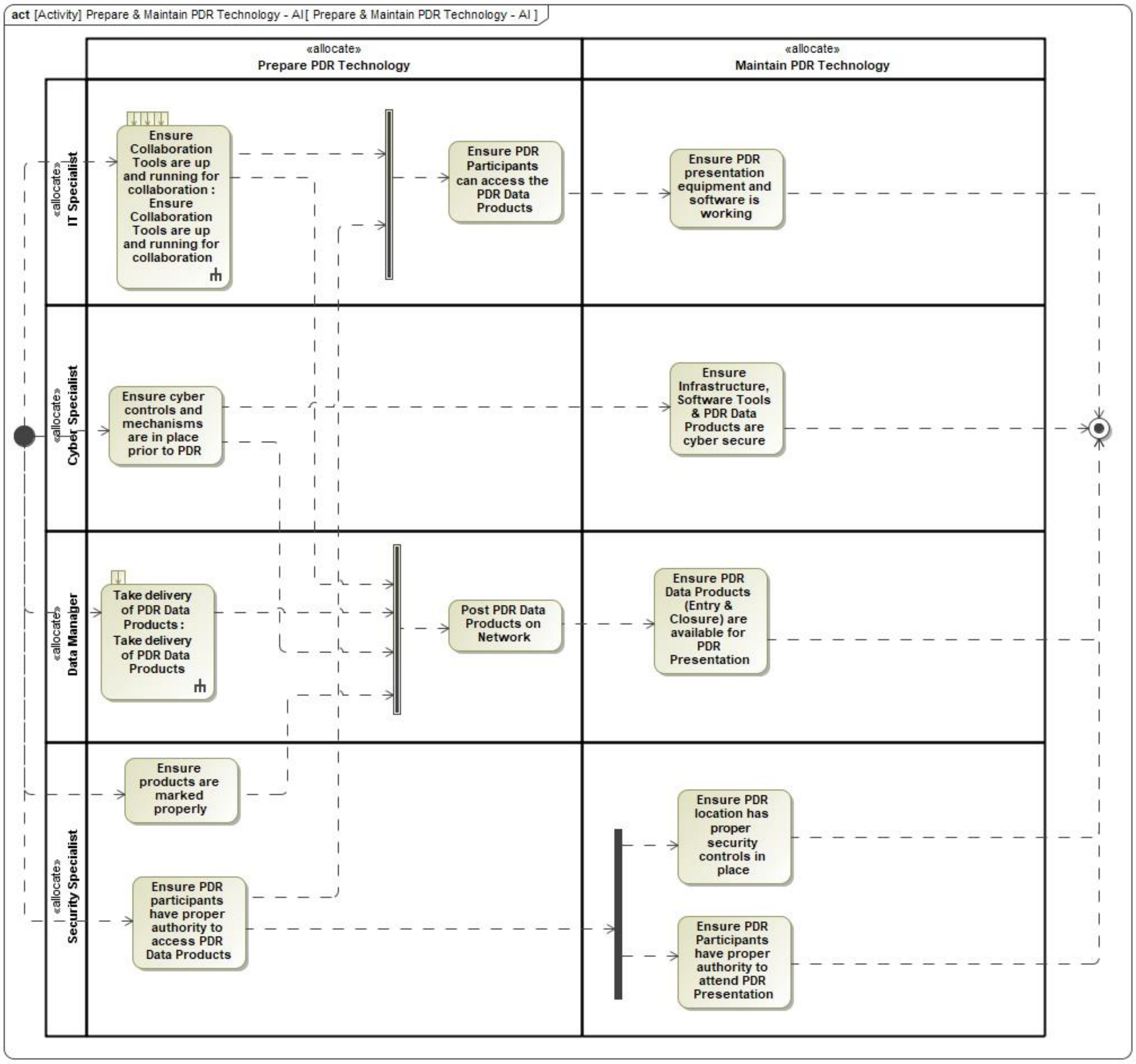


Figure 27: Prepare & Maintain PDR Technology for the Systems Engineer (Cell: How (Engr))

The engineer cares about the specialists who are needed to prepare and maintain the IT and software needed for the PDR processes. As shown in Figure 29, this shows personnel such as IT specialists, cyber specialists, security specialists, and data managers

who do not make a direct impact to the materiel solution but who are necessary for the successful completion of a PDR for the AFMC Acquisition Enterprise. These individuals must be available to deploy software tools and make needed connections, provide help desk role when issues arise, and ensure communication devices are working properly, among other tasks. This BDD shows relationships between the program office and these specialists. These specialists may not all come from the program office but may be supplied by a support office within the enterprise.

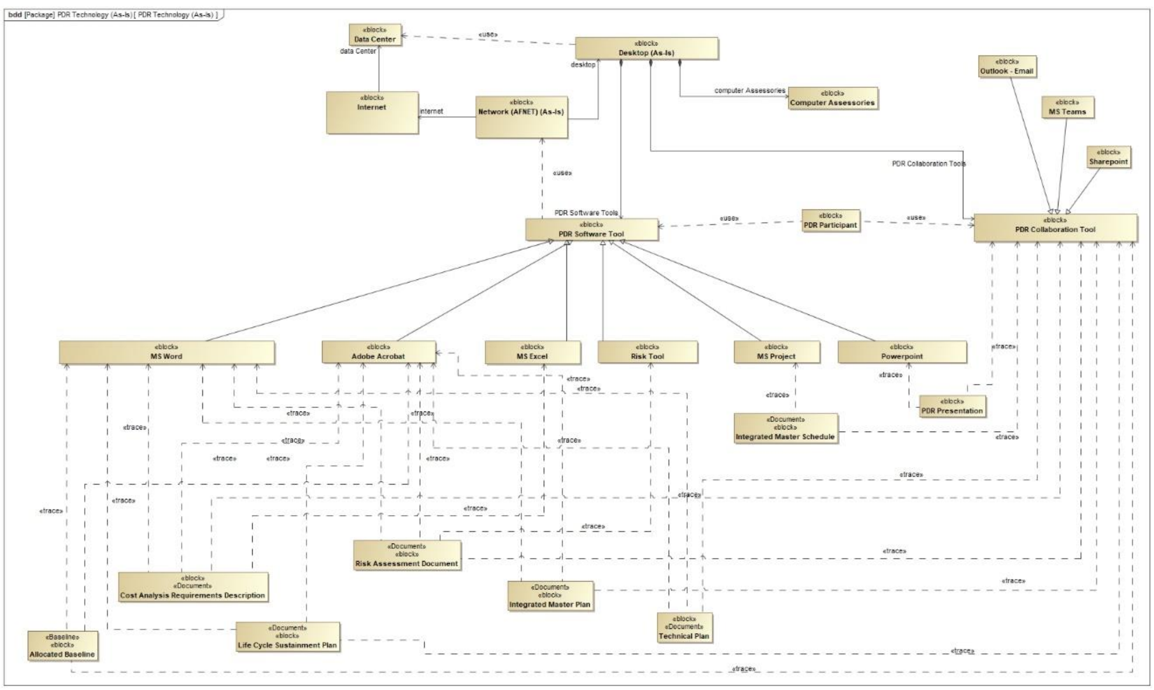


Figure 28: PDR Technology for Systems Engineer (Cell: What (Engr))

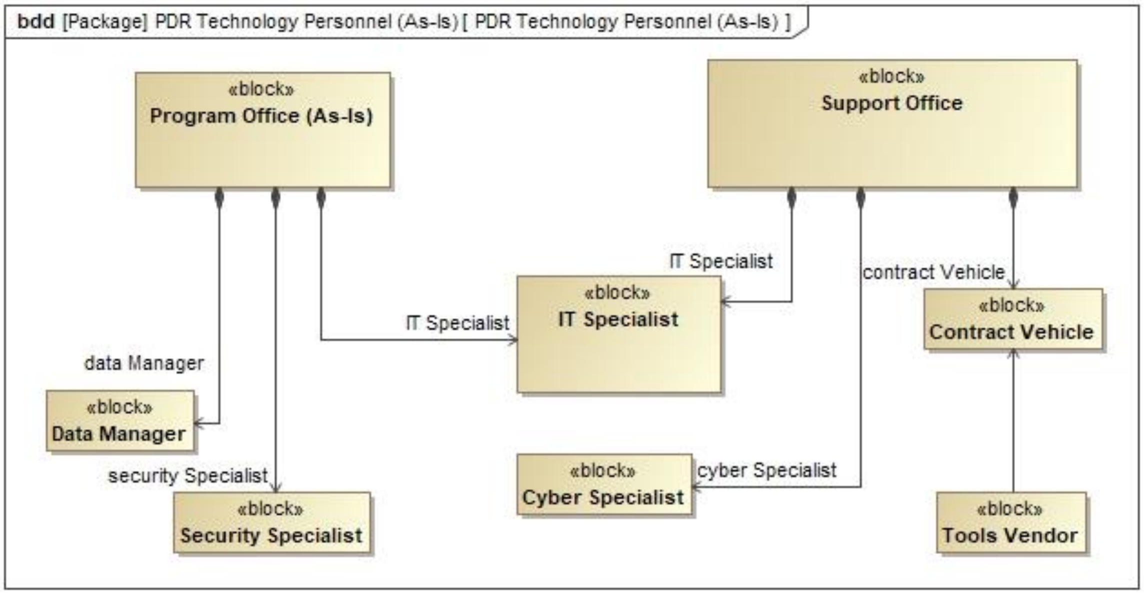


Figure 29: PDR Technology Personnel for the Systems Engineer (Cell: Who (Engr))

As shown in Figure 30, the systems engineer is concerned about where the technology is for him to ensure he can do all the other aspects of his job. This BDD shows the two generalized locations (On and off premises), and where the technology might exist for a typical PDR process. PDR participants will have computers (desktop) which are considered on-premise, whereas they will use the internet to get to a data center that may be off-premise. In addition, everything that the contractor does will be completed within an off-premise system usually in their facilities.

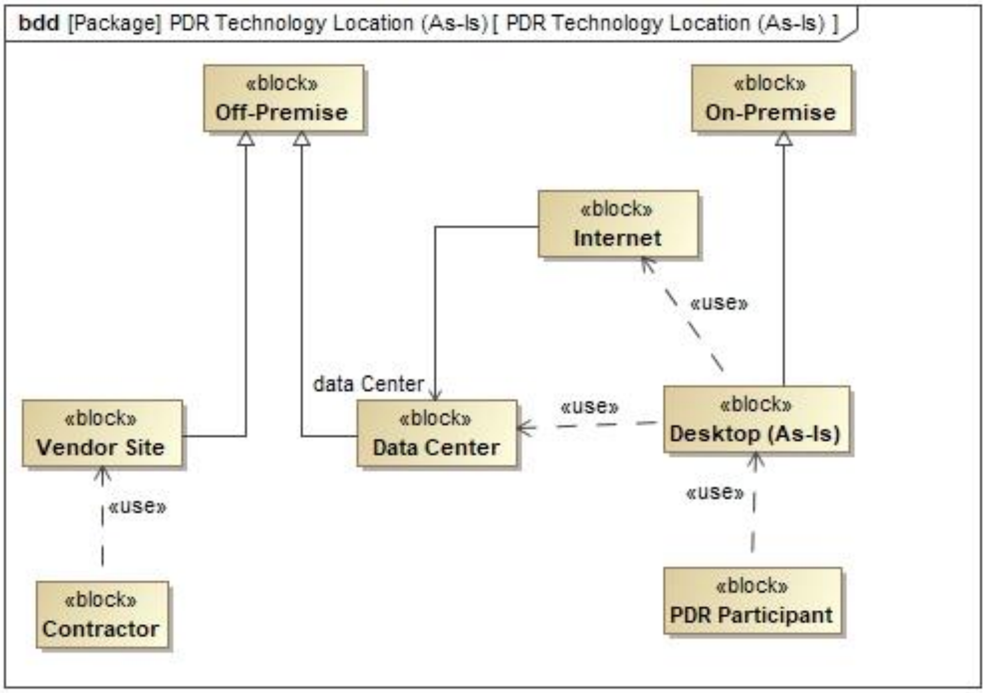


Figure 30: PDR Technology Location for Systems Engineer (Cell: Where (Engr))

This section laid out the as-is model of the AFMC Acquisition Enterprise for the PDR process. It laid it out within a framework that addressed four perspectives of the enterprise. For each perspective, the interrogatives of *why*, *how*, *what*, *who* and *where* were addressed resulting in a picture of the business of conducting PDRs. The next step is to look at what are the primary effects of the Digital Campaign goals on this as-is enterprise model.

Digital Campaign Primary Impacts

To address the digital transformation impacts to the as-is AFMC Acquisition Enterprise model, the next step taken was to map the Digital Campaign's goals to the Zachman Framework. The Digital Campaign was established to digitally transform the acquisition enterprise. The Campaign leadership set up six lines of effort around six

goals to accomplish this transformation. Those goals are shown in Table 1 and were developed by consulting subject matter experts in March 2020 who in some cases vaguely knew what the end should look like and what was possible under an austere budget climate. LOE 4 addresses policy and guidance with its primary objective to review policies outside the AFMC Acquisition Enterprise. Therefore, this research does not address the LOE 4 goal. The assumption made by the campaign was that internal policy and guidance will change when impacted by changes to policies from outside the enterprise. Therefore, this research focused on the other five LOE goals.

This research mapped the remaining five goals to the cells of the Zachman Framework based on the expected primary impact that goal achievement would have on a specific perspective and interrogative. Figure 31 shows the summary of mapping each line of effort goal to its primary cell impacted (green cell). This research reviewed the words used in the goal to interpret what Zachman cells are primarily affected. It was discovered that it is the Zachman perspectives and the interrogatives that are considered when choosing which cells are impacted. This sounds counterintuitive in that one would expect that the entities and/or relationships within the cells need to be considered for impact. It turns out that when a goal mentions influencing for instance the infrastructure of the enterprise, it is pretty easy to say that the engineer perspective and the *what* interrogative are primarily impacted. The engineer because this person is concerned with the infrastructure and its constraints in meeting the needs of the enterprise, and the *what* because the infrastructure is a thing that exists within the enterprise. This process therefore is interpretative based on the words of the LOE goal and is described in the following paragraphs.

This research interpreted the goals of LOE 0 and 1 to have an impact on the *what* interrogative of the engineer perspective because the two goals mention changing the IT infrastructure (LOE 0) and Models and Tools (LOE 1). This research interpreted the goal of LOE 2 to impact the *what* interrogative of the architect as the goal mentions using a Government Reference Architecture (GRA) and related standards and datasets to take maximum advantage of an integrated digital environment. This directly impacts the form of the data products (models vice documents) which the chief engineer is most concerned about. This research interpreted the LOE 3 goal to impact the *how* interrogative of the architect. The architect is mostly concerned with the PDR process which would be impacted under LOE 3 goal achievement. This research interpreted the LOE 5 goal to impact the workforce training and the workforce motivation to change to this new way of business. This primary impact was applied to the *what* and the *who* interrogative of the architect perspective because there would be a change in training (*what*) affecting the skills of the PDR participants (*who*). Another primary impact of LOE 5 was applied to the *why* of all of the perspectives because the goal reads that change needs to occur across the entire enterprise. Therefore, every perspective will be affected by this line of effort. The impact within each cell by each LOE goal is described further in the following paragraphs.

Table 1: Line of Effort Goals of the AFMC Digital Campaign

Line of Effort	Line of Effort Name	Line of Effort Goal
0	Integrated Environment - IT Infrastructure	Provide overarching guidance to influence corporate IT improvement investments to enable a robust, secure infrastructure for the enterprise-wide Digital Campaign
1	Integrated Environment - Tools and Models	Provide an Integrated Digital Environment (IDE) of models and tools for collaboration, analysis, and visualization across the functional domains of AF users
2	Standards, Data, and Architectures	Provide overarching guidance on the use of Government Reference Architectures (GRA) and related standards and datasets for use in an integrated digital environment for application at the enterprise and system levels
3	Lifecycle Strategies and Processes	Develop Life Cycle Strategies and Processes for Technology Transition, System Acquisition and Product Support using an IDE, supporting lifecycle activities from concept development to disposal
4	Policy and Guidance	Assess and define the required policy and guidance updates/changes to enable full implementation of the Digital Transformation
5	Workforce and Culture	Drive culture change across the AFMC enterprise through training and change management, enabling a workforce well versed in Digital Engineering

	WHY	HOW	WHAT	WHO	WHERE	WHEN
EXECUTIVE (AFMC Executive Leader)	Change to Stakeholders Requirements (LOE 5)	Conduct Acquisition Process	Enterprise Data	Acquisition Enterprise	Acquisition Enterprise Locations	X
BUSINESS MANAGER (Program Director)	Change Technical Review Requirements (LOE 5)	Conduct Technical Review Process	PDR Data	Program Office	Technology Maturation and Risk Reduction Phase	X
ARCHITECT (Chief Engineer)	Change PDR Requirements (LOE 5)	Change to PDR Process (LOE 3)	Change to PDR Data Products (LOE 2, LOE 5)	Change to PDR Participants (LOE 5)	PDR Location	X
ENGINEER (Systems Engineer)	Change PDR Technology Requirements (LOE 5)	Prepare/Maintain PDR Technology	Change to PDR Technology (LOE 0, LOE 1)	PDR Technology Personnel	PDR Technology Location	X
TECHNICIAN (CONTRACTOR)	X	X	X	X	X	X

Line of Effort (LOE) 0
- Provide overarching guidance to influence corporate IT improvement investments to enable a robust, secure infrastructure for the enterprise-wide Digital Campaign

LOE 1
- Provide an Integrated Digital Environment (IDE) of models and tools for collaboration, analysis, and visualization across the functional domains of AF users

LOE 2
- Provide overarching guidance on the use of Government Reference Architectures (GRA) and related standards and datasets for use in an integrated digital environment for application at the enterprise and system levels

LOE 3
- Develop Life Cycle Strategies and Processes for Technology Transition, System Acquisition and Product Support using an IDE, supporting lifecycle activities from concept development to disposal

LOE 5
- Drive culture change across the AFMC enterprise through training and change management, enabling a workforce well versed in Digital Engineering

Primary Digital Change | (LOE X) = Line of Effort(s) Primary Impact to Cell | PDR - Preliminary Design Review

Figure 31: Summary of primary impacts from Digital Campaign Goals indicated by Green Cells

LOE 0 and LOE 1 goals are related and were broken into two goals and two line of effort teams because the Campaign leadership thought the workload was too big for a single team. Mapping these two goals to the Zachman Framework show that they impact the same cell. Based on the wording of the LOE 0 goal of "Provide overarching guidance to influence corporate IT improvement investments to enable a robust, secure infrastructure for the enterprise-wide Digital Campaign," one concludes that the primary changes are the infrastructure and IT investments entities such as the data centers, desktops and the Air Force Network (AFNET) of the as-is cell as shown in Figure 32 to the use of Cloud One, Platform One, AFNET and desktops of the "to-be" cell as shown in Figure 33. Cloud One is the Air Force's branding for contracting and receiving service of one or more of the major commercial cloud providers. Platform One is an Air Force provided service to system programs to host software products within a Cloud One instantiation.

For the LOE 1 goal of "Provide an Integrated Digital Environment (IDE) of models and tools for collaboration, analysis, and visualization across the functional domains of AF users," the LOE 1 leadership and SMEs knew that using integrated models and tools was the to-be state they wanted and knew that this would best happen within a single integrated digital environment. Therefore, as shown in Figure 34, this goal impacts the various office products used to create and display documents in the as-is cell to the various model-based tools of the to-be cell.

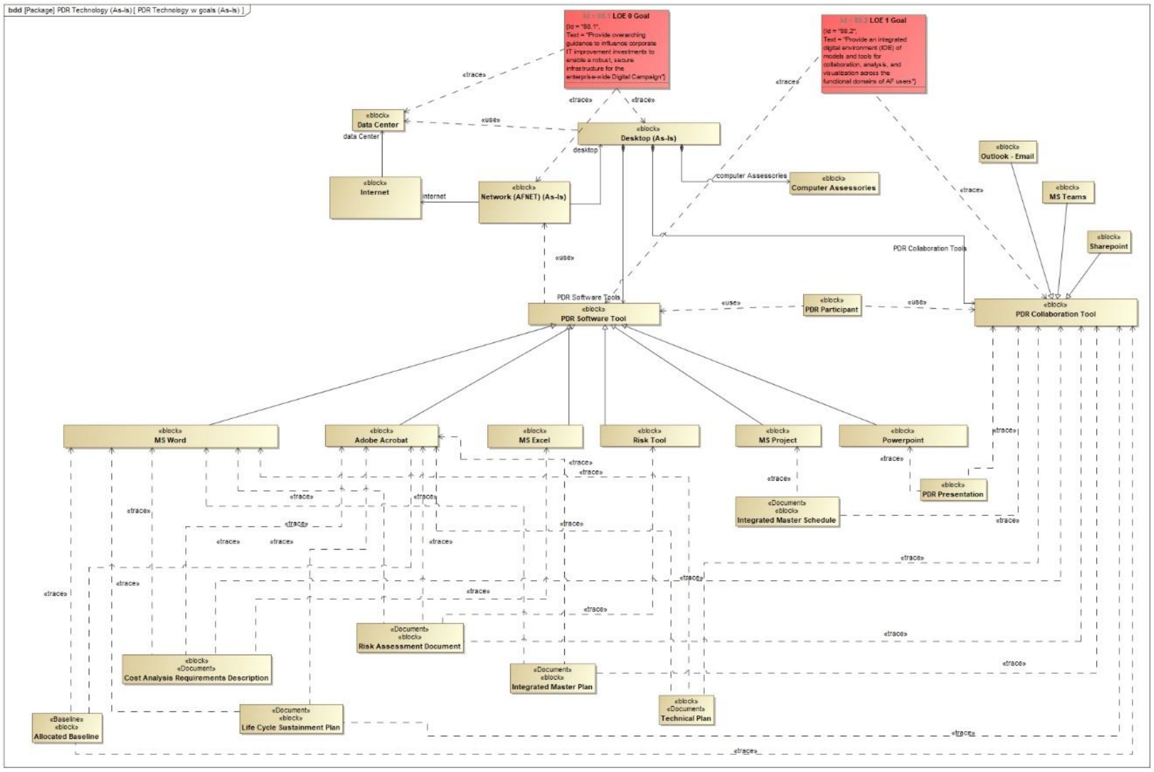


Figure 32: PDR Technology (As-Is) (Cell: What (Engr))

The LOE 2 goal of "Provide overarching guidance on the use of Government Reference Architectures (GRA) and related standards and datasets for use in an integrated digital environment for application at the enterprise and system levels", centers on the development of reference models to replace the documents that would ordinarily be produced during an acquisition. In the PDR process, this changes the data products created, used, reviewed and approved (see Figure 34). Instead of an allocated baseline in a series of specification documents, it is documented in a model representing the system (i.e., a system model). Other impacted documents such as the Systems Engineering Plan, the Test and Evaluation Master Plan, the Integrated Master Plan as well as other acquisition planning documents have their data show up in a model called an Acquisition

Reference Model (current term being used by the Digital Campaign) as shown in Figure 35. And a third model is defined as the Government Reference Model (GRM).

For the purposes of this research and to avoid confusion, explanation is required on what a GRM is and its relationship to a Government Reference Architecture. DoD defines a GRA "as an authoritative source of information about a specific subject area that guides and constrains the instantiations of multiple architectures and solutions" (DoD CIO, 2010). That definition holds for this research. The GRA is the source of the information that is documented in at least one model or view. The GRM is that set of models and/or views that represents the GRA. Therefore, it is the conclusion of this research that the GRM contains the data that constraints and guides the design of the solution contained in a system model including a top-level architecture model, and requirements and rules for a developer (usually a contractor) to follow in proposing, creating and validating the system design.

The LOE 3 goal of "Develop Life Cycle Strategies and Processes for Technology Transition, System Acquisition and Product Support using an Integrated Digital Environment (IDE), supporting lifecycle activities from concept development to disposal" is focused on modifying processes or the *how* column of the Zachman Framework. The owner of these processes is the architect for the PDR. The LOE 3 goal change to processes impacts the "How (Arch)" cell as represented by the model as shown in Figure 36. The LOE goal impacts the conduct of the PDR process therefore it is represented by a trace to the process diagram.

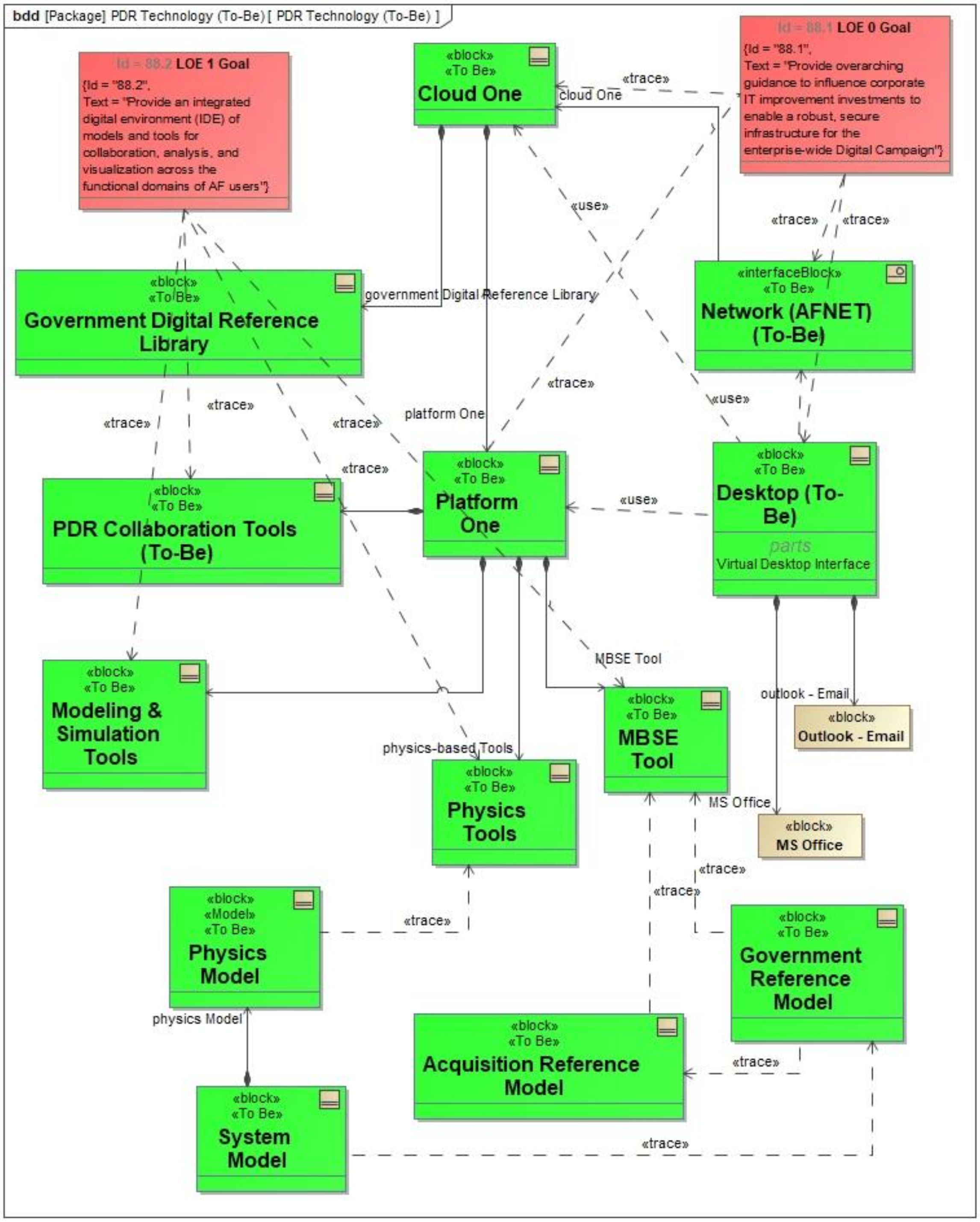


Figure 33: Impact of LOE 0 and LOE 1 Goals (Cell: What (Engr))

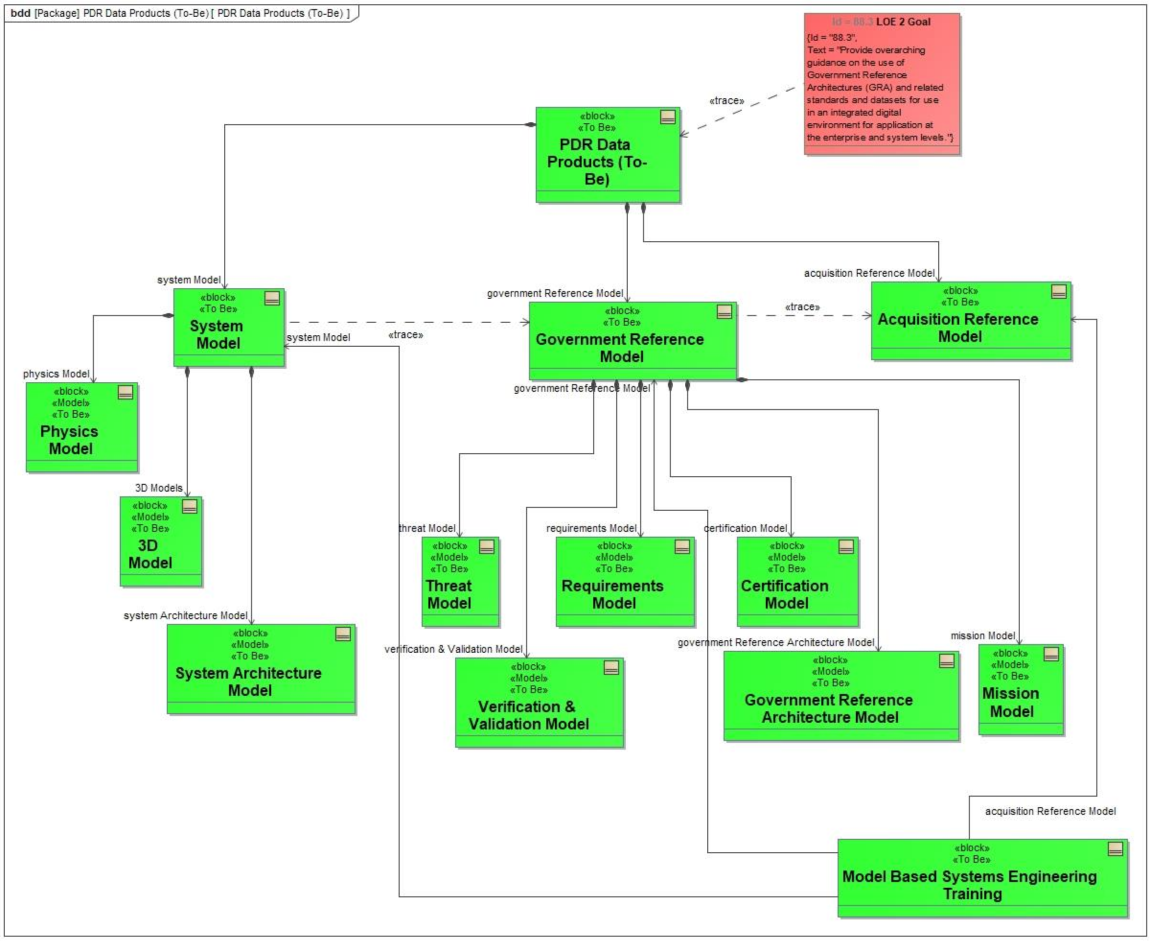


Figure 34: LOE 2 Impact to PDR Data Products (Cell: What (Arch))

The LOE 5 goal of "Drive culture change across the AFMC enterprise through training and change management, enabling a workforce well versed in Digital Engineering" is written such that its impact is two-fold by the LOE 5 team. The team must affect change to workforce training as well as to what the workforce thinks of the digital engineering requirement and its willingness to implement. The training affects the *who* of the architect's perspective. The chief engineer is responsible to ensure that the

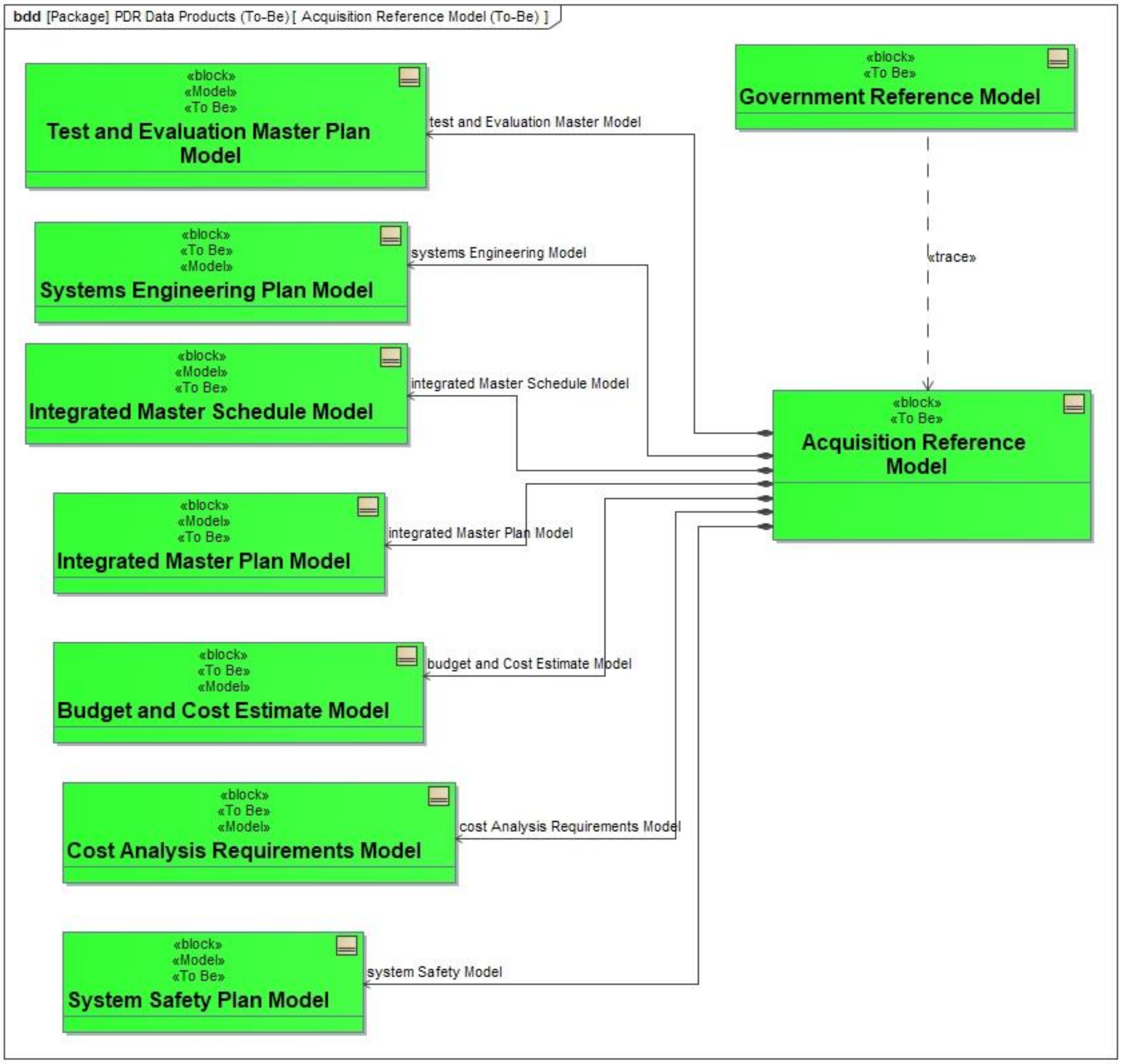


Figure 35: Acquisition Reference Model (Cell: What (Arch))

PDR participants have the knowledge that they require to fulfill the roles that they have assumed within the PDR process. In addition, the LOE 5 team has the task of driving the entire workforce to transform, so the goal impacts all four of the *why* cells from the executive down to the engineer perspectives. This is shown for each perspective in Figure 37 (executive), Figure 38 (business manager), Figure 39 (architect) and Figure 40 (engineer).

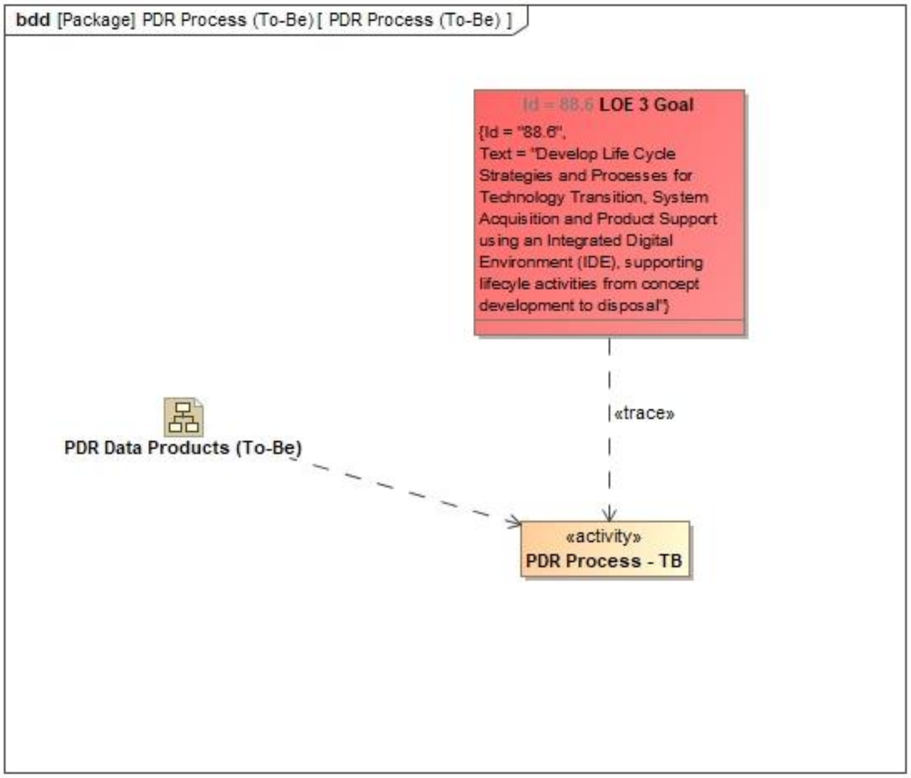


Figure 36: LOE 3 Goal Impact to PDR Process (Cell: How (Arch))

It is not automatic to discover the LOE goal impacts to the enterprise. It takes SMEs assessing the impacts to their areas of expertise based on the state-of-the-art of technology that the organization wishes to implement. The modeling using the Zachman Framework does make it easier to see where those impacts are within the models of the framework, making assessment and assignment much easier by a SME. Once having identified the primary impacted cells, the next step of this research is to analyze the enterprise for secondary impacts which is covered in Chapter IV.

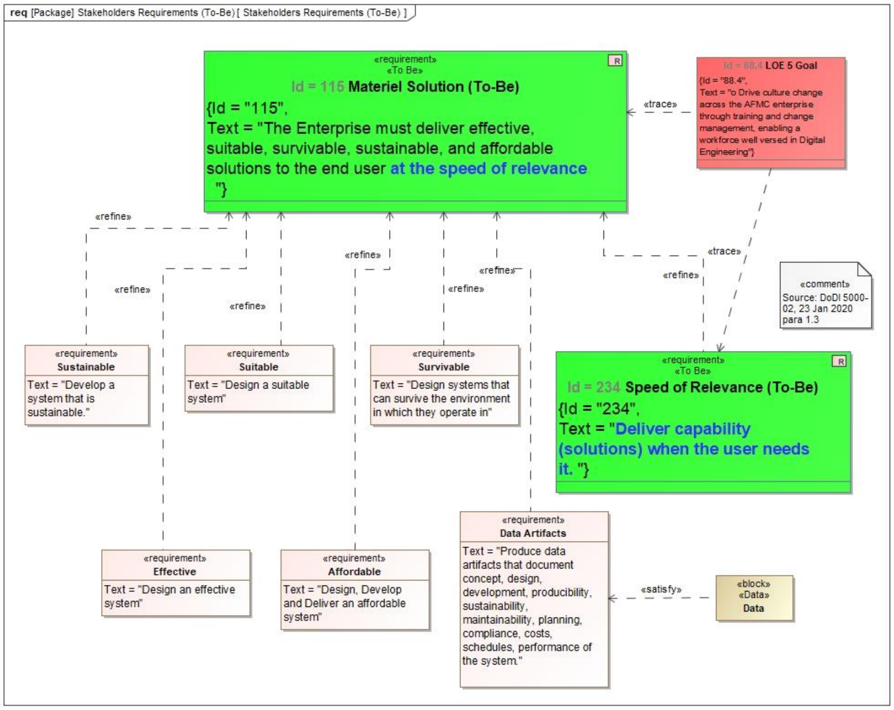


Figure 37: LOE 5 Impact to the AFMC Executive (Cell: Why (Exec))

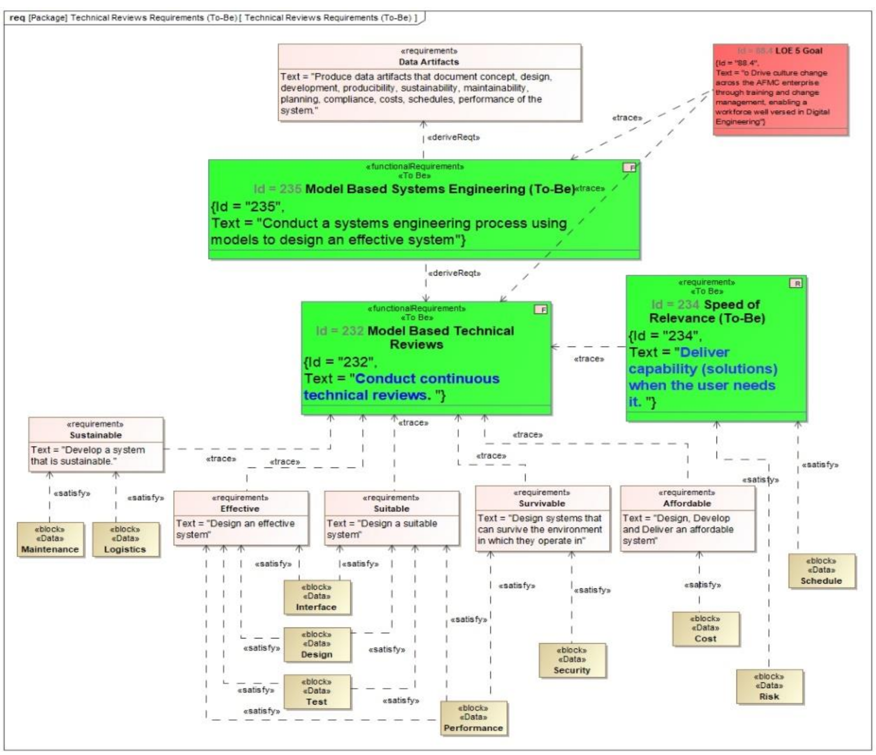


Figure 38: LOE 5 Impact to Technical Review Requirements (Cell: Why (BusM))

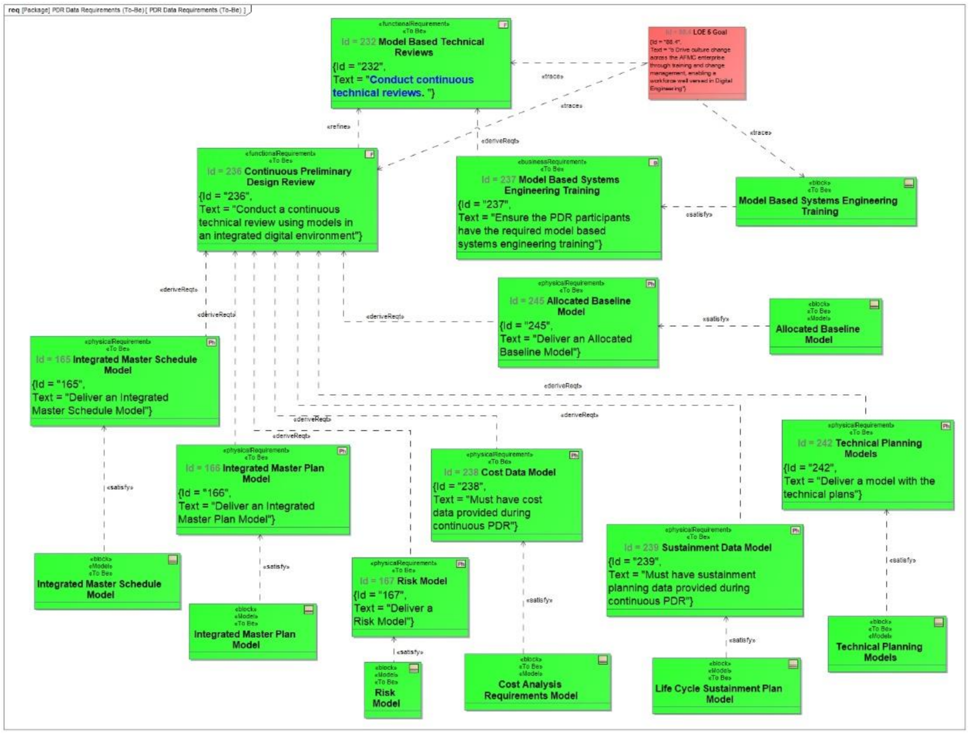


Figure 39: LOE 5 Impact to PDR Data Requirements (Cell: Why (Arch))

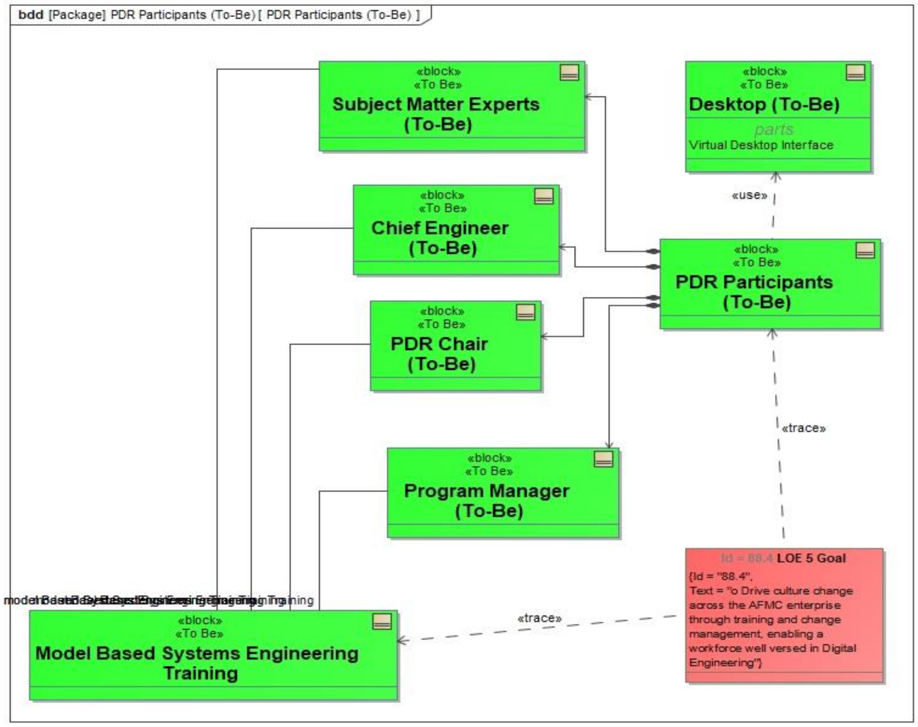


Figure 40: LOE 5 Goal Impact to the Architect Perspective (Cell: Who (Arch))

Summary

This research followed a systems engineering methodology using OOSEM in building the as-is AFMC Acquisition Enterprise. To summary this, refer to Figure 41, where the left-hand side shows this research's systems engineering decomposition process parallel to the OOSEM process for building the as-is enterprise. This was completed within the structure of the Zachman Framework. This research addressed four of the perspectives (AFMC executive, program director, chief engineer and systems engineer). Within these perspectives, models were built for each of five interrogatives (*Why*, *How*, *What*, *Who* and *Where*).

Similar to the systems engineering process, the Zachman Framework provides the basis to build the contextual perspective (equivalent to the AFMC executive perspective) of the acquisition enterprise followed by more details of the design as one moves down the framework perspectives. This results in adding more detail in the conceptual perspective (equivalent to the program director perspective), even more detail in the logical perspective (equivalent to the chief engineer perspective) and finally, the most detail in the physical perspective (equivalent to the systems engineer perspective). Models were built within each cell of the framework with this process. The result of building models in each of the five interrogatives of each of four perspectives completes a picture of that perspective.

The goals of each of the Digital Campaign Lines of Effort were then mapped into the Zachman Framework by tracing the goals into both the as-is and the to-be enterprise models of each Zachman cell. This is also shown in Figure 41, where the right-hand side shows the process of modeling the to-be enterprise using the OOSEM steps. There was

enough insight into the activities of the Digital Campaign to make impact calls to the entities of the enterprise. It is expected that this normally would be done by SMEs within the enterprise. The next step is to complete the build out of the to-be enterprise within the Zachman Framework and assess the secondary effects of the impacted entities and relationships.

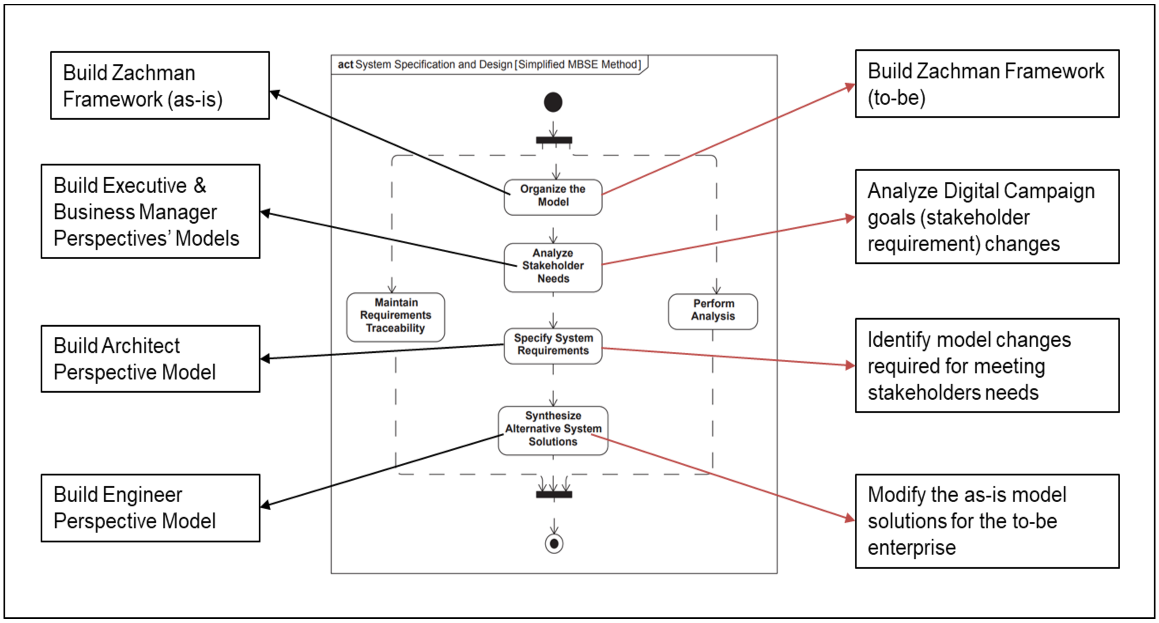


Figure 41: Mapping Thesis Method to OOSEM

IV. Analysis and Results

Chapter Overview

This chapter covers the analysis of using the Zachman Framework and model-based systems engineering to visualize secondary impacts and assess the planned digital transformation of the Digital Campaign. Modeling must have a purpose. The purpose of this modeling was to learn the impacts of the Digital Campaign on the acquisition enterprise given one area of concern. That area of concern was chosen as the systems engineering process involved with conducting a PDR. This research will first analyze ways to use the CAMEO tool to discover secondary impacts in cells of the Zachman Framework for each line of effort.

Once the as-is model or the current state of the enterprise is completed within the Zachman Framework, normally an enterprise would establish a to-be architecture model. Essentially answering "where do we plan to be with our business processes and technology as an enterprise within the next one to five years?" In the case of the AFMC Acquisition Enterprise's digital transformation, the Digital Campaign did not build an architecture and map where it wanted to be in one to five years. The Digital Campaign built top-level goals and established lines of efforts around those goals with a single top goal of "delivering materiel solutions at the speed of relevance." This top goal matched up well with objectives within DoD and AF level strategic plans to reform the overall enterprise. Enterprise in these strategic plans are defined as the overall DoD and the overall Air Force operational enterprises but for the campaign it referred to the AFMC Acquisition Enterprise. The lines of effort developed plans for achieving the goals

without a central core plan and without at first fully understanding what state-of-the-art technology and process change could be brought to bear to achieve the goals. This next couple of sections address the considerations of each primary impacted goal on other cells of the Zachman Framework. These are secondary impacts to the enterprise and are important to understand. This research also will use this modeling and analysis effort to see if there are any gaps within the Digital Campaign's approach.

LOE 0 Secondary Impacts

The LOE 0 goal to "influence corporate IT improvement investments to enable a robust, secure infrastructure" primarily impacts the *what* interrogative of the engineer perspective. To understand other secondary impacts of this goal, one must modify the as-is models with to-be models. Because there is no strategic plan for where the campaign wants the enterprise to be in one to five years, this research has to make these determinations based on the on-going work within the LOE 0. The to-be model is shown back in Figure 33.

The CAMEO tool has an analysis capability through its Model Visualizer to review all of the dependencies of a package on other packages. This is called a package dependency diagram. The diagram for this analysis is developed for all of the cells of the Zachman Framework for both the as-is and the to-be. The as-is package dependency diagram is shown in Figure 42. The to-be package dependency diagram is shown in Figure 43. One observation is that one should expect that every cell of a particular enterprise framework should have at least one relationship to another cell, otherwise one could question whether that cell model is accurate. If the cell doesn't have a relationship

to any other cell, it does not exist in the enterprise because it does not matter to the enterprise being modeled.

As can be seen in each of these two figures, the interrogative for each perspective is a package (cell). The dashed lines between the packages are the dependencies between the two packages. The “n=” identifies the number of dependencies from one package to the other. The dependencies are identified as one-way arrows to be interpreted as a package “is dependent” on the other package in the direction of the arrow. The “TB” designation in Figure 43 stands for the to-be architecture. There are arrows between several packages going both ways.

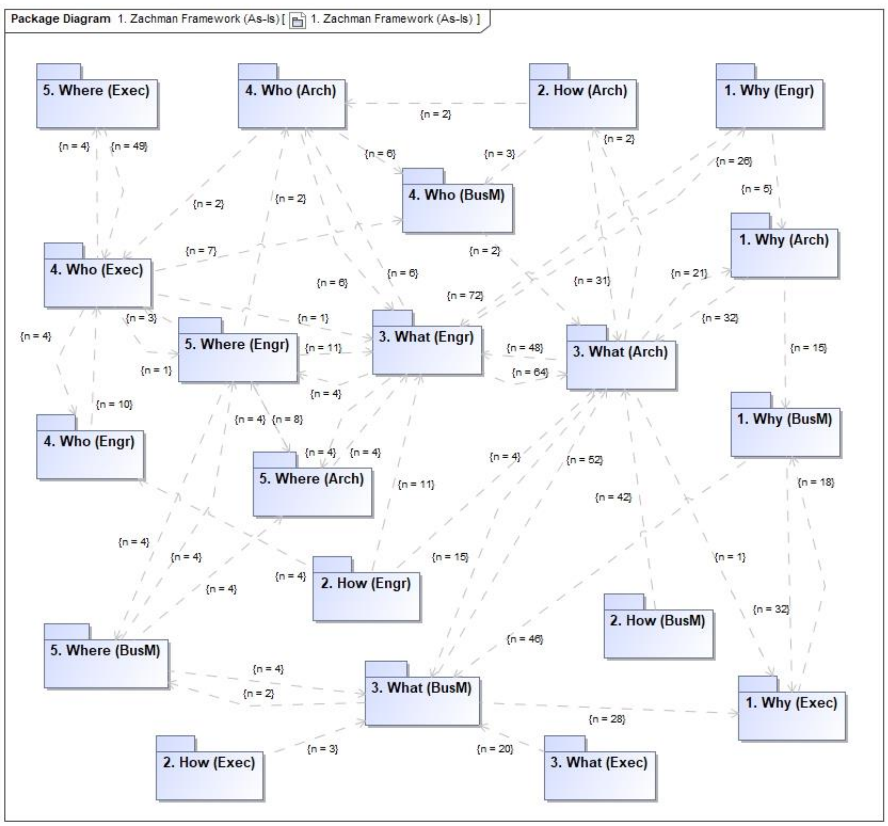


Figure 42: Package Dependency Diagram of Zachman Framework (As-Is)

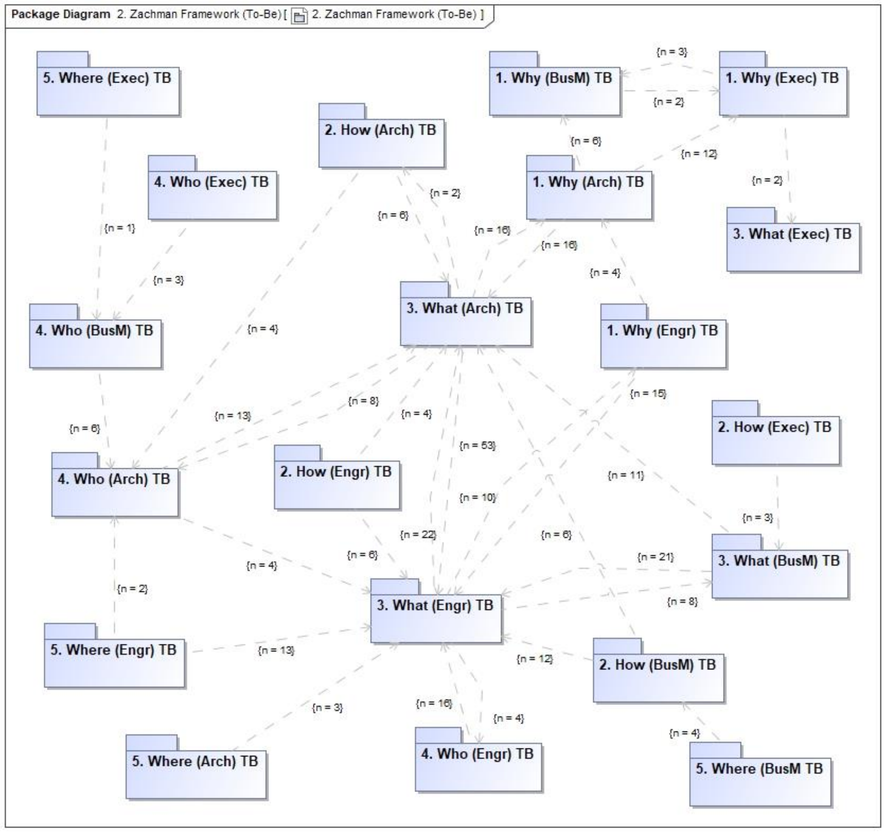


Figure 43: Package Dependency Diagram of Zachman Framework (To-Be)

Another observation is that the as-is package dependency diagram has more dependencies between the packages than the to-be package dependency diagram. This is seen by counting up all of the dependencies ("n=" numbers) in each figure. There are 1321 dependencies in the as-is package dependency diagram and 753 dependencies in the to-be package dependency diagram. There are close to half the number of dependencies in the to-be package dependency diagram as compared to the as-is diagram. When pursuing a digital transformation, one expects that the complexity between the entities and relationships should decrease significantly. This is a demonstration of this fact as applied to the Digital Campaign's efforts.

Each package within this diagram can be clicked on (within the tool) to visualize the package specification and view the actual dependencies within the relations tab. For example, the “What (Engr)” package relations tab is shown in Figure 44 and the “What (Engr) TB” package relations tab is shown in Figure 45. There is not a one for one relationship between the as-is relations and the to-be relations because there can be relations that go away as a result of a to-be implementation in the model. For instance, there is a dependency between the “What (Engr)” and the “Who (Exec)” elements of the as-is model, yet that dependency does not exist in the to-be model. One can also add to the relations between the as-is and the to-be. For instance, the as-is model of the “What (Engr)” package has twelve dependencies (seven dependencies from “What (Engr)” to other packages) and the to-be model of the “What (Engr)” package has thirteen dependencies (nine dependencies from “What (Engr)” to other packages), an overall increase of a package’s dependencies.

While these views help visualize where dependencies exist for the overall enterprise, it still is incumbent on a subject matter expert to review the as-is model and determine what changes are possible within the time frame the enterprise plans to make changes. It is also necessary for the modeler to accurately model the relationships and entities, otherwise it is possible to miss relationships that exist or create relationships that do not exist.

The model is then updated to reflect these changes in the to-be model to help visualize the impacts. These impacts then are reflected in an implementation plan so that the enterprise can pursue the improvements. The issue with this CAMEO tool Model Visualizer capability is that the package dependencies represent all of the dependencies

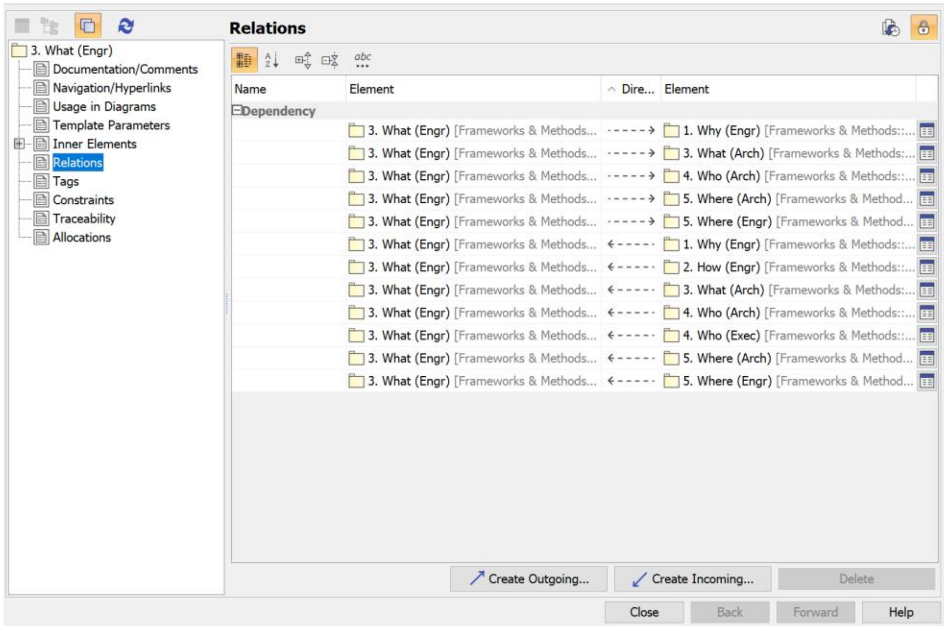


Figure 44: Relations Tab of Specification for “What (Engr)” as-is Package

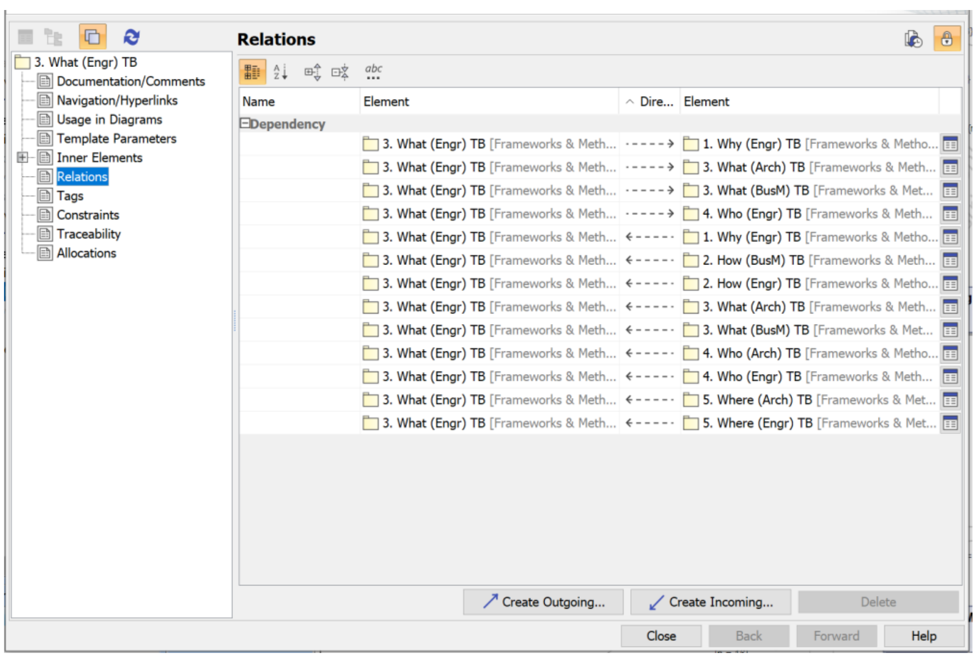


Figure 45: Relations Tab of Specification for “What (Engr) TB” to-be Package

of the LOE goals in that package, and not just one goal by itself (i.e. LOE 0). Therefore, there is another capability addressed in the next paragraph that helps localize the individual goal impacts.

Another CAMEO tool analysis method is using the CAMEO tool to display a relation map showing the relationships affected by the LOE 0 goal. This is shown in Figure 46 for the as-is enterprise and Figure 47 for the to-be enterprise. These figures clearly show the dependent packages as a result of the primary impacted “What (Engr)” cell as listed on the far right of the maps. The Desktop (As-Is) and the Network (AFNET) (As-Is) entities of the as-is enterprise and the Desktop (To-Be) and the Platform One entities of the to-be enterprise are suppressed because they duplicate the relations shown by the Data Centers and the Cloud One entities, respectively.

The LOE 0 goal creates the need for a Cloud One implementation. This is owned by the PDR Technology (To-Be) package. This package is owned by the “What (Engr) TB” package. The “What (Engr) TB” package has a dependent relationship (source to target) to nine other cells (packages). These are the same nine package relationships shown in Figure 45. This is also summarized in the Zachman Framework shown in Figure 48. This demonstrates that there are several ways to visualize the secondary impacts using a Zachman Framework within the CAMEO Tool. The analysis of the remaining LOEs will be accomplished using the relation map analysis capability of the tool.

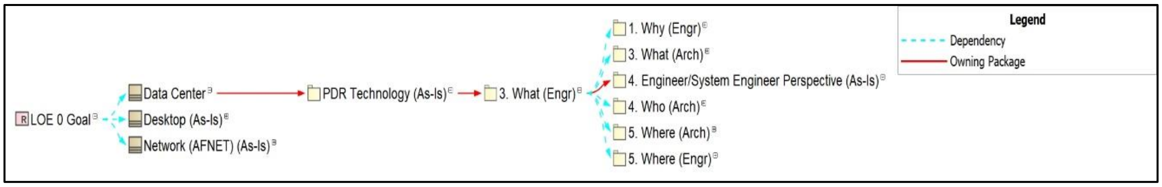


Figure 46: Relation Map for LOE 0 Goal for As Is Enterprise

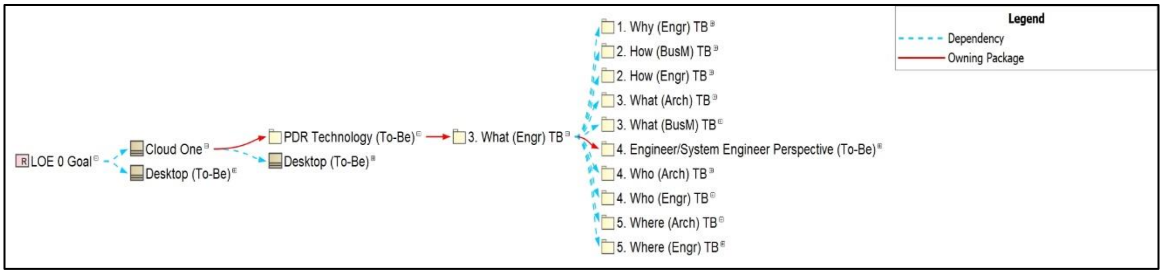


Figure 47: Relation Map for LOE 0 Goal for To Be Enterprise

	WHY	HOW	WHAT	WHO	WHERE	WHEN
EXECUTIVE (AFMC Executive Leader)	Stakeholder Requirements	Conduct Acquisition Process	Enterprise Data	Acquisition Enterprise	Acquisition Enterprise Locations	X
BUSINESS MANAGER (Program Director)	Technical Review Requirements	Conduct Technical Review Process	PDR Data	Program Office	Technology Maturation and Risk Reduction Phase	X
ARCHITECT (Chief Engineer)	PDR Data Requirements	Conduct PDR Process	PDR Data Products	PDR Participants	PDR Location	X
ENGINEER (Systems Engineer)	PDR Technology Requirements	Prepare/Maintain PDR Technologies	Change to PDR Technology	PDR Technology Personnel	PDR Technology Location	X
TECHNICIAN (CONTRACTOR)	X	X	X	X	X	X

Line of Effort (LOE) 0
Provide overarching guidance to influence corporate IT improvement investments to enable a robust, secure infrastructure for the enterprise-wide Digital Campaign

Secondary Digital Change | Primary Digital Change

PDR - Preliminary Design Review

Figure 48: LOE 0 Impacts to the PDR

LOE 1 Secondary Impacts

The LOE 1 goal is to "provide an Integrated Digital Environment of models and tools for collaboration, analysis, and visualization across the functional domains of AF users." Earlier, the primary impact was determined to be the tools within the "What (Engr)" cell of the Zachman Framework as shown in Figure 33. The incorporation of these tools has secondary dependencies to four other cells ("Why (Engr)," "What (Arch)," "What (BusM)" and "Who (Engr)") as shown in the relation map of Figure **49** and summary framework of Figure 50. To explain this, the tools provided by the systems engineer ("What (Engr)" cell) satisfy his requirement ("Why (Engr)" cell) and are used to produce data products (models) that are owned by the chief engineer (architect – "What (Arch)" cell). These data products contain PDR data that the program director (business manager) cares about. The technology specialists ("Who (Engr)" cell) are responsible for maintaining the systems and tools of the "What (Engr)" cell.

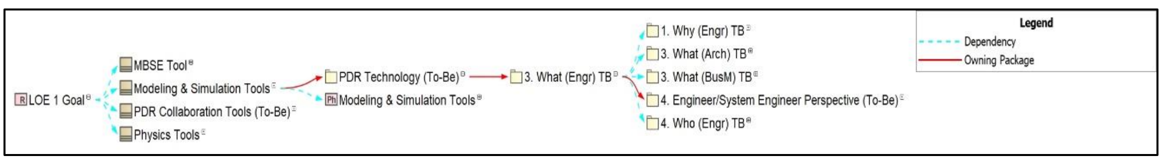


Figure 49: Relation Map of LOE 1 Goal for To Be Enterprise

	WHY	HOW	WHAT	WHO	WHERE	WHEN
EXECUTIVE (AFMC Executive Leader)	Stakeholder Requirements	Conduct Acquisition Process	Enterprise Data	Acquisition Enterprise	Acquisition Enterprise Locations	X
BUSINESS MANAGER (Program Director)	Technical Review Requirements	Conduct Technical Review Process	PDR Data	Program Office	Technology Maturation and Risk Reduction Phase	X
ARCHITECT (Chief Engineer)	PDR Data Requirements	Conduct PDR Process	PDR Data Products	PDR Participants	PDR Location	X
ENGINEER (Systems Engineer)	PDR Technology Requirements	Prepare/Maintain PDR Technology	Change to PDR Technology	PDR Technology Personnel	PDR Technology Location	X
TECHNICIAN (CONTRACTOR)	X	X	X	X	X	X

Line of Effort (LOE) 1
Provide an Integrated Digital Environment (IDE) of models and tools for collaboration, analysis, and visualization across the functional domains of AF users

Secondary Digital Change | Primary Digital Change

PDR - Preliminary Design Review

Figure 50: LOE 1 Impacts to the PDR

LOE 2 Secondary Impacts

LOE 2 primarily impacts the "What (Arch)" cell. This impact achieves the goal of "provide overarching guidance on the use of Government Reference Architectures (GRA) and related standards and datasets for use in an integrated digital environment for application at the enterprise and system levels" and is shown in Figure 51. To understand Figure 51, one must know that the LOE 2 team is the team to implement integrated models and data into the acquisition enterprise. The concept that has been discussed involves integrated models that would contain the data that would have normally been in many documents including both deliverables from a contractor and in-house created documents for program planning and execution. As shown in the figure, the Government Reference Model is a model that would guide and constrain a design by a vendor. The Acquisition Reference Model is a model that contains all of the programmatic data that would normally have been contained in risk documents, systems engineering plans, test

and evaluation master plans, schedules, system safety plans and budget and cost estimation documents. Ultimately these models might take on different data or be either combined or split further down, but for illustrative purposes, this research used the latest thinking within the Digital Campaign. The main point is that the transformation result will be no documents and all the data will be in models. The models will be the authoritative source for the programmatic data, reference data and the design data. The system model is also a model that would contain the vendor's design solution and architecture that would integrate with the other two primary models: Government Reference Model and Acquisition Reference Model.

Considering the LOE 2 Team goal, the research looked for secondary impacts on the model as a result of these to-be changes. There are four secondary impacts based on entity use and relationships to surrounding Zachman cells as shown in Figure 52. These are the "Why (Arch)," "How (Arch)," "Who (Arch)" and "What (Engr)" cells.

Changing from Entry and Closure PDR documents of Figure 23 to the PDR models of

Figure 51 also has an effect on the PDR process occurring in the "How (Arch)" cell. With the implementation of models and the ability to automate and document model validation as the system model is being designed, a program can now envision conducting continuous PDR reviews. This changes completely the flow of the process to something resembling that shown in Figure 53 while also achieving a secondary goal of the "Why (Arch)" cell of continuous technical reviews (See Figure 54). No more need for building preparatory material and post meeting materials which only takes time away from the design process.

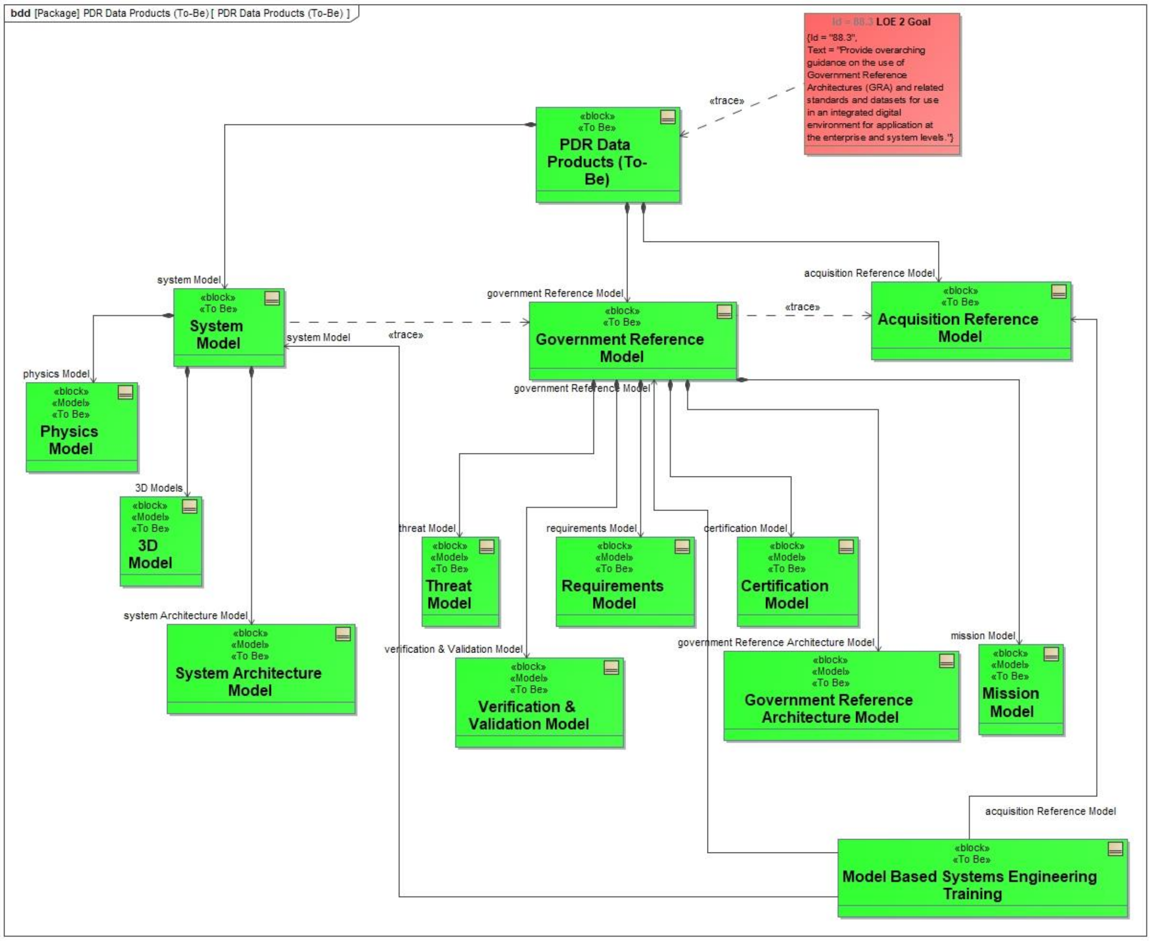


Figure 51: Models used in to-be architecture for PDR (Cell: What (Arch))

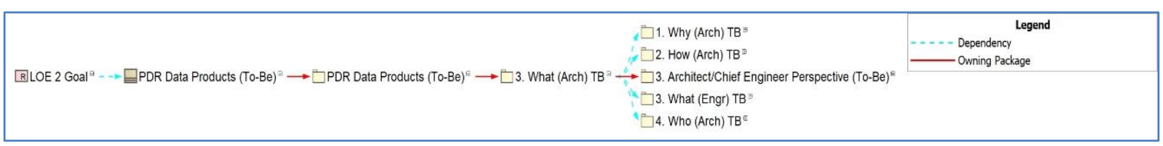


Figure 52: Relation Map for LOE 2 Goal for To Be Enterprise

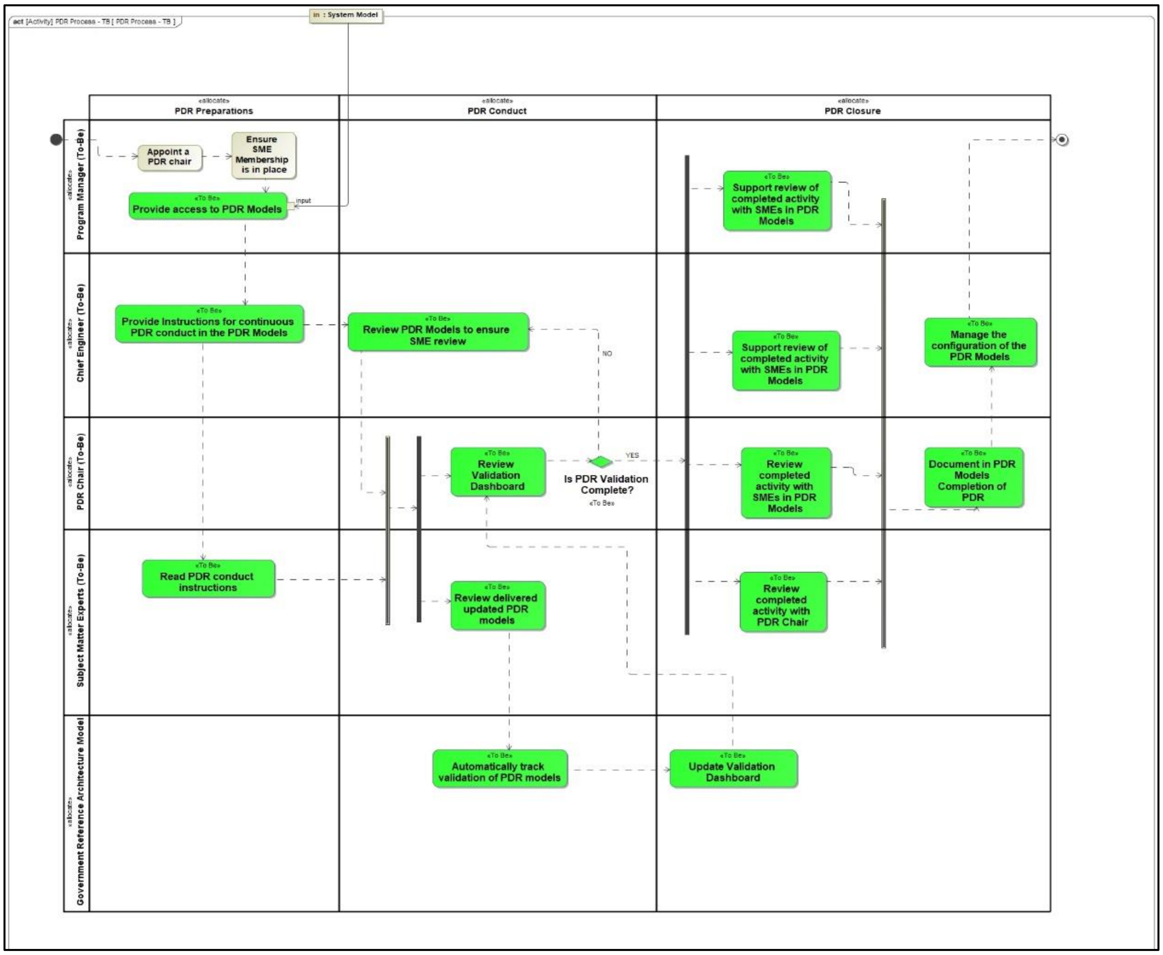


Figure 53: To-Be PDR Process (Cell: How (Arch))

Another secondary impact of changing the data products of the "What (Arch)" cell is to the "What (Engr)" cell. So now the models coming from LOE 2 in the "What (Arch)" cell are requiring different tools to build, review, and approve the models instead of the MS office tools in the as-is enterprise of Figure 28. Figure 33 shows this change from the documents to the models affected on the modeling tools which is being pursued as an LOE 1 goal. And a last secondary impact of changing the data products of the "What (Arch)" cell are to the PDR participants of the "Who (Arch)" cell. These

individuals will interact with these new tools and models through a desktop system as shown in Figure 55.

In summary, the full impact of the LOE 2 Goal is shown in Figure 56, where the green cell is the primary impact of the LOE 2, and the yellow cells are secondary impacts due to relationships between the cells.

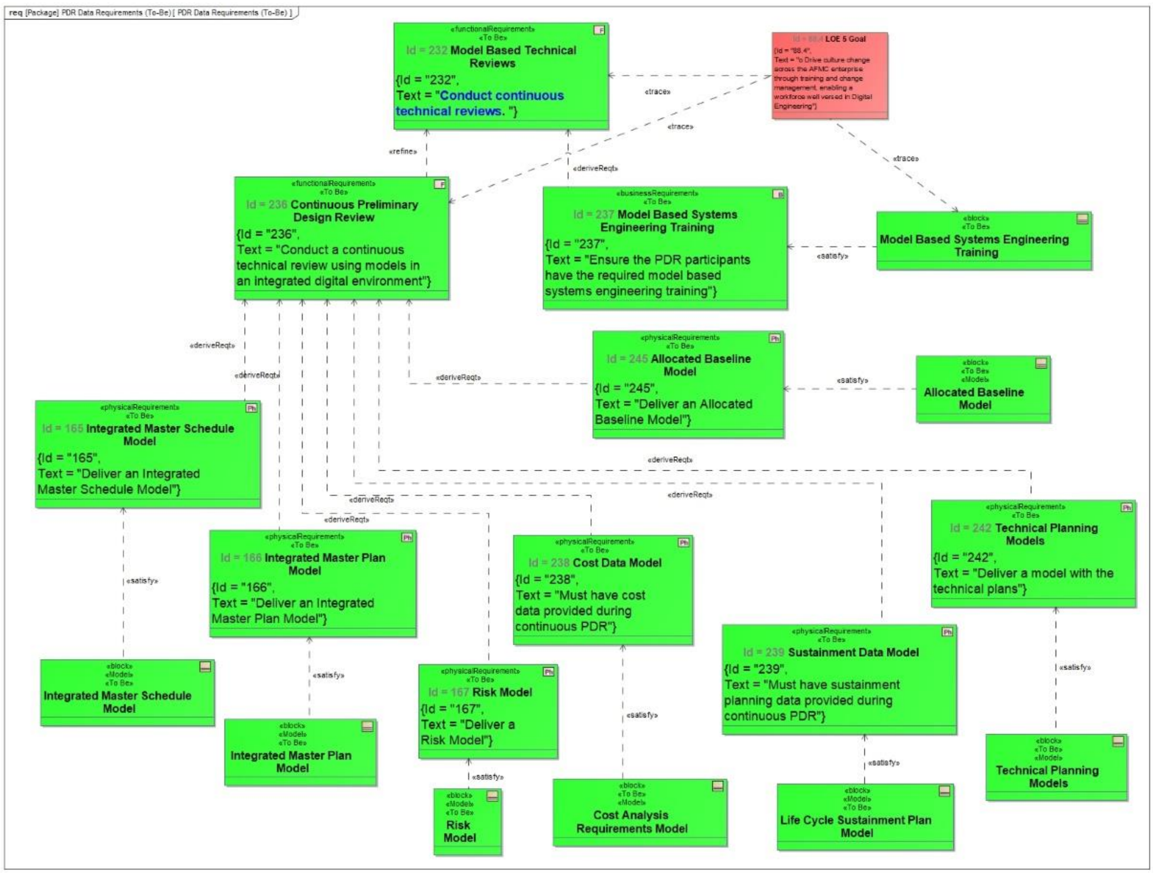


Figure 54: To-Be PDR Data (Cell: Why (Arch))

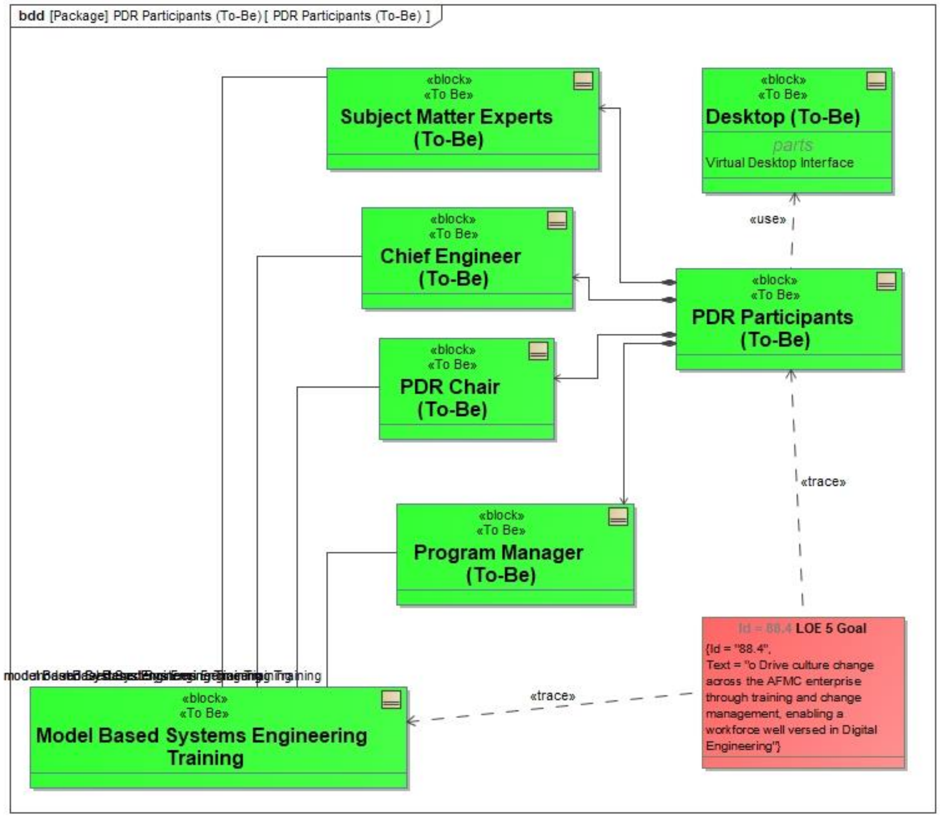


Figure 55: LOE 2 Secondary Impact to PDR Participants (Cell: Who (Arch))

	WHY	HOW	WHAT	WHO	WHERE	WHEN
EXECUTIVE (AFMC Executive Leader)	Stakeholder Requirements	Conduct Acquisition Process	Enterprise Data	Acquisition Enterprise	Acquisition Enterprise Locations	X
BUSINESS MANAGER (Program Director)	Technical Review Requirements	Conduct Technical Review Process	PDR Data	Program Office	Technology Maturation and Risk Reduction Phase	X
ARCHITECT (Chief Engineer)	PDR Data Requirements	PDR Process	Change PDR Data Products	PDR Participants	PDR Location	X
ENGINEER (Systems Engineer)	PDR Technology Requirements	Prepare/Maintain PDR Technology	PDR Technology	PDR Technology Personnel	PDR Technology Location	X
TECHNICIAN (CONTRACTOR)	X	X	X	X	X	X

Line of Effort (LOE) 2
Provide overarching guidance on the use of Government Reference Architectures (GRA) and related standards and datasets for use in an integrated digital environment for application at the enterprise and system levels

Secondary Digital Change | Primary Digital Change

PDR - Preliminary Design Review

Figure 56: Summary of LOE 2 Impacts

LOE 3 Secondary Impacts

The LOE 3 goal primarily impacts the *how* of the chief engineer (architect ("How (Arch)" cell)) who is expected to digitally transform the PDR acquisition process. The research here shows that the PDR process changes also affect the "What (Arch)" and the "Who (Arch)" cells of the Zachman Framework as shown in the relation map of Figure 57. The products needed as input and completed as outputs of the PDR processes are captured in the "What (Arch)" cell. The roles of the people involved in the PDR are also affected by changing the process to a continuous technical review as reflected in the "Who (Arch)" cell.

As in all of the cases of this research, the modeler needs to build accurate views and relationships between the entities within the entire framework. The benefit of the framework is that it gives the modeler and the subject matter experts the tool for visualizing and thinking about the impacts of the transformation. While this research captured two secondary impacts, a subject matter expert who knows their process well might identify others and the modeler would capture those to aid in the implementation. A summary of the LOE 3 impacts within the Zachman Framework is shown in Figure 58.

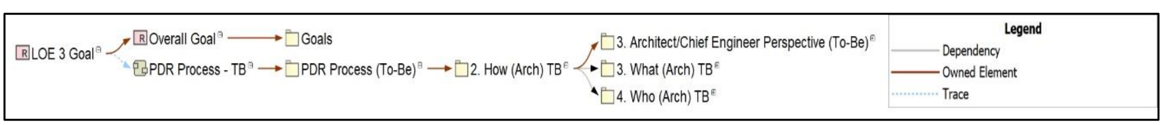


Figure 57: LOE 3 Goal Secondary Impacts

	WHY	HOW	WHAT	WHO	WHERE	WHEN
EXECUTIVE (AFMC Executive Leader)	Stakeholder Requirements	Conduct Acquisition Process	Enterprise Data	Acquisition Enterprise	Acquisition Enterprise Locations	X
BUSINESS MANAGER (Program Director)	Technical Review Requirements	Conduct Technical Review Process	PDR Data	Program Office	Technology Maturation and Risk Reduction Phase	X
ARCHITECT (Chief Engineer)	PDR Requirements	Change to PDR Process	PDR Data Products	PDR Participants	PDR Location	X
ENGINEER (Systems Engineer)	PDR Technology Requirements	Prepare/Maintain PDR Technology	PDR Technology	PDR Technology Personnel	PDR Technology Location	X
TECHNICIAN (CONTRACTOR)	X	X	X	X	X	X

Line of Effort (LOE) 3
Develop Life Cycle Strategies and Processes for Technology Transition, System Acquisition and Product Support using an IDE, supporting lifecycle activities from concept development to disposal

Secondary Digital Change | Primary Digital Change | PDR - Preliminary Design Review

Figure 58: Summary of LOE 3 Impacts

LOE 5 Secondary Impacts

LOE 5 is probably the most complicated of the LOEs, because Workforce and Culture affects many aspects of an enterprise. This research characterized the LOE 5 goal into two areas of primary impact, the *why* of the enterprise and the training of the enterprise. This was explained back in the methodology of Chapter III. The *why* of the enterprise are the requirements that motivate the enterprise to use the model-based technical reviews of the business manager perspective; continuous preliminary design reviews and model-based systems engineering of the architect perspective; Cloud One, Platform One and fast internet access of the engineer perspective. The executive needs to be onboard with the digital transformation and is concerned with the data ("What (Exec)" cell) required to be provided to the stakeholders of the materiel solution. In addition, the need is for the architect and the engineer to act on the requirements through their relationship in using (i.e., process) and building the "things" of the enterprise. Therefore,

the secondary impacts are the *what* interrogatives of the architect and engineer perspectives ("What (Arch)" and "What (Engr)" cells). These relationships can be traced in the relation map of Figure 59.

The other LOE 5 impact is to the training. This research modeled the training change from systems engineering training to model-based systems engineering training. This causes secondary impacts that can be traced from the *what* of the architect (the training) to the *who* interrogative of the architect (those who need to take the training), as expected. The summary of the LOE 5 goal impacts are illustrated in the framework of Figure 60.

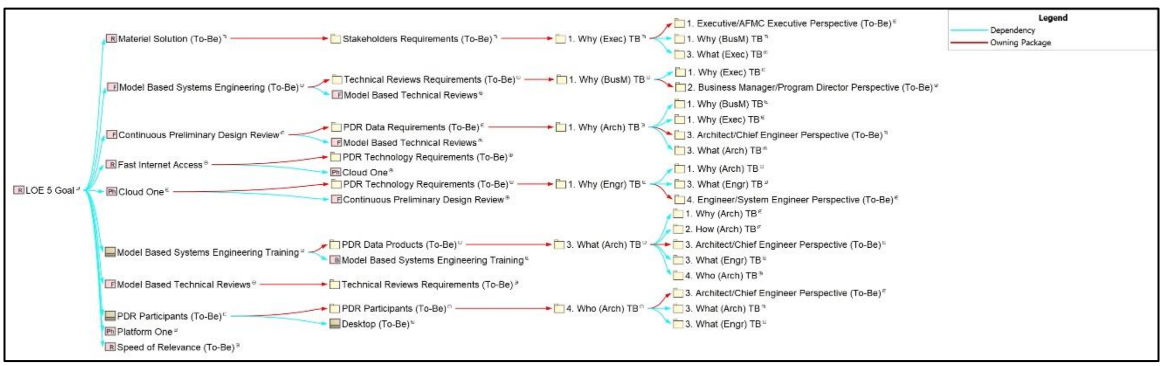


Figure 59: LOE 5 Goal Relation Map showing Secondary Impacts

	WHY	HOW	WHAT	WHO	WHERE	WHEN
EXECUTIVE (AFMC Executive Leader)	Change Stakeholder Requirements	Conduct Acquisition Process	Enterprise Data	Acquisition Enterprise	Acquisition Enterprise Locations	X
BUSINESS MANAGER (Program Director)	Change Technical Review Requirements	Conduct Technical Review Process	PDR Data	Program Office	Technology Maturation and Risk Reduction Phase	X
ARCHITECT (Chief Engineer)	Change PDR Data Requirements	Conduct PDR Process	Change PDR Data Products	Change PDR Participants	PDR Location	X
ENGINEER (Systems Engineer)	Change PDR Technology Requirements	Prepare/Maintain PDR Technology	PDR Technology	PDR Technology Personnel	PDR Technology Location	X
TECHNICIAN (CONTRACTOR)	X	X	X	X	X	X

Line of Effort (LOE) 5
Drive culture change across the AFMC enterprise through training and change management, enabling a workforce well versed in Digital Engineering

Secondary Digital Change | Primary Digital Change

PDR - Preliminary Design Review

Figure 60: Summary of LOE 5 Goal Impacts

Investigative Questions Answered

Three questions were proposed at the beginning of this thesis. They drove the direction of the research pursued. This section will provide the answers. The first question is below:

How can the digital transformation of the AFMC acquisition enterprise be modeled to visualize the primary impacts?

The answer was addressed through building a SysML model of a piece of the as-is AFMC Acquisition Enterprise. The piece of the AFMC Acquisition Enterprise is the systems engineering process of conducting a PDR, a part of most AFMC acquisition programs. The modeling was accomplished using a MBSE SysML tool, following a systems engineering method, and adapting the Zachman Framework to the tool. As illustrated in Figure 61, the AFMC Acquisition Enterprise is fitted into twenty cells of the

Zachman Framework for the PDR process. This research expects that this same process and framework could be expanded to encompass the entire AFMC Acquisition Enterprise digital transformation (or any areas of concern) with enough program time and resources.

Looking at it from a transformation standpoint the analysis shows that the enterprise has capitalized on five general areas to affect primary change; using models in place of documents, defining a goal that speed (and derived goals) was an important attribute, modifying training, updating acquisition processes and changing the IT infrastructure including tools. This exercise shows that the primary perspective affected by the changes proposed is the architect or the chief engineer perspective in the AFMC Acquisition Enterprise and the primary interrogative impacted is the *why* as driven by the LOE 5 Workforce and Culture goal. As stated within DoDAF 2.0 Volume 1, "When effectively designed, graphical views can facilitate understanding and recognition; promote analysis; and support learning and sharing of ideas" (Defense, Department of, 2019). This Zachman Framework is proof of a simple way to understand the changes as a result of a digital transformation. The modeling behind each framework cell can then be addressed in context with a SME for that area of concern. These primary changes drive changes to other areas of the enterprise based on modeled relationships and the research addressed how this modeling leads to identifying these secondary impacts. This leads to the second question.

	WHY	HOW	WHAT	WHO	WHERE	WHEN
EXECUTIVE (AFMC Executive Leader)	Change to Stakeholders Requirements (LOE 5)	Conduct Acquisition Process	Enterprise Data	Acquisition Enterprise	Acquisition Enterprise Locations	X
BUSINESS MANAGER (Program Director)	Change Technical Review Requirements (LOE 5)	Conduct Technical Review Process	PDR Data	Program Office	Technology Maturation and Risk Reduction Phase	X
ARCHITECT (Chief Engineer)	Change PDR Requirements (LOE 5)	Change to PDR Process (LOE 3)	Change to PDR Data Products (LOE 2, LOE 5)	Change to PDR Participants (LOE 5)	PDR Location	X
ENGINEER (Systems Engineer)	Change PDR Technology Requirements (LOE 5)	Prepare/Maintain PDR Technology	Change to PDR Technology (LOE 0, LOE 1)	PDR Technology Personnel	PDR Technology Location	X
TECHNICIAN (CONTRACTOR)	X	X	X	X	X	X

Line of Effort (LOE) 0 ○Provide overarching guidance to influence corporate IT improvement investments to enable a robust, secure infrastructure for the enterprise-wide Digital Campaign
LOE 1 ○Provide an Integrated Digital Environment (IDE) of models and tools for collaboration, analysis, and visualization across the functional domains of AF users
LOE 2 ○Provide overarching guidance on the use of Government Reference Architectures (GRA) and related standards and datasets for use in an integrated digital environment for application at the enterprise and system levels
LOE 3 ○Develop Life Cycle Strategies and Processes for Technology Transition, System Acquisition and Product Support using an IDE, supporting lifecycle activities from concept development to disposal
LOE 5 ○Drive culture change across the AFMC enterprise through training and change management, enabling a workforce well versed in Digital Engineering

Primary Digital Change	(LOE X) = Line of Effort(s) Primary Impact to Cell		PDR - Preliminary Design Review

Figure 61: Summary of Primary Impacts to Zachman Framework from LOE Goals

The second research question expands on the first question by addressing how modeling can aid in identifying secondary impacts across the enterprise as a result of the primary goal impacts. The question is:

How does modeling the digital transformation of the AFMC Acquisition Enterprise identify secondary impacts?

Each cell is modeled separately and is considered a view of a specific perspective and interrogative but if done correctly, modeling relationships between the entities of different cells will be required. These considerations will create secondary impacts between cells. An important consideration is ensuring that ownership of an entity is properly assigned within the right package of the model. When doing this, one must decide which perspective should contain an entity based on who owns it in the enterprise. For instance, the owner of a model within this AFMC Acquisition Enterprise for a PDR

should be the Chief Engineer, so the model entity should be contained in the architect perspective and because it is a "thing" and modeled as a block, it would be placed in the *what* interrogative ("What (Arch)") package.

Figure 62 shows the secondary impacts of the overall enterprise (yellow cells) that appear outside the primary impacted cells (green cells). Each Digital Campaign Goal has secondary impacts that overlap onto primary impacted cells of other Digital Campaign Goals and are shown in each summary figure for each Line of Effort (LOE 0: Figure 48; LOE 1: Figure 50; LOE 2: Figure 56; LOE 3: Figure 58; LOE 5: Figure 60). A simple to use relationship analysis capability of the CAMEO modeling tool is the relation map. Relation maps were used to identify the cells (packages) which had relationships creating secondary impacts.

	WHY	HOW	WHAT	WHO	WHERE	WHEN
EXECUTIVE (AFMC Executive Leader)	Change to Stakeholders Requirements (LOE 5)	Conduct Acquisition Process	Enterprise Data [LOE 5]	Acquisition Enterprise	Acquisition Enterprise Locations	X
BUSINESS MANAGER (Program Director)	Change Technical Review Requirements (LOE 5) [LOE 0]	Conduct Technical Review Process [LOE 0]	PDR Data [LOE 0, 1]	Program Office	Technology Maturation and Risk Reduction Phase	X
ARCHITECT (Chief Engineer)	Change PDR Requirements (LOE 5) [LOE 2]	Change to PDR Process (LOE 3) [LOE 2, 5]	Change to PDR Data Products (LOE 2, 5) [LOE 0, 1, 3]	Change to PDR Participants (LOE 5) [LOE 0, 2, 3]	PDR Location [LOE 0]	X
ENGINEER (Systems Engineer)	Change PDR Technology Requirements (LOE 5) [LOE 0, 1]	Prepare/Maintain PDR Technology [LOE 0]	Change to PDR Technology (LOE 0, 1) [LOE 2, 5]	PDR Technology Personnel [LOE 0, 1]	PDR Technology Location [LOE 0]	X
TECHNICIAN (CONTRACTOR)	X	X	X	X	X	X

Secondary Digital Change	Primary Digital Change	(LOE X) = Line of Effort(s) Primary Impact to Cell	[LOE Y] = Line of Effort(s) Secondary Impact to Cell	PDR - Preliminary Design Review

Line of Effort (LOE) 0 ○Provide overarching guidance to influence corporate IT improvement investments to enable a robust, secure infrastructure for the enterprise-wide Digital Campaign
LOE 1 ○Provide an Integrated Digital Environment (IDE) of models and tools for collaboration, analysis, and visualization across the functional domains of AF users
LOE 2 ○Provide overarching guidance on the use of Government Reference Architectures (GRA) and related standards and datasets for use in an integrated digital environment for application at the enterprise and system levels
LOE 3 ○Develop Life Cycle Strategies and Processes for Technology Transition, System Acquisition and Product Support using an IDE, supporting lifecycle activities from concept development to disposal
LOE 5 ○Drive culture change across the AFMC enterprise through training and change management, enabling a workforce well versed in Digital Engineering

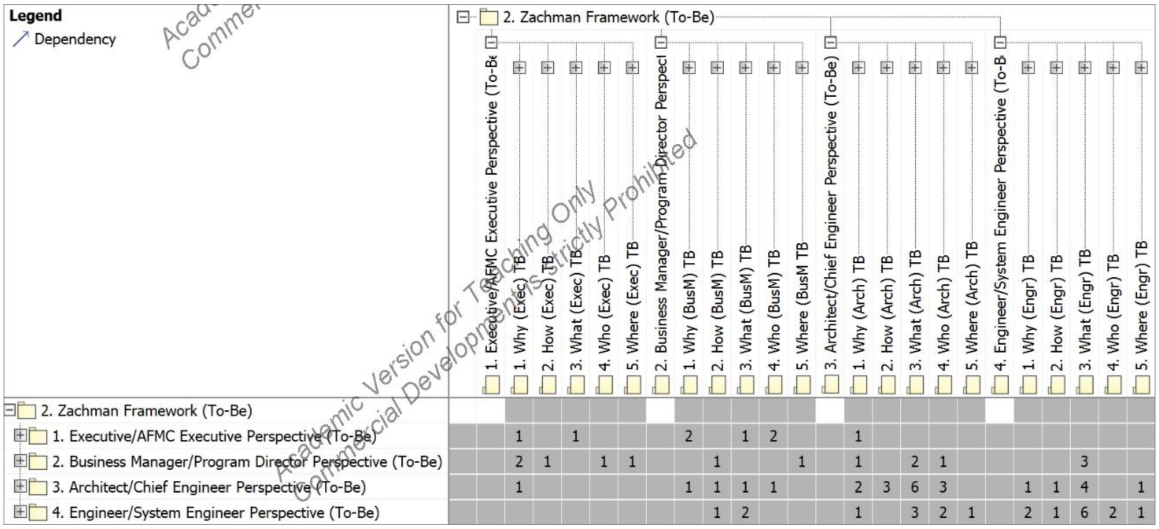
Figure 62: Summary of Overall Impacts of LOE Goals on Zachman Framework

This third question below takes the visual and simplified model of this research showing the primary and secondary impacts from the first two questions and draws conclusions on the Digital Campaign pursuit of digital transformation.

What, if any, are the Digital Campaign gaps in pursuing change?

As stated at the beginning of this research paper, the Digital Campaign consists of six lines of effort with each their own goals. At the beginning of the Digital Campaign formation, it may have seemed like all six LOEs were aligned based on their goals and that all aspects of the transformation were accounted for. No analysis was done to confirm or deny this conclusion. This research attempted to draw alignment or gaps with the LOEs' pursuits using model analysis techniques.

When considering quantity of relationships, Figure 63 shows that the Digital Campaign primarily affects the chief engineer perspective. This is where the modeling shows the most relationships. This was determined by adding the numbers in Figure 63 in each row (or perspective). There are 26 relationships within the chief engineer perspective versus 22 relationships for the System Engineer perspective, 14 relationships for the program director, and eight relationships for the AFMC executive. This same conclusion holds when looking at the number of primary impacted cells of Figure 61 which shows four for the chief engineer perspective and two for the systems engineer.



	1. Executive/AFMC Executive Perspective (To-Be	1. Why (Exec) TB	2. How (Exec) TB	3. What (Exec) TB	4. Who (Exec) TB	5. Where (Exec) TB	2. Business Manager/Program Director Perspect	1. Why (BusM) TB	2. How (BusM) TB	3. What (BusM) TB	4. Who (BusM) TB	5. Where (BusM TB	3. Architect/Chief Engineer Perspective (To-Be)	1. Why (Arch) TB	2. How (Arch) TB	3. What (Arch) TB	4. Who (Arch) TB	5. Where (Arch) TB	4. Engineer/System Engineer Perspective (To-B	1. Why (Engr) TB	2. How (Engr) TB	3. What (Engr) TB	4. Who (Engr) TB	5. Where (Engr) TB
2. Zachman Framework (To-Be)																								
1. Executive/AFMC Executive Perspective (To-Be)		1		1				2		1	2			1										
2. Business Manager/Program Director Perspective (To-Be)		2	1		1	1			1			1		1		2	1					3		
3. Architect/Chief Engineer Perspective (To-Be)		1						1	1	1	1			2	3	6	3			1	1	4		1
4. Engineer/System Engineer Perspective (To-Be)									1	2				1		3	2	1		2	1	6	2	1

Figure 63: To Be Relationship Dependencies for the Perspectives

To address a pattern that would follow a systems engineering decomposition of requirements into logical and physical representation of the enterprise from the expected changes of the Digital Campaign, one would expect that all the chief engineer and the system engineer cells would be a primary target for the Digital Campaign. When we are referring to the enterprise which is the system in this case, the chief engineer perspective represents the logical representation of the enterprise. The chief engineer is concerned with the processes which are analogous with the functions of the enterprise (system). He ensures the enterprise complies with the enterprise requirements. In the case of the PDR process, he is the owner of the process, the data coming in and going out, the participants in the process, and where the processes will take place. In other words, this perspective is an arrangement of related technical concepts and principles that support the logical operation of the enterprise. In order to accomplish a digital transformation of the logical perspective, this research contends that all interrogatives must have primary goals to drive change to the functions of the enterprise.

The system engineer is concerned with the physical systems that are needed to meet the needs of the digital changes. The physical perspective is where all of the physical systems are for the enterprise. These must be synchronized with the logical perspective. This perspective is an arrangement of the elements that provide the physical solution to the enterprise change. This research contends for that to happen, all interrogatives of the physical perspective must have a primary goal to drive implementation activities for an efficient transformation.

To achieve a more aligned transformation following a systems engineering process, the Digital Campaign should have primary goals addressing all of the interrogatives of the chief engineer and the systems engineer. The chief engineer perspective has four of the five interrogatives with primary impacts. If the Campaign was to focus also on the *where* interrogative then the perspective would be completely covered (and perhaps the *when* interrogative not covered in this research). Since a majority of this transformation involves implementing state-of-the art technology, an improvement to the Campaign approach would be to also focus on the *how*, *who* and *where* of the engineer perspective. Currently the Campaign focus is only on the *what* and *why* of the engineer perspective. An example of a goal that might achieve this is the following: "Provide overarching guidance to influence IT locations for robust and secure infrastructure for business activities; ensure an organization and process is in place for the sustainment of IT infrastructure changes." This goal mentions the "IT locations" taking care of the *where*, the "business activities" taking care of the *how*, and the "organization" being in place taking care of the *who*.

The executive and business manager perspectives are contextual and conceptual perspectives. Setting up goals that would primarily impact these do provide for a complete picture, but would not result in concrete changes to the enterprise. They are like ideas, and ideas need to be fleshed out with the logical and physical perspectives. Therefore, it is not as important to address the executive and business manager perspectives with specific primary Digital Campaign goals.

Summary

This chapter showed how modeling of primary impacts of the Digital Campaign goals within a Zachman Framework can help identify through relationships the secondary impacts. These secondary impacts would be areas that an enterprise should include in any planning so that they do not end up as gaps or issues after digital transformation causing loss of confidence in the new acquisition process.

This chapter also addressed the research questions. It answered how a systems engineering modeling method can be used to decompose the enterprise into views of the Zachman Framework that simplify the understanding of both primary and secondary impacts of a digital transformation. It also addressed that a balanced focused plan based on the impacted relationships and entities within the logical and physical perspectives following a systems engineering process would help prevent gaps with the current Digital Campaign effort.

V. Conclusions and Recommendations

Chapter Overview

This chapter presents the conclusions of this research, discusses the significance of the research and makes suggestions for future research.

Conclusions of Research

This research effort presented a method to build a model within an architecture framework to address the digital transformation of the AFMC Acquisition Enterprise. The findings of this research are:

1. It is possible to simplify visually the enterprise and provide better insight into the intricacies and relationships between the people, processes and infrastructure. Modeling an enterprise into the Zachman Framework using OOSEM and SysML is analogous to a system decomposition under typical systems engineering approaches.

2. As long as the transformation goals do not change, the Zachman cells impacted by the LOE goals will be the same. The goals are interpreted using the definitions of the perspectives and the interrogatives to map the LOE goals within the proper Zachman Framework cell. Any enterprise entity mapped into those cells will be primarily affected in a to-be digital enterprise. For this research, the focus was the effect of the digital transformation on the PDR process within the AFMC Acquisition Enterprise. The focus could have been on other areas of the enterprise, such as the Air Force Depots or the Supply chain. The result of modeling these processes would be an impact to the part of the model (views) within the affected Zachman cells by the digital transformation goals. These observations make it easier to assess the perspectives that are affected by any

transformation effort and dependent on the purpose chosen for change within the enterprise effort. Secondary impacted cells require SMEs to review relationships between the as-is entities and document the changes that will occur with a to-be implementation.

3. The DoD, the Air Force and the Digital Campaign is starting with an overall requirement to go fast or to deliver weapon systems at the "speed of relevance". This implies that the changes would occur to enterprise processes. Attacking the processes is typically the way the Air Force has gone about change. Implementing lean processes, trying to be become more efficient and effective to save time and money. This time around, the Digital Campaign is focusing on addressing the *what* and then expecting that the processes will follow. As shown in this research, changing to models from documents and upgrading IT infrastructure have become the focus of the transformation. The LOE 3 goal to change process is not to change process to achieve "speed of relevance" but, instead, is written to support the change to the Integrated Digital Environment. The Integrated Digital Environment consists of the models and the IT infrastructure. This implies that process will change as a result of the technology change. All this is visible with a mapping of the Digital Campaign goals onto a Zachman Framework and the subsequent relationship modeling shows the secondary impacts to processes based on the technology changes.

4. Lastly, the Digital Campaign should take a more formal and organized architecture modeling approach to transforming the AFMC Acquisition Enterprise. The model analysis revealed Zachman cells that should be addressed within the Digital Campaign goals to ensure LOE alignment and complete coverage for transforming the

overall enterprise. There were gaps in the transformation goals that do not cover all of the architect's and engineer's perspectives. In addition, an architecture model would reveal gaps if used as a tool for documenting progress over the transformation period and help ensure an efficient digital transformation.

Significance of Research

As stated in the introduction of this paper, this thesis is related to the current AFMC Acquisition Enterprise digital transformation. As of the finish of this thesis the AFMC Digital Campaign is completing up one year of a multiyear effort to transform the acquisition enterprise into a digital enterprise. There are concepts within this thesis modeling effort that can help provide an easy to visualize view of this complex transformation. It might also help uncover important disconnects and relationships not realized during the current AFMC Digital Campaign. Similarly, there are other efforts ongoing such as the LogIT and AF Futures efforts where modeling of their enterprises has become a foundation for their efforts. With an implementation of a similar effort once the AFMC Digital Campaign obtains funding, could help drive a five-year implementation plan that could be more coordinated and help identify and resolve issues before a situation results in the need for a large and unaffordable mitigation activity or more critical: a failure to achieve acquisition speed.

Recommendations for Future Research

There are several areas not addressed within the scope of this research that could advance the promise of modeling enterprises undergoing digital transformation. Many enterprises are transforming to digital to increase speed of acquisition and/or production,

including the AFMC Acquisition Enterprise. This effort though did not address time as a parameter through behavior modeling. In fact, this could be an important factor to consider and understand in a future effort.

This research hypothesized based on a single process within the AFMC Acquisition Enterprise, that the Digital Campaign goals always will impact the same Zachman Framework cells regardless of the process mapped. This conclusion could be further proven with an effort to map additional processes within the Zachman Framework. In addition, this could also add to the conclusion that the gaps identified within the Digital Campaign goals show themselves as Zachman cells where a primary goal does not exist within the logical and physical perspectives.

Building models for other areas of the acquisition enterprise was outside the scope of this effort but a future effort could look at what more could be discovered or confirm the conclusions of this research. Expanding the enterprise boundary could be accomplished. The AFMC Acquisition Enterprise is actually an enterprise within the larger Department of the Air Force (DAF) Acquisition Enterprise which is within an even larger enterprise of the Department of Defense. Looking at the entire DAF Acquisition Enterprise could provide more insight into other areas of how acquisition could be improved through digital transformation. And instead of expanding the enterprise boundary, there might be usefulness of decreasing the scope down to an AFMC program office, and focusing on the subset of processes, people and infrastructure of the smaller enterprise.

This effort used the Zachman Framework as the foundation for simplifying the understanding of the enterprise. There are many other enterprise architecture frameworks

that could be studied and compared to this effort research. Others that could be related within the military services include DODAF and UAF.

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14. ABSTRACT

The Air Force Materiel Command is undergoing a digital transformation to increase the speed of delivering new warfighter capabilities. This Digital Campaign consists of six Lines of Effort (LOEs) formed with diverse goals to transform the enterprise. This research investigated using the Zachman Framework and Systems Modeling Language to analyze this transformation. Extensive modeling captured the as-is Preliminary Design Review (PDR) process, and mapped LOE goals as primary impacts to Zachman cells. This led to an identification of a to-be digital PDR process. Secondary affected cells were then traced following a relationship analysis. Four discoveries were made. (1) Enterprise modeling in Zachman is analogous to a system decomposition under typical systems engineering approaches. (2) As long as the transformation goals do not change, the Zachman cells, and those entities mapped into those cells, will be directly affected by the new digital enterprise. (3) Different from past process transformation efforts, the Digital Campaign has focused on technology upgrades to drive process change. (4) Lastly, model analysis revealed transformation gaps within certain cells that should be covered with new goals. This research provides a formal, model-based methodology for guiding improvements in pursuit of Air Force digital transformation.

15. SUBJECT TERMS

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