SYM-AM-21-067

Excerpt from the Proceedings of the Eighteenth Annual Acquisition Research Symposium

Analyzing Digital Transformation using the Zachman Framework and SysML

May 11–13, 2021

Published: May 10, 2021

Approved for public release; distribution is unlimited.

Prepared for the Naval Postgraduate School, Monterey, CA 93943.

Disclaimer: The views represented in this report are those of the author and do not reflect the official policy position of the Navy, the Department of Defense, or the federal government.

Acquisition Research Program
Graduate School of Defense Management
Naval Postgraduate School

The research presented in this report was supported by the Acquisition Research Program of the Graduate School of Defense Management at the Naval Postgraduate School.

To request defense acquisition research, to become a research sponsor, or to print additional copies of reports, please contact any of the staff listed on the Acquisition Research Program website (www.acquisitionresearch.net).

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF DEFENSE MANAGEMENT
NAVAL POSTGRADUATE SCHOOL

Analyzing Digital Transformation using the Zachman Framework and SysML

Mark Kassan—is graduating with a Master of Science degree in Systems Engineering from the Air Force Institute of Technology as a part-time student. He currently supports the leadership of the Air Force Digital Campaign full-time as a plans and programs engineer of the Air Force Materiel Command Engineering and Technical Management Directorate, Systems Engineering Division. [mark.kassan.2@us.af.mil]

John Colombi, PhD—is a professor and curriculum chair of the Systems Engineering program at the Air Force Institute of Technology, Department of Systems Engineering and Management. Before joining the faculty, he served 21 years of active duty in the Air Force as a developmental engineer. He is author or coauthor on over 100 publications. [john.colombi@afit.edu]

Thomas Ford, PhD—is a Principal Systems Engineer with KBR (Government Solutions) assigned as an Assistant Professor of Systems Engineering at the Air Force Institute of Technology, Department of Systems Engineering and Management. Prior to joining KBR, he served for 22 years as an Air Force officer. He has authored or co-authored 14 publications on topics relating to model-based systems engineering and interoperability. [thomas.ford@centauricorp.com]

Major Warren Connell, PhD—is an assistant professor of systems engineering at the Air Force Institute of Technology, Department of Systems Engineering and Management. Prior to joining the faculty, he served for 24 years of active duty in a variety of software development and cybersecurity roles, most recently as the Cyber Test Lead for the F-35 Joint Program Office. [warren.connell@afit.edu]

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 impacts were also identified and traced using 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 enterprise-wide improvements in pursuit of Air Force digital transformation.

Introduction

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 50 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 6 years, whereas the latest aircraft developed, the F-35, will exceed 20 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).

This need for change has been realized by senior Air Force leadership including the former Assistant Secretary of the Air Force for Acquisition, Technology, and Logistics, Dr. Will Roper, and the commander of the Air Force Materiel Command (AFMC), General Arnold Bunch. The primary focus of this transformation is the use of digital models and artifacts integrated across the lifecycle. To address this digital transformation, Gen Bunch in March 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. These six lines of effort (LOE) address (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.

Digital Campaign LOE 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. The processes have been continuously evolving since the 1960s (Fox, 2011). The Digital Campaign 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 successfully complete the digital transformation. This paper demonstrates a methodology for modeling the AFMC acquisition enterprise to visualize and gain insight into the digital transformation effort.

This research used a systems engineering approach to build a System Modeling Language (SysML) model within the Zachman Framework for a technical review of the AFMC acquisition enterprise. Once that was completed, the Digital Campaign goals were mapped as requirement changes to the model. The primary effects of these changes on the enterprise's people, products, and processes were studied and documented. The research then used the inherent structure found in the Zachman Framework of the AFMC EA to show how secondary impacts can be identified. The final step of the research identified gaps with the Digital Campaign digital change approach following a systems engineering approach applied to the SysML model of the enterprise.

This exploration addresses the digital transformation of the AFMC acquisition community and directly supports the AFMC Digital Campaign, its goals, and activities. The AFMC acquisition enterprise is large and complex; modeling all of it to the appropriate fidelity would take considerable amount of time beyond the scope of a single effort. Therefore, this research focused on the particular event of a 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 permitting adequate research analysis.

The enterprise is assumed to be acquiring a major capability, either a new program or a major modification to an existing weapon system that would require a PDR within the defense acquisition process. As always, there are shortcuts and tailoring activities available to a program manager and chief engineer.

The next section addresses the Zachman framework used for this research. Then, the paper describes the SysML method used to build the as-is and to-be enterprises. Next, the paper addresses the primary impacts analysis from mapping the Digital Campaign goals. The paper then details the analysis for secondary impacts and gap analysis, and finally concludes with findings and future research opportunities.

Zachman Enterprise Architecture Framework

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.

The earliest beginnings of EAs can be traced to an IBM methodology in the late 1960s 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. (Kotusev, 2016). There were several improvements of the BSP through the 1980s when John Zachman introduced his framework internally to IBM.

John Zachman published his original framework in 1987 and in 1992 extended his framework into 30 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 30 cells in this matrix is unique, suggesting that it serves as a "periodic table" for entities. This resulted in a diagram representing a different abstraction and perspective of the EA (Sowa & Zachman, 1992). In 2011, Zachman updated his framework matrix to version 3.0 and titled it *The Zachman Framework for Enterprise Architecture*. This version, shown in Figure 1, is a matrix of six perspectives (executive, business management, architect, engineer, technician and the enterprise) and six interrogatives (*what*, *how*, *where*, *who*, *when*, and *why*).

There are many different definitions of an enterprise in the literature. The major theme in many 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. This research focuses 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 goal achievement is focused.

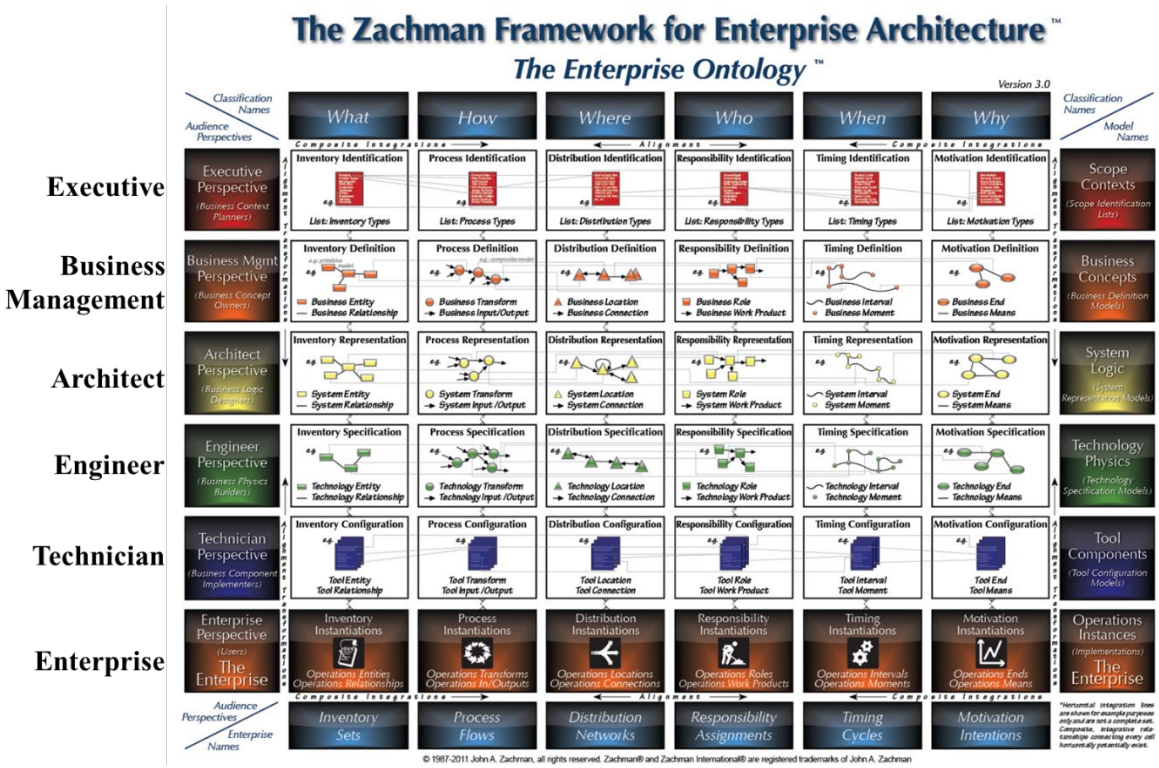

Figure 1: Zachman Framework, published with the permission of John A. Zachman and Zachman International®, Inc. (https://www.zachman.com)

Modeling Methodology

Dassault No Magic CAMEO Systems Modeler v19 was used as the modeling tool because it was available in the Air Force Institute of Technology (AFIT) academic 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 Framework is a structure 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 a systems engineering approach using the SysML language as outlined in Figure 2.

The PDR was picked because it is a prominent technical review within the acquisition process that the majority of Air Force programs must go through. 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 (contractor) and a program office, where the contractor 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 are looked at during a PDR (IEEE, 2015).

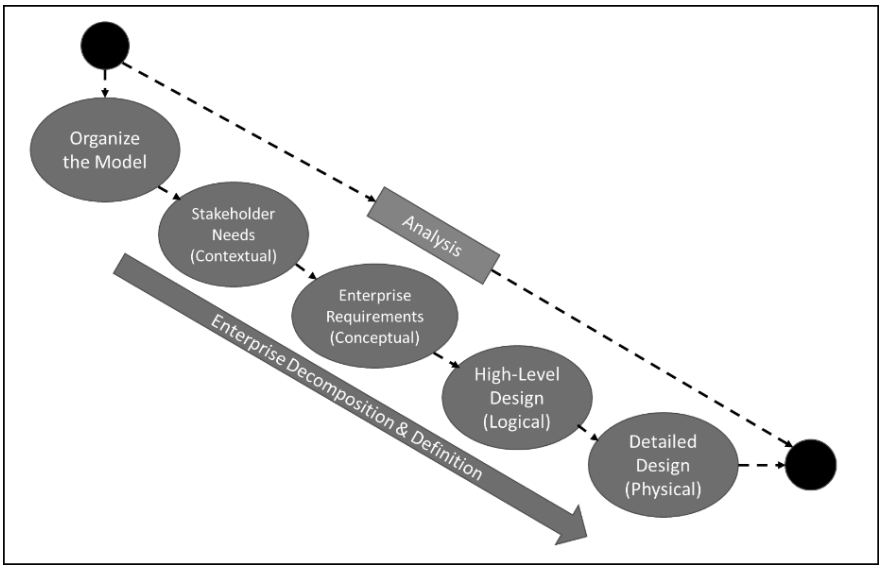

Figure 2: Systems Engineering Method for Enterprise Design

Organizing the Acquisition Enterprise Architecture Model

The first step of this approach is to "organize the model" as shown in Figure 2. To accomplish this step within CAMEO, a package model was built as shown in Figure 3, which represents the Zachman Framework of Figure 1. 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.

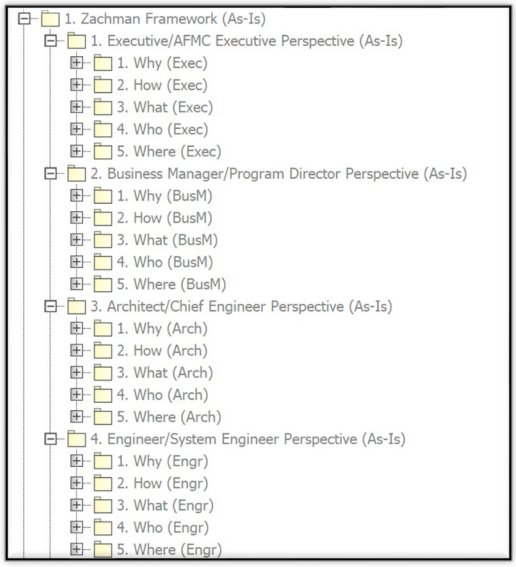

Figure 3: Package Structure Representing Zachman Framework Matrix

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, and Engineer) were addressed. The other two perspectives are the Technician (contractor) and the Enterprise (instantiations). Within each of the perspective packages were packages representing the Interrogatives (columns) of the Zachman

Framework. These sub-packages represent the intersection of the perspectives and the interrogatives and will be referred to as a cell. 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.

The Executive perspective is 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 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 (Sowa & Zachman, 1992). This research defines this person as a program office director responsible for producing a product and related data that meets a customer's materiel requirement.

The Architect perspective is 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 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). Activity Diagrams (ACT) were used 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). BDDs were used 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). BDDs, blocks and relationships were used to represent locations, where locations are defined as a place for organizations or IT systems within the acquisition enterprise.

This effort used the nomenclature of Figure 4 to refer to each Zachman cell. 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 4**:** Zachman 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 step is to start with modeling the contextual level (executive perspective) representing the stakeholder needs, followed by the conceptual level (business manager) representing the enterprise requirements. Once complete with these two perspectives, the research moved to the next step of high-level design. This step is accomplished by modeling the architect's logical-level cells. And finally, the last step of the systems engineering method is to model the detailed design for the engineer's physical-level cells. Relationship analysis is performed throughout this modeling process. Each of these steps is referenced in the process of Figure 2.

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

Executive Perspective

The things that the AFMC Executive is concerned about are represented in the block definition diagram of Figure 5. These are the top-level data needed to manage and provide a materiel solution to the customer stakeholder. These data include the design, performance, cost, risk, requirement, maintenance, operational, logistics, security, test, interface, and schedule data of the materiel solution.

The creation of all diagrams for each cell 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.

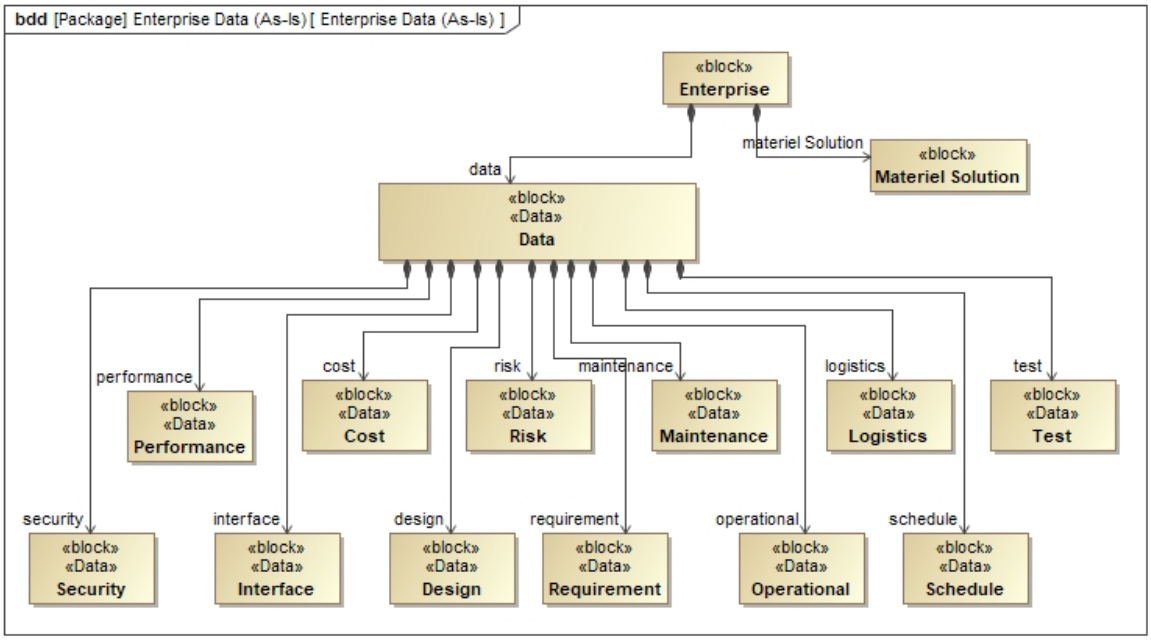

Figure 5: Enterprise Data for the AFMC Executive (Cell: What (Exec))

Business Manager/Program Director Perspective

The program director is concerned with all of the technical and business processes within the AFMC acquisition enterprise. IEEE 15288.2 *Standard for Technical Reviews and Audits on Defense Programs* (IEEE, 2015) was used as the basis for defining the processes and documents. The program director is concerned with the data products that are related to the data that validate the materiel solution. These are represented by the model in Figure 6. 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 in the PDR process.

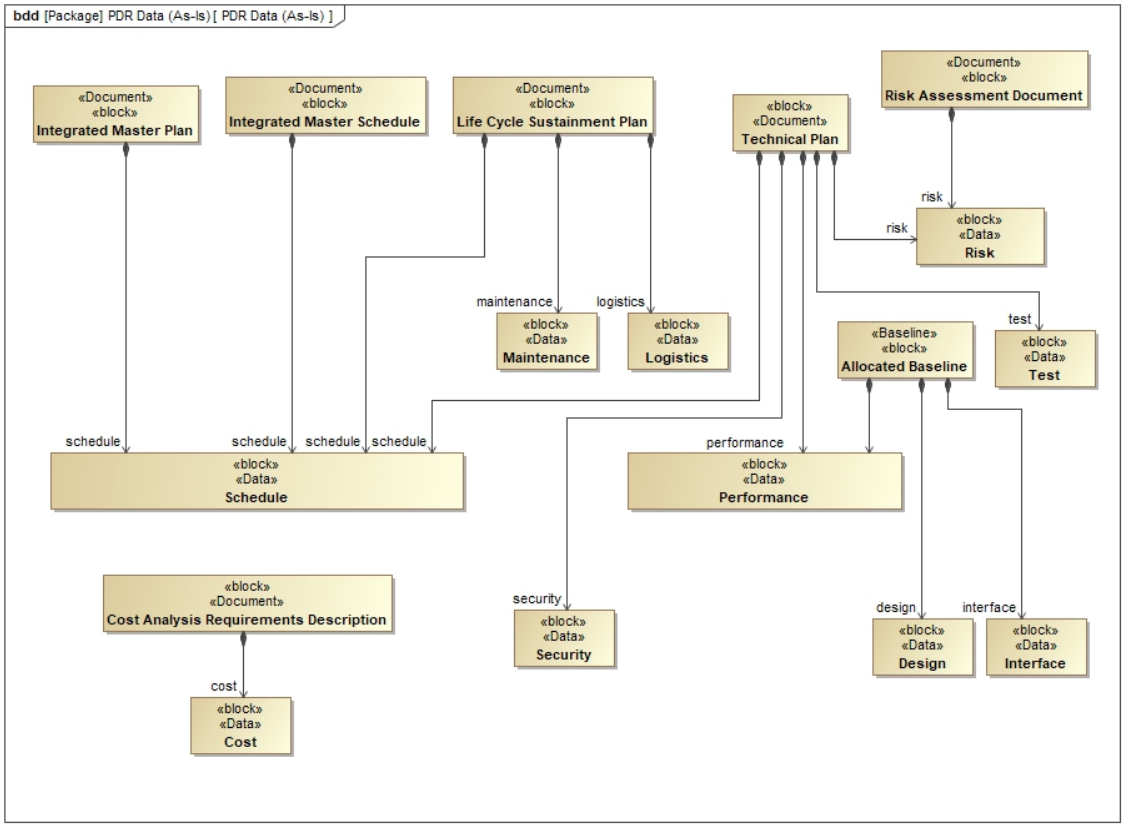

Figure 6: PDR Data for the Program Director (Cell: What (BusM))

Architect/Chief Engineer Perspective

The chief engineer is responsible for setting up, complying with, managing, and executing the PDR process. They have a need to deliver necessary documents for the PDR that represent the system under development. These documents include 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 (IEEE, 2015).

These documents are the entry products that will contain the data required by the materiel solution as shown in Figure 7. In addition, the chief engineer is concerned about other entry documents needed to conduct a PDR which include the presentation document, the PDR membership list, and the PDR agenda. The other consideration is the PDR closure products as shown in Figure 7, which include products such as the PDR minutes, action items, and PDR summary report.

Engineer/Systems Engineer Perspective

The systems 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, and the IT and software tools needed to conduct the PDR meeting. Software tools include the MS Office products used to create and review documents, SharePoint site, and email used to share documents. The IT tools include the desktop computer, the network, and the server where documents are transmitted and stored. The

documents include the PDR presentation, which is normally a PowerPoint-created document projected on a screen in the room and shared during the meeting for all participants to see. There are also several BDDs in this cell 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 considered the "things" that the system engineer is concerned with.

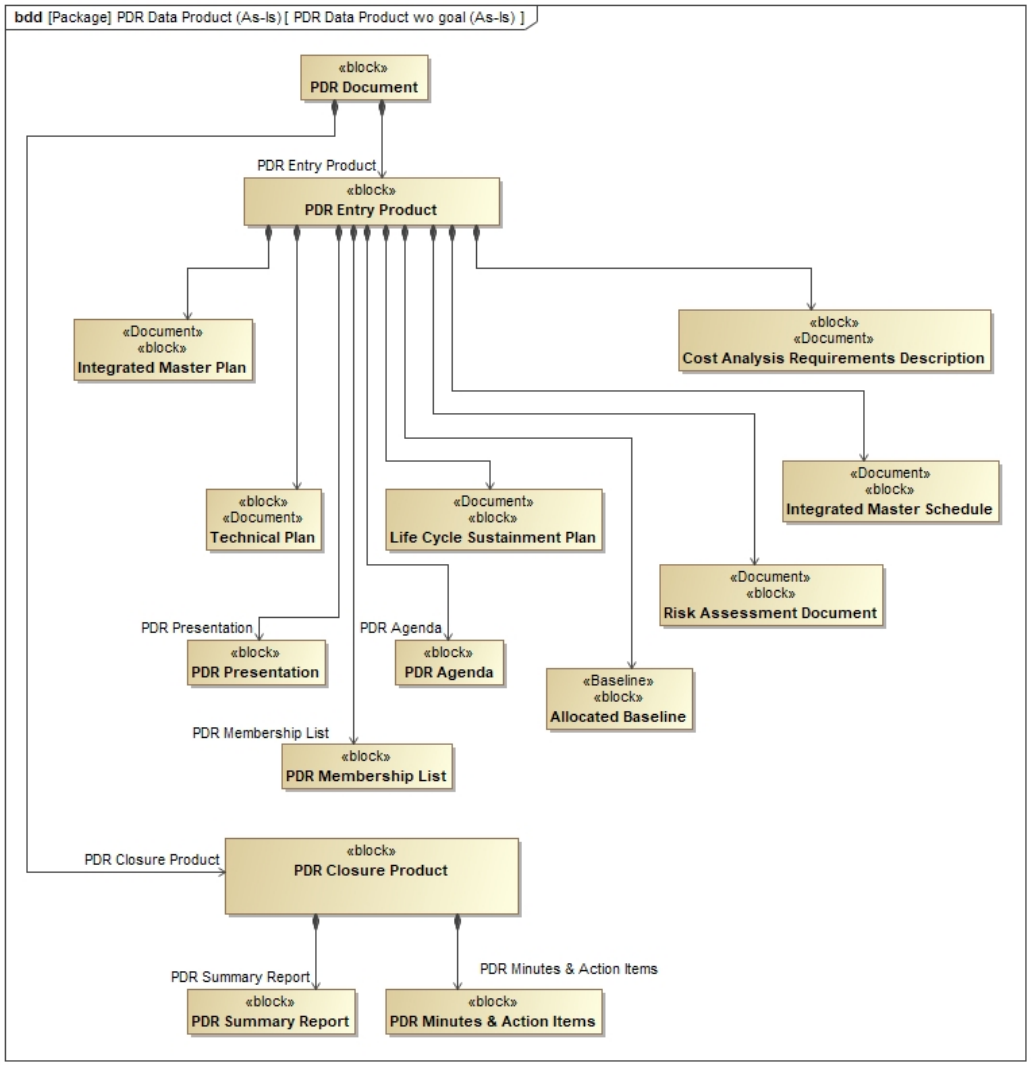

Figure 7: PDR Entry and Closure Products for the Chief Engineer (Cell: What (Arch))

This research modeled the enterprise within a framework that addressed four perspectives. For each perspective, the research addressed all the interrogatives of *why*, *how*, *what*, *who*, and *where* resulting in a picture of the business of conducting PDRs. Only the *what* interrogative was shown here as an example. The next step is to look at what are the primary effects of the Digital Campaign goals on this as-is enterprise model.

Primary Impact Analysis

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 LOE goals to accomplish this transformation. Those goals are shown in Table 1. LOE 4 addresses policy and guidance with its primary objective to review policies outside the AFMC acquisition enterprise and was not considered in this research.

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

Figure 8 shows the summary of mapping each LOE goal to its primary cell impacted (green cell). The goal words were reviewed and interpreted to determine 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.

LOE 0 and LOE 1 goals impact the *what* interrogative of the engineer perspective because the two goals mention changing the IT infrastructure (LOE 0) and Models and Tools (LOE 1). The LOE 2 goal impacts 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. The LOE 3 goal impacts the *how* interrogative of the architect. The architect is mostly concerned with the PDR process, which would be impacted under LOE 3 goal achievement. The LOE 5 goal impacts 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 LOE.

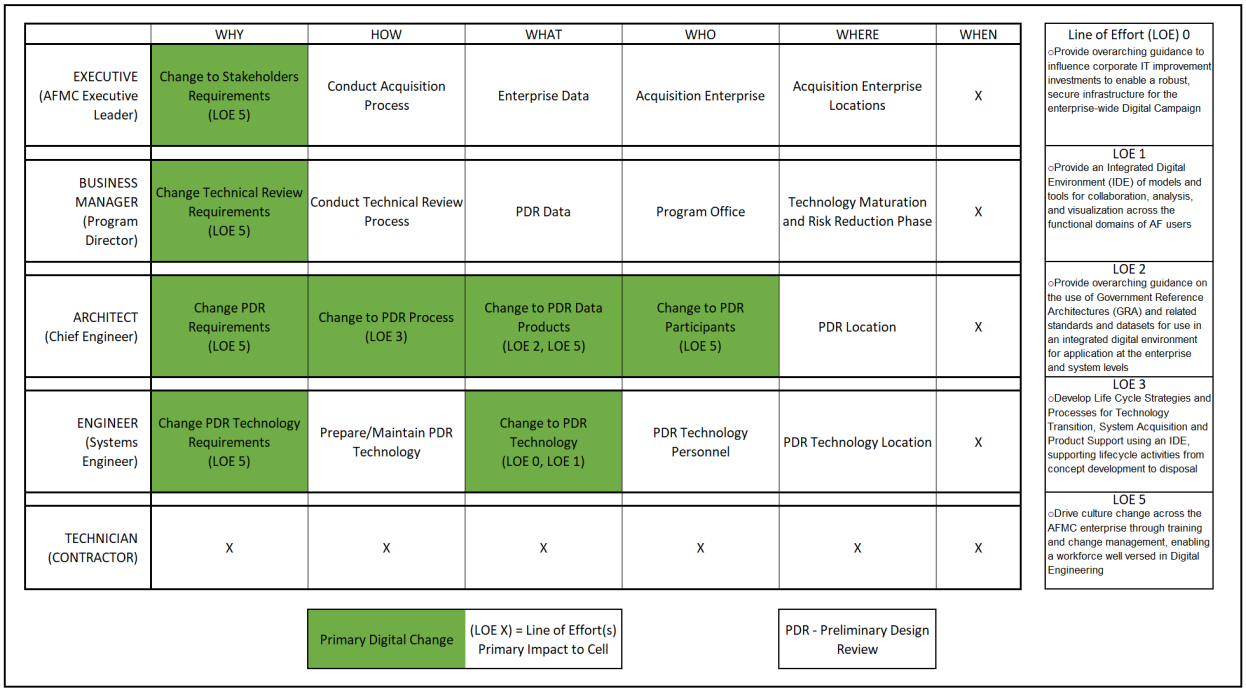

Figure 8: Summary of Primary Impacts from Digital Campaign Goals Indicated by Green Cells

The LOE goal impacted cells give the modeler a place to start in developing the to-be digital enterprise. Using LOE 2 as an example will provide a deeper understanding. The LOE 2 goal 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 as shown in Figure 9. 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, and 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 10.

A third model is defined as the Government Reference Model (GRM) and has a 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). 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, the GRM contains the data that constrains and guides the solution design contained in a system model including a top-level architecture model, and requirements and rules for a contractor to follow in proposing, creating, and validating the system design.

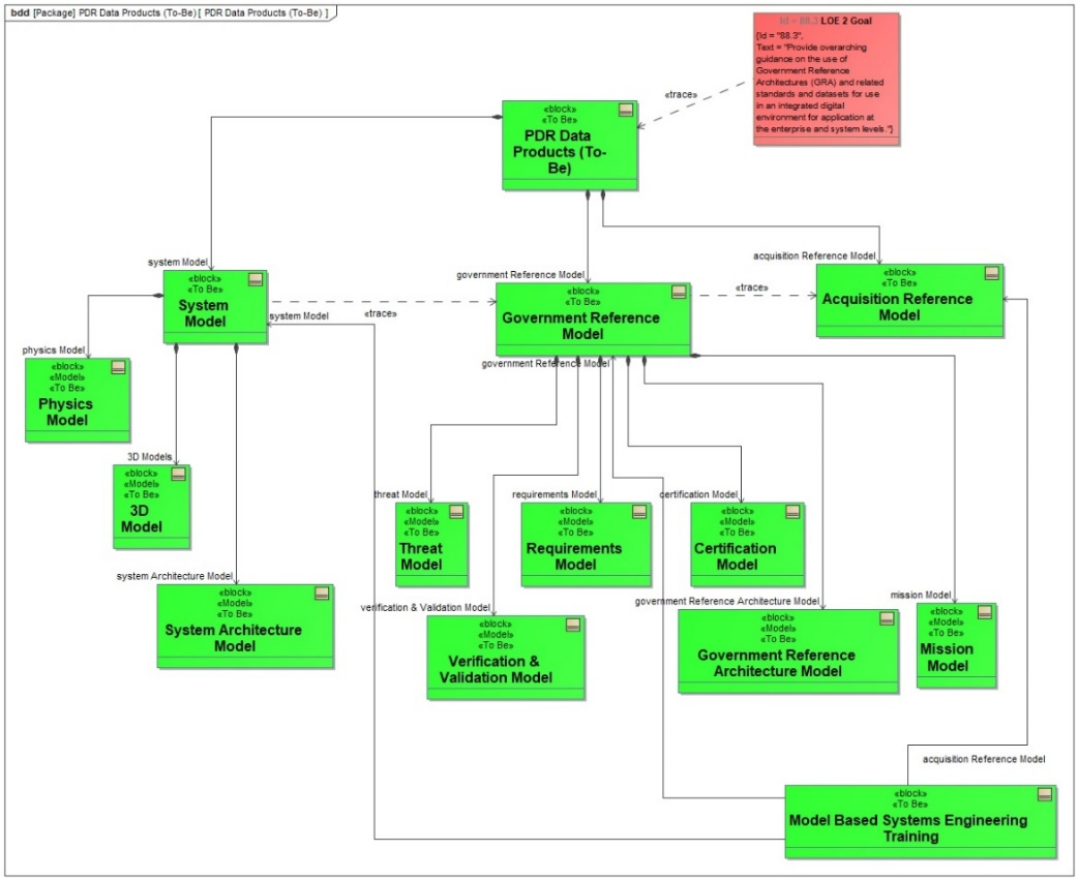

Figure 9: LOE 2 Impact to PDR Data Products (Cell: What (Arch))

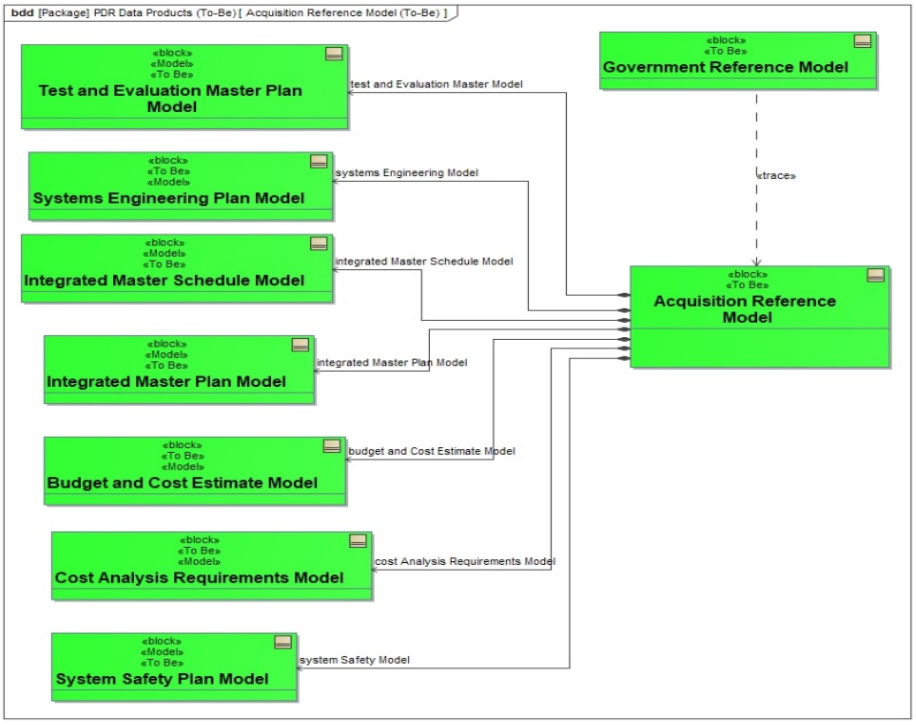

Figure 10: Acquisition Reference Model (Cell: What (Arch))

It is not automatic to discover the LOE goal impacts to the enterprise. SMEs must assess the impacts to their areas of expertise based on the technology state-of-the-art that the organization desires to implement. The modeling using the Zachman Framework does make it easier to see where those impacts are within the framework models, making assessment and assignment much easier.

Secondary Impacts & Gap Analysis

This section explains the analysis behind determining secondary impacts. These secondary impacts are important to visualize because change agents may not understand the cascading effects from their original change requirements. This research also will show how this modeling and analysis effort was used to find gaps within the Digital Campaign's approach.

Tracing Secondary Impacts

LOE 2 is used as an example to show how secondary impacts can be found from the modeling effort. LOE 2 primarily impacts the "What (Arch)" cell as shown in Figure 9. The LOE 2 team is implementing integrated models and data into the acquisition enterprise through architectures and standards as explained in section 4.

A CAMEO tool analysis method is used to display a relation map showing the relationships affected by the LOE 2 goal as shown in Figure 11. This figure shows that there are four secondary impacts based on entity use and relationships to other cells. These are the "Why (Arch)," "How (Arch)," "Who (Arch)," and "What (Engr)" cells. This could be done manually, but the CAMEO relation map capability makes it easy and does the searching automatically.

Changing from Entry and Closure PDR documents of Figure 7 to the PDR models of Figure 12 has an effect on the PDR process occurring in the "How (Arch)" cell as shown in Figure 13. With models implemented 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 process flow from one major review presentation to a cyclical and agile review flow within the models themselves. Another secondary impact of changing the data products of the "What (Arch)" cell is to the "What (Engr)" cell. So now the models needed for LOE 2 in the "What (Arch)" cell are requiring different tools (such as CAMEO) to build, review, and approve the models instead of the MS Office tools for documents in the as-is enterprise. A last secondary impact of changing the "What (Arch)" cell data products 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 14. This desktop is now connected to a new network and cloud environment (a LOE 0 and 1 goal) where the tools reside. The full impact of the LOE 2 goal is shown in Figure 15, where the green-shaded cell is the primary impact of the LOE 2, and the yellow-shaded cells are secondary impacts due to relationships between the cells.

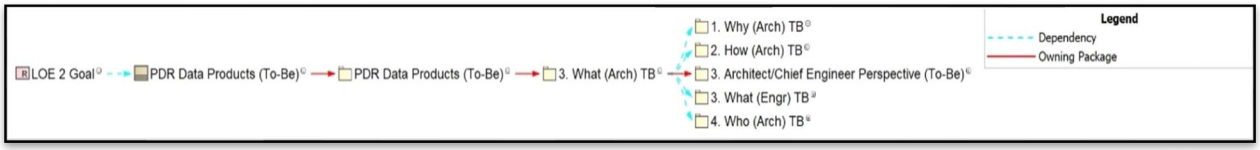

Figure 11: Relation Map for LOE 2 Goal for To Be Enterprise

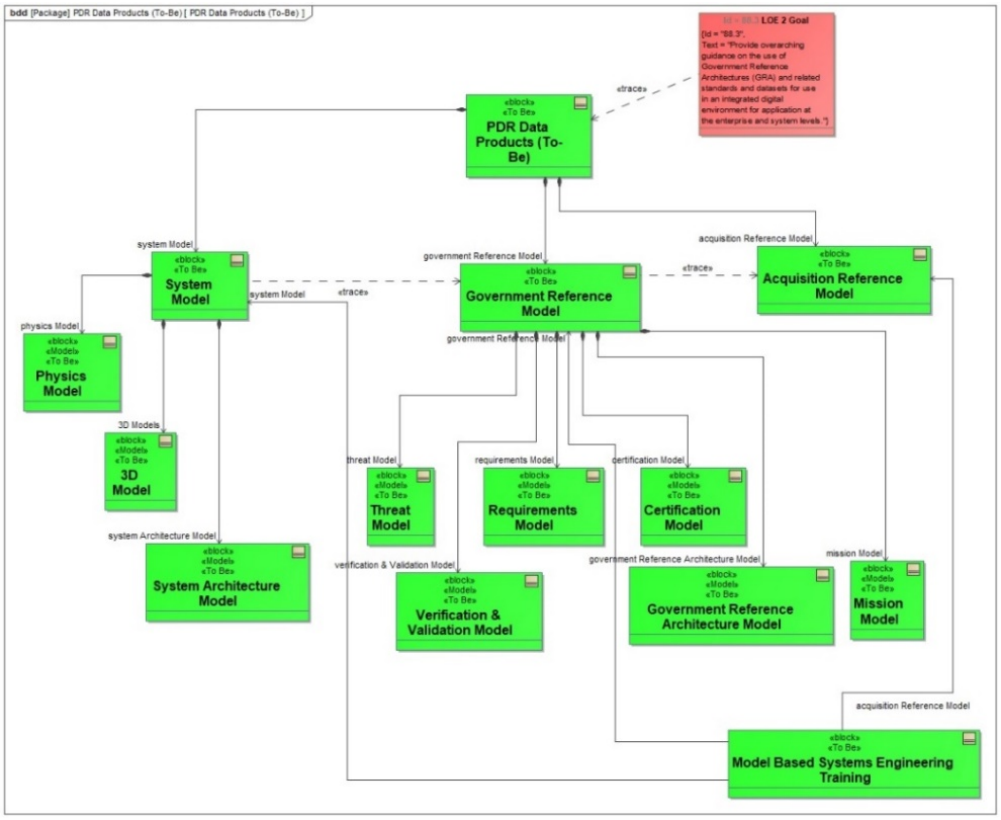

Figure 12: Models Used in To-Be Architecture for PDR (Cell: What (Arch))

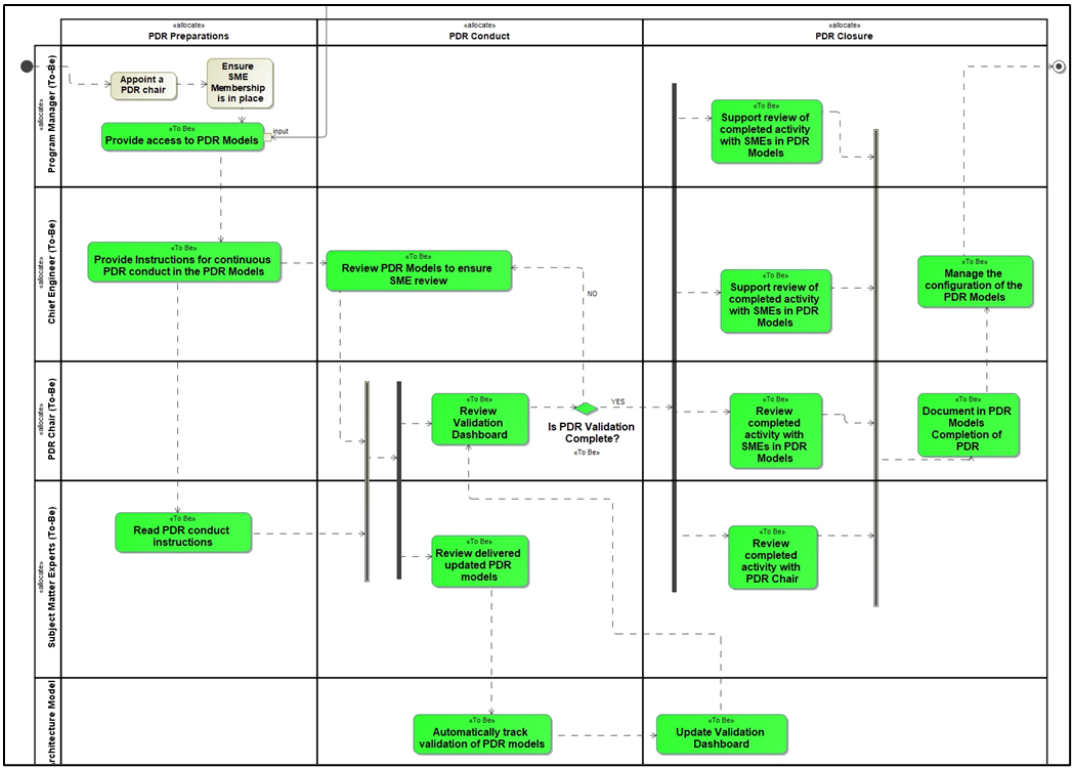

Figure 13: PDR Process for To-Be Architecture (Cell: How (Arch))

Relation maps were used to identify all the cells (packages), which had secondary impacts for each of the LOE goals. Figure 16 shows these secondary impacts for the overall enterprise (yellow cells) that appear outside the primary impacted cells (green cells). As can be seen, many LOE secondary impacts overlap onto primary impacted cells of other Digital Campaign Goals.

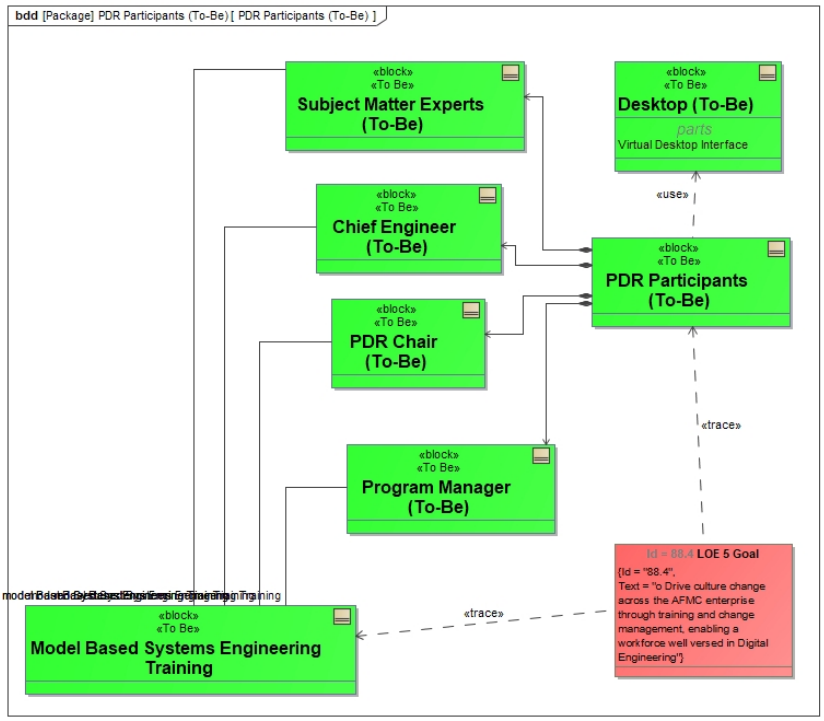

Figure 14: LOE 2 Secondary Impact to PDR Participants (Cell: Who (Arch))

Finding Digital Campaign Gaps

Upon formation of the Digital Campaign, 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 discover gaps within the LOEs' pursuits using a systems engineering model analysis.

Following a decomposition of requirements into the logical and physical representation of the enterprise from the expected changes of the Digital Campaign, one would expect that the Architect/Chief Engineer and the Engineer cells would be a primary target for the Digital Campaign. The Architect/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). They ensure the enterprise design complies with the enterprise requirements. In the case of the PDR process, they are the process owner, 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, as would similarly be expected by a requirement change to a weapon system.

The Engineer/System Engineer role 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. This detailed design 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.

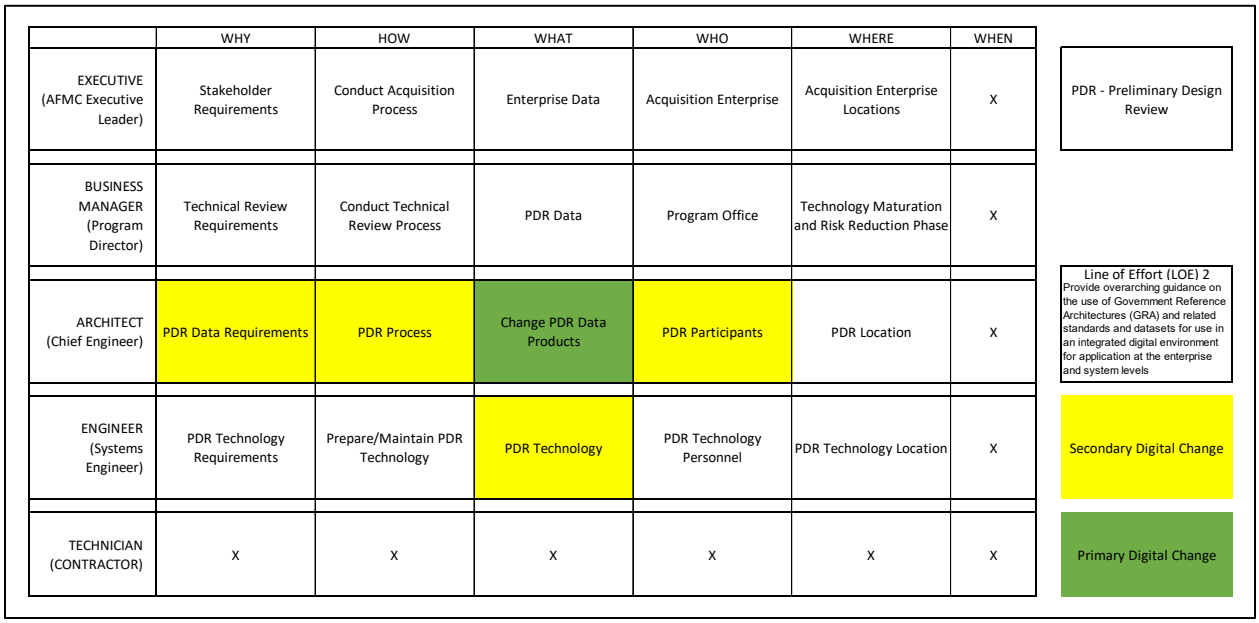

Figure 15: Summary of LOE 2 Impacts

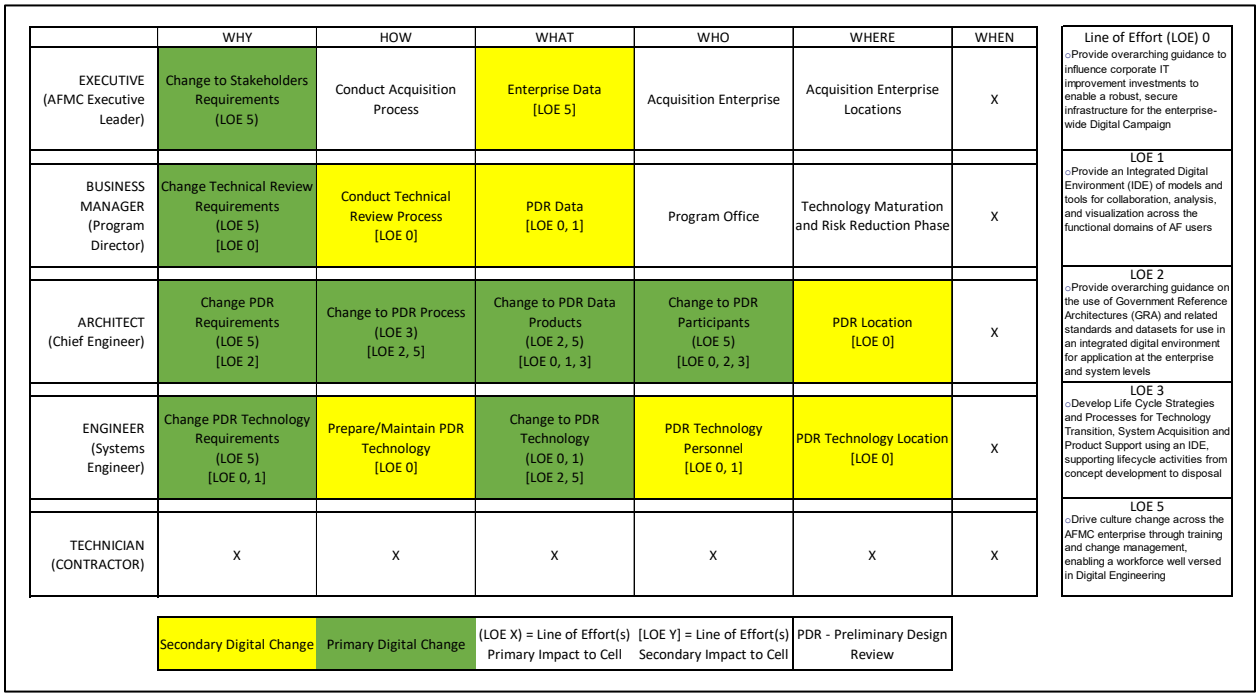

Figure 16: Summary of Overall Impacts of LOE Goals on Zachman Framework

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 architect

(chief engineer) and the engineer (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 goals would be to also focus on the *how*, *who* and *where* of the systems engineer perspective. Currently, the Campaign focus is only on the *what* and *why* of the system 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 permanent 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.

Conclusions and Recommendations

This research presented a method to build a model that addresses the digital transformation of the AFMC acquisition enterprise. The findings of this research are:

1. It is possible to visualize 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 SysML is analogous to a system decomposition and definition using well-established systems engineering processes.

2. As long as the transformation goals do not change, the Zachman cells impacted by the LOEs 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. The focus of this research was the effect of the digital transformation on the PDR process. The focus could have been on other enterprise areas, 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.

3. Changing process is typically the way the Air Force has gone about change (i.e., trying to be more efficient and effective by leaning the acquisition processes). Guided by the Office of Secretary of Defense (OSD) Digital Strategy, the AFMC Digital Campaign is instead focusing on addressing the *what* (acquisition data using digital system models) and then expecting that the *how* will follow. As shown in this research, changing to digital models from documents and upgrading IT infrastructure is the focus of the transformation. The LOE 3 goal is not to change process to achieve efficiency, but instead, is written to support the change to the Integrated Digital Environment. The Integrated Digital Environment consists of the models, the data, and the standards, as well as the tools and IT infrastructure. This implies that process will change as a result of the technology change. This is visible with mapping the Digital Campaign goals onto a Zachman Framework and performing relationship analysis showing cascading impacts to processes from 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 gaps in the LOE goals that do not cover all Architect's and Engineer's interrogatives. Building an EA would reveal gaps if used as a tool for documenting progress and help ensure an efficient digital transformation.

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 acquisition speed. This effort did not address *time* as a parameter. This could be an important factor to research in a future effort. This research demonstrated the method based on a single exemplary process – PDR. It assumed that the Digital Campaign goals always will impact the same Zachman Framework cells regardless of the process mapped. This hypothesis could be refined with an effort to map additional acquisition processes. This would contribute to the concept 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. Lastly, a future effort could expand the enterprise boundary. Air Force Materiel Command (AFMC) is an enterprise within the larger Department of the Air Force (DAF). Looking at the entire DAF Acquisition Enterprise could provide more insight into other areas of how acquisition could be improved through digital transformation.

References

Alia-Novobilski, M. (2020, June 5). *AFMC Digital Campaign aims to modernize, streamline life cycle process*. Air Force Materiel Command. https://www.afmc.af.mil/News/Article-Display/Article/2209560/afmc-digital-campaign-aims-to-modernize-streamline-life-cycle-process/

Bernard, S. A. (2012). *An introduction to enterprise architecture* (3rd ed.). AuthorHouse.

Brown, G. Q. (2020). *Accelerate change or lose.* United States Air Force. https://www.af.mil/Portals/1/documents/csaf/CSAF_22/CSAF_22_Strategic_Approach_Accelerate_Change_or_Lose_31_Aug_2020.pdf

DoD CIO. (2010, June). *DoD reference architecture description*. Assistant Secretary of Defense for Networks and Information Integration.

Fox, J. R. (2011, April 29). *Defense acquisition reform, 1960–2009. An elusive goal.* Center of Military History, United States Army. https://history.defense.gov/Portals/70/Documents/acquisition_pub/CMH_Pub_51-3-1.pdf

IEEE. (2011). *ISO/IEC/IEEE 42010:2011. Systems and software engineering, architecture description*.

IEEE. (2015). *IEEE Std 15288.2-2014. IEEE standard for technical reviews and audits on defense programs.*

Kotusev, S. (2016). The history of enterprise architecture: An evidence-based review. *Journal of Enterprise Architecture, 12*(1), 29–37.

Sowa, J. F., & Zachman, J. A. (1992). Extending and formalizing the framework for information systems architecture. *IBM Systems Journal, 31*(3), 590–616.

Zachman, J. A. (1987). A framework for information systems architecture. *IBM Systems Journal*, *26*(3), 276–292.

Acquisition Research Program
Graduate School of Defense Management
Naval Postgraduate School
555 Dyer Road, Ingersoll Hall
Monterey, CA 93943

www.acquisitionresearch.net