Proceedings of the 2020 Annual General Donald R. Keith Memorial Capstone Conference
West Point, New York, USA
April 30, 2020
A Regional Conference of the Society for Industrial and Systems Engineering

An Analysis of Model Based Systems Engineering in the Army Acquisition Process

Lacey Swafford and Michael Parrish

Department of Systems Engineering
United States Military Academy, West Point, NY

Corresponding Author: lacey.swafford@westpoint.edu

Author Note: Cadet Lacey Swafford is a senior at the United States Military Academy at West Point pursuing a degree in Engineering Management within the Department of Systems Engineering. This project was completed as part of the requirement in the honors program under the advisement of Colonel (Retired) Michael Parrish. Cadet Swafford would like to thank the Department of Systems Engineering and her advisor for all their support.

Abstract: The Army Acquisition Process (AAP) currently uses documents to track a project's progress. Each time a change is made, all documents must be manually edited to reflect it. This results in the process requiring significant time and resources while also being error prone. The purpose of this project was to research the feasibility of Model Based Systems Engineering (MBSE) as a possible method to improve the AAP. The approach was to conduct a literature review of relevant scholarly sources to gain a baseline knowledge of the topics, then select and use a MBSE software, Innoslate in this case, to create a model of the AAP and evaluate it for future relevance and sustainability in improving the AAP. The results of this project were that MBSE is a viable option for improving the AAP, but that the Innoslate software is not the ideal software for U.S. Army use in future efforts.

Keywords: Model Based Systems Engineering, Digital Transformation, Army Acquisition Process, DOD Acquisition Reform, Systems Engineering

1. Introduction

The current Army Acquisition Process (AAP) is an antiquated way for the Army to validate, select, integrate, and maintain programs. While updating programs and enabling soldiers to have the most up to date capabilities is critical, Army acquisition programs can spend years and even decades in the life cycle of the AAP to develop or upgrade current systems. This requires the Army to allocate resources to the monitoring and controlling of a program long after its origination. Any change to a requirement requires significant manual effort to ensure all appropriate documents, such as the Capability Development Document, and maintenance and operators manuals are correctly updated. A new approach that is gaining traction in industry is the Model Based Systems Engineering (MBSE) process. Corporations have been working on embracing the MBSE concept for years (Puthiyamadam, 2017). As such, MBSE could be a viable option to improve the AAP.

1.1 Background

1.1.1 Model Based Systems Engineering

The first step to understanding model based systems engineering (MBSE) is to understand that its goal is to streamline and improve traditional document based systems engineering (will be referred to as systems engineering for the duration of this paper). "Systems engineering is the intellectual, academic, and professional discipline the principal concern of which is the responsibility to ensure that all requirements for a bioware hardware software system are satisfied throughout the life cycle of the system (Wymore, 1993)." Systems engineers are experts at defining problems using value focused thinking and provide creative perspectives with which to look at problems and generate, select, and implement alternatives. One common example of systems engineering is the systems decision process (SDP) (Parnell et al., 2011). The SDP provides a framework for systems engineers to determine what brings value to the stakeholder, generate alternatives, select an alternative, and implement a solution. Additionally, each phase of the SDP has documents that are produced as the process progresses. These documents must be edited as adjustments are made throughout the process. The process of editing is where traditional document-based systems engineering and MBSE differ. "MBSE intends to formally apply modeling and simulation to support definition of

system requirements, system design, system analysis, and system verification and validation" (Beery, 2016). MBSE aims to accomplish all the benefits of systems engineering, but by using a more efficient method, modeling.

1.1.2 The Army Acquisition Process

The AAP is the process that the Army must go through to approve, purchase, modify, and distribute new capabilities on a large scale. Currently, the process has five phases ranging from the initial decision to allow a project to enter into the process, to sustaining and maintaining the project after it has already been integrated into the force, to deciding when to terminate and the project. At this point a program is phased out of use and a new program is ideally taking its place, beginning the process all over again. This happens with any new program the Army wants to adopt, so the need to accurately track of these programs' progress is necessary to prevent inefficient use of resources. This is not an easy feat, however, and is often plagued by errors. The organization must then spend the time to go back and correct these errors. This has led to many attempts to reform the acquisition process, none providing much success (Fox, 2011). If improvements are to be made to the AAP, then what is to be improved upon must be established. There are many factors that lead the AAP to encounter delays. Most of these factors are related to the training of personnel or budget. For example, in order to make one's project competitive, one might underestimate the total cost of the project. This leads to budget issues once the process has already begun. Additionally, with the way the Army is designed, personnel are continuously rotating in and out of positions every few years due to permanent changes of station (PCS). This leads to additional time and resources spent retraining personnel (Fox, 2011). Integrating MBSE into the AAP could help improve both of these factors that commonly cause delays, which would improve the AAP as a whole.

1.2 Motivation for Research

1.2.1 Limitations of a Documentation Based Acquisition Process

The AAP's lack of speed of execution, is its primary limitation. Multiple attempts at reforming the process have not had their intended impacts (Fox, 2011). However, the quest for defense acquisition reform is still ongoing, even inspiring multiple studies by various thinktanks such as the RAND corporation (Stem et al., 2006). The AAP is limited severely by its dependence on documents. Different documents of varying length and complexity are used in each phase of the AAP to keep a record of different data (DAU, 2019). For example, the first phase of the AAP, Material Solution Analysis (MSA) requires the production of at least eight different documents, which are maintained throughout the rest of the phases. All of this data can be contained in more than one document, which can make it very difficult to make changes during the process because of the cross referencing required. This not only makes maintaining accurate documents difficult, but also creates problems with version control whenever there is more than one person working on a document. For example, if it is decided that the project needs 7 widgets instead of 6, then each document in the entire process containing the number of widgets needed must be edited. Having multiple people responsible for a document only complicates this process because of the additional communication necessary to keep track of edits made. This process, as well as the errors that often accompany it, are costly in time and resources. Because of this, an improved, modernized methodology such as MBSE is required to upgrade the AAP.

1.2.2 The Applications of Digital Transformation in the Civilian Sector

In the civilian sector, the idea of incorporating technologies like MBSE into the operational structure of a company is called digital transformation and has been occurring for years (Puthiyamadam, 2017). The industry has proved itself to be more successful in the endeavor to automate processes and eliminate the need to maintain multiple documents containing redundant information. This is evidenced by the increased involvement of CIOs in strategic planning (Puthiyamadam, 2017). This makes it an ideal case study to benchmark how to make tracking mechanisms more efficient. Applications of digital transformation in the civilian sector motivated this research because they accomplished some of the same goals for an improved AAP, like reducing costs and easing the users experience, with digital transformation (Puthiyamadam, 2017).

2. Methodology: Creating a Model

2.1 Selecting a Software

Based upon stakeholder analysis and interviews with subject matter experts in the field of US Army acquisition and MBSE, the computer software Innoslate was selected to develop the model for this research since it provides greater flexibility in replicating the acquisition process. The software was further researched and determined to be a fit for this project primarily because of its user friendliness. This factor was seen as key to the future implementation of a MBSE solution to improving the AAP because it would limit the amount of training acquisition officers would need to transition to this new way of conducting

and keeping up with the process. Other valuable features of the software include the ability to create documents, templates for those documents, the ability to create a database, and the ability to simulate the process.

The other software that was heavily considered for this research was SysML. However, the complexity of this software prevented it from being selected. It was judged that SysML was not ideal for an officer with no experience with modeling languages or MBSE to learn quickly and easily. It was desirable that the software chosen be easy and quick to learn because that would best facilitate the future implementation of a solution. Fewer training requirements would allow for a smoother transition from the current AAP to an AAP that involves MBSE.

2.2 Constructing the Model

The main source used as a guide when creating a model of the AAP was the Defense Acquisition University's Life Cycle Wall Chart, which can be seen below in Figure 1 (DAU, 2019). The Life Cycle Wall Chart illustrates the difficulty of reading/understanding the AAP. The complexity of the process is why a solution like MBSE would be helpful. Digitization would make it much easier for acquisition officers to keep track of and understand the current documentation of a given project.

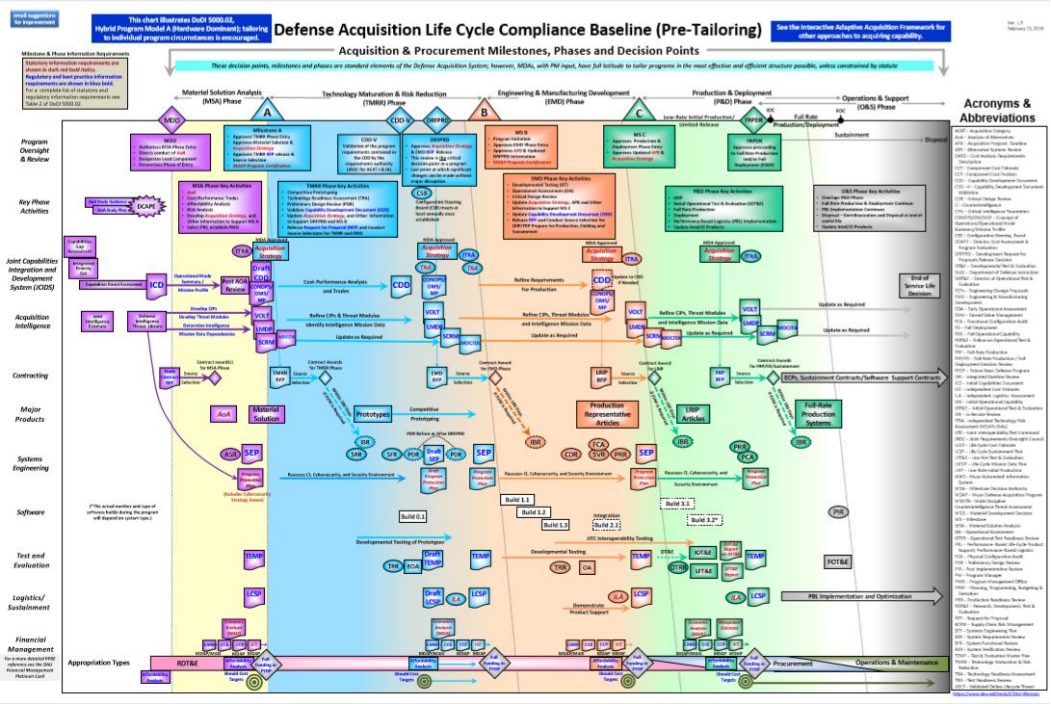

Figure 1. The Defense Acquisition Life Cycle Wall Chart

The approach used when creating the model (referenced in figure 4) was to scope the process to the most important aspects of each of the models DAU has of the process. The significance of the aspects included in the Innoslate model were confirmed through additional research. It was found that in other depictions of the AAP, they were repeatedly represented. One example can be found in figure 2 below (Systems Engineering Fundamentals, 2001).

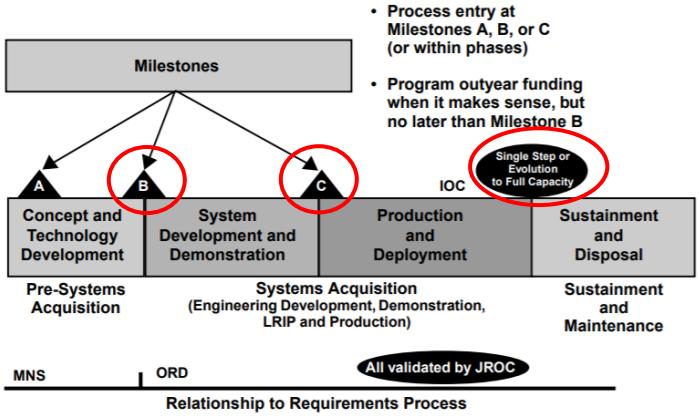

Figure 2. Additional Representation of the AAP, Highlighting Key Components

These models are not interactive. They are purely graphical representations of the sequence of what happens in the acquisition process from different perspectives. These perspectives include accelerated, software intensive, hardware intensive, etc. This model combines the largest, most complex model and the software intensive models. This is a key point because the advantage of the MBSE model of the AAP created in this project is interactive in that it calculates the time of the process, documents and data associated with the process, and can track an entity (a program being acquired) as it travels through the AAP. This digitalization of all the data surrounding the AAP would allow for improvements like the quicker acquiring of programs, and more efficient use of manpower. Another key factor of the AAP incorporated into the Innoslate model are milestones usually crossed in the AAP. These milestones are represented in the model as outputs. The software lacks a way to connect documents to the model at a specified location, which is definitely a limitation of the model. However, two different documents were generated to illustrate the two different ways documents could be used with this model. The first is a systems engineering plan (SEP). Innoslate did not have a template already made for an SEP, so an external template was used on a blank document (Maier, 2019), illustrating how documents traditionally made during the AAP could be formed into a template to be used the same way every time the model is used. The second document is a project management plan document, which is a template provided by the site. The takeaway from the creation of these two documents is that each of the many documents contained within the AAP could be recreated and templated for a MBSE model like this one. Moving forward, with a model like this one it would be necessary to transform any information not already encompassed by existing templates into a document that could be standardized and used for a variety of different acquisition projects. This would be a painful and unnecessary process, since theoretically any of the data contained in the documents is already contained in the model. It is a possible course of action though, if the organization wanted an intermediate step between documents based, and full dependence on a model alone.

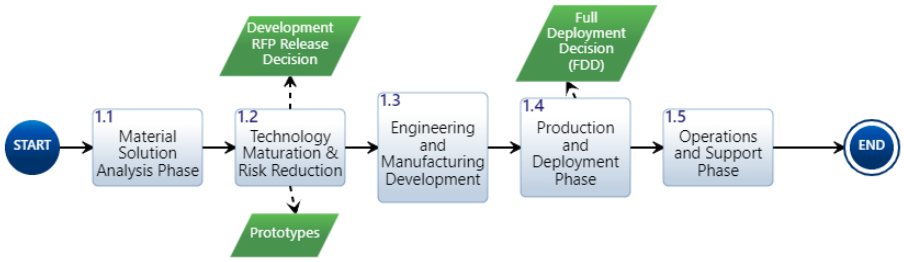

Figure 3. A Model of the AAP using the MBSE software Innoslate

2.3 Evaluating the Software

Once the model was built, it could be used to evaluate the effectiveness of the chosen software. Specifically, the criteria for an ideal software would be that it can be shared by multiple users, it can be worked on simultaneously (updating

automatically), it is capable of accurately representing the AAP, and there is a way to track what edits were made to the model and when they were made. This criterion was built with the goal to make the model as effective as possible once it is implemented. For example, it is vital that the software has the capability to accurately represent the most important interdependencies in the AAP for the model to be useful. Thus, for the software to be satisfactory is must produce a validated model, or a model that "accurately reflects the system under analysis" (Russel & Taylor, 2017). Additionally, the ability to collaborate on a document while monitoring how the program has changed over time could offer convenience to acquisition officers.

3. Results

3.1 Findings

3.1.1 The Viability of MBSE for Improving the AAP

MBSE is an applicable candidate for improving the AAP because MBSE is geared towards improving the areas that influence the shortcomings of the AAP. These areas are maintaining documents without error and speed of execution. MBSE aims to improve those areas by eliminating the need for documents and automating tasks currently done by a person. MBSE also addresses the difficulties with version control currently encountered by the AAP by eliminating the need for personnel to be responsible for editing documents. Digital transformation has consistently lowered costs when successfully implemented (Puthiyamadam, 2017).

3.1.2 The Suitability of Innoslate for Future Research Efforts

Despite the software tracking when specific edits were made and enabling collaboration on a model, Innoslate was not robust enough to enable the modeling of the true relationships between phases of the AAP and milestones, outputs, and resources. Thus, it is not a satisfactory software to use in future research efforts. This is primarily because of the simplicity of the software. Future attempts at modeling the AAP should incorporate more data and be more detailed than was capable of this model due to the modesty of the software used. Innoslate simply does not enable the accurate representation of reality, which is vital to the model's validation.

3.2 Limitations of the Model

This model is limited by the simplicity of the software used to create it. Innoslate lacks the ability to connect documents to the model, meaning they would not automatically update with the editing of the model. Additionally, the simplistic features of Innoslate, while user friendly, also prevented the model from reaching its ideal level of complexity. Relationships between nodes or actions in the model were restricted to the offered relationships in Innoslate. This resulted in the model lacking accuracy because the relationship type depicted doesn't always reflect reality, just something close to reality. This model is also limited by the fact that it is not simulating a specific program in the AAP, but the process itself. This causes the model to lack relevance because all the data inputted into the model is arbitrary, purely an example of what a model of the AAP could look like. This model could be used in future projects as a reference but is a summary of only the most important parts of the AAP, and would need specific data (which would come from the program being acquired) added to it for it to fully serve its true purpose.

3.3 Recommendations for Future Research

A truly successful model of the AAP needs to be all encompassing, meaning the model contains all the data that would usually be in each of the documents produced in each phase of the AAP. This is the only way that the organization could work towards cutting out the use of documents all together, which is the ideal end state as it eliminates the most waste of resources that occur during the AAP. Additionally, it is vital that future models of the AAP are complex enough to be useful, meaning that acquisition officers are not starting from scratch with each new program acquired, but generalized and simplified enough that they can be used for a wide variety of programs. To accomplish this, the primary recommendations for future research are to widen the pool of individuals making the model. Simply put, the more information that is put into the model, the better the model will be. This is up to the point that any additional information would over specifying the model, making it not usable for an eclectic array of possible programs. MBSE is a viable option for improving the AAP; however, it will take dedicated and deliberate allocation of resources in the form of personnel, time, and funds on the front end in order to reap the benefits of an implemented solution. Additionally, future research on integrating MBSE into the AAP should continue to use businesses that have been successful in implementing technology in their daily operations as a reference. As friction points are encountered in

this research, it is possible that the civilian sector has also encountered those problems and already come up with solutions. Lastly, technology promotes increased transparency throughout the supply chain (in this case the AAP) (Bowersox et al., 2005). While this would be a positive result in that it would help to decrease some of the bureaucratic hurdles in the AAP, it could also introduce some security risks that would need to be mitigated.

4. Conclusion

The AAP currently requires significant time and resources, while also being prone to error. This is because the AAP currently depends on documents to track a project's progress. Each time a change is made, all documents must be manually edited to reflect the change. The purpose of this project was to research the feasibility of Model Based Systems Engineering (MBSE) as a possible method to improve the AAP. The approach was to conduct a literature review of scholarly sources relevant to the topic to gain a baseline knowledge of the topics, then select and use a MBSE software, Innoslate in this case, to create a model of the AAP and evaluate that model for future relevance and sustainability in improving the AAP. The results of this project were that MBSE is a viable option for improving the AAP, but that the Innoslate software is not the ideal software for U.S. Army use in future efforts.

5. References

Beery, P. (2016, June). A Model-Based Systems Engineering Methodology for Employing Architecture in System Analysis. Monterey, California, United States of America.

Bowersox, D., Closs, D., & and Drayer, R. (2005). The Digital Transformation: Technology and Beyond. *Supply Chain Management Review*.

CPT Kennedy, D. (2019, ~September). Recommending a Software. (L. Swafford, Interviewer)

Delligatti, L. (2014). *SysML Distilled A Brief Guide to the Systems Modeling Language.* New York: Pearson Education.

Fox, J. R. (2011). *Defense Acquisition Reform, 1960-2009 An Elusive Goal.* Washington D.C.: Center of Military History.

Gillespie, S. (2019, October). Recommending a MBSE software. (L. Swafford, Interviewer)

Major Hoak, S. (2019, October 17). Discussion about the Defense Acquisition University. (L. Swafford, Interviewer)

Parnell, S. G., Driscoll, J. P., & Henderson, L. D. (2011). *Decision Making in Systems Engineering and Management.* Hoboken: John Wiley & Sons Inc.

Puthiyamadam, T. (2017). How the Meaning of Digital Transformation Has Evolved. . *Harvard Business Review*.

Russel, S. R., & Taylor, W. B. (2017). *Operations and Supply Chain Management.* Hoboken: John Wiley & Sons, Inc. .

Stem, E. D., Boito, M., & Younossi, O. (2006). *Systems Engineering and Program Management* . Santa Monica: RAND Corporation.

(2001). *System Engineering Fundamentals.* Fort Belvoir: Defense Acquisition University Press.

University, T. D. (2019, February 13). *Defense Acquisition Life Cycle Wall Chart.* Retrieved from DAU: https://www.dau.edu/tools/t/Department-of-Defense-Acquisition-Life-Cycle-Chart

Wymore, A. W. (1993). *Model Based Systems Engineering.* Boca Raton: CRC Press.