Proceedings of the Annual General Donald R. Keith Memorial Conference
West Point, New York, USA
April 24, 2025
A Regional Conference of the Society for Industrial and Systems Engineering

Assessing Systems Engineering Needs for the 160th SOAR's Systems Integration and Management Office

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Authors' Note: Nicholas Crary, Zachary Perez, Zoe Rennison, and Garrett Salisbury are a group of senior cadets at the United States Military Academy (USMA). They completed this capstone research with the assistance of their faculty advisor, Colonel Julia Coxen, who is the Department Head of the Department of Systems Engineering at USMA. All communication and coordination with the client, the Systems Integration and Management Office (SIMO) for the 160th Special Operations Aviation Regiment (SOAR) (Airborne), was conducted through Mr. Jared VanCuren at SIMO. The views expressed herein are those of the authors and do not reflect the position of the United States Military Academy, the 160th SOAR, the Department of the Army, or the Department of Defense.

Abstract: The Systems Integration Management Office (SIMO) serves as the innovating force for the 160th Special Operations Aviation Regiment (SOAR) (Airborne), employing a top-down approach to warfighting and lethality. Its primary mission is to develop and field innovative technologies that enhance the 160th's battlefield effectiveness. SIMO aims to increase its use of systems engineering practices in order to gain greater efficiency throughout the lifecycle of the projects in its portfolio. Creating a set of qualitative and quantitative models based on sample project data highlighted specific opportunities to employ systems engineers. Rooted in concepts from the Systems Decision Process, the qualitative model indicates the logical process that SIMO should follow to ensure the proper utilization of systems engineering practices. This methodology could increase the readiness and lethality of the 160th through aiding SIMO in more efficiently developing modern technologies.

Keywords: Systems engineering, confidence intervals, flowchart

1. Introduction

The Systems Integration Management Office (SIMO), located at Fort Campbell, Kentucky, is responsible for the innovation of new technologies for the 160th Special Operations Aviation Regiment (SOAR) (Airborne) under the United States Army Special Operations Aviation Command. The Systems Integration Management Office's mission is to "equip the Soldiers of the USASOAC Enterprise with the most capable rotary wing aircraft and mission systems in the world" through sustainment and improvement of their specialized equipment (United States Army Special Operations Command, n.d.). SIMO is an organization with a staff consisting of commissioned officers, warrant officers, noncommissioned officers, government civilians, and contractors, who are employed across thirteen branches of projects. These projects are essential when equipping and preparing the 160th SOAR(A) for the future of warfare. SIMO's fundamental objective is staying up to date with over one hundred projects despite constraints on personnel, time, and budget. With the budget and team size already at their limit, adding multiple systems engineers within SIMO is not feasible. However, starting in April 2025, SIMO will be hiring one full-time systems engineer. While this contributes additional knowledge to SIMO's resources, there remain opportunities for implementing a systems engineering framework throughout each project's lifecycle. Because SIMO has a relatively small workforce, fully integrating systems engineering practices could assist in fully defining requirements, increasing traceability within designs, and maximizing the project process's standardization.

Currently, SIMO faces the challenge of implementing systems engineering practices and employees throughout the project lifecycle. The following problem statement focused on assisting with this challenge: "This project aims to enhance project execution within SIMO by developing processes for when, how, and where systems engineering can be most effectively implemented throughout the project lifecycle." Although each project has unique requirements and timelines, employing systems engineering practices could be a powerful framework to ensure that SIMO continues to fulfill its mission statement. We created two models focused on aiding SIMO in implementing systems engineering during the development of new technologies. The first relies on a quantitative approach that identifies when testing values are outside of an acceptable range, thus giving an early warning that a component is not in compliance with Modular Open Systems Approach (MOSA) standards. The second focuses on a qualitative approach, combining concepts from the Systems Decision Process (SDP) and the Systems V-Model into a flowchart to outline a holistic framework that addresses SIMO's gaps. This flowchart has milestones and deliverables that will maximize the implementation of systems engineering and create a highly traceable, easy-to-follow process. With both tools, SIMO can deliberately employ systems engineering practices and provide the 160th SOAR(A) with increasingly capable and lethal technologies.

2. Background

The research methodology began with a review of the currently established literature regarding the capabilities of systems engineering. This research emphasized analyzing the Modular Open Systems Approach, the Future Airborne Capability Environment, and the defense industry's best practices for designing and integrating systems. This analysis identified critical gaps in SIMO's systems engineering practices, which directly informed the development of the quantitative and qualitative models.

2.1 Modular Open Systems Approach

The focus of MOSA is to create a set of standards shared by all contributors to a project, allowing components to operate with one another (Azani & Khorramshahgol, 2006). The MOSA framework incorporates five principles for consideration when implementing it, which combine to ensure that designs can work effectively with other systems. These five principles are establishing an enabling environment, employing a modular design, designating key interfaces, certifying conformance, and using open standards (Rendon, 2007). Because different contractors design subsystems under the MOSA framework, they must be able to work together to allow the system to function properly. MOSA relies heavily on the standardization of technological interfaces, which allows adding or subtracting each individually without having a major impact on the functionality of the system, thus maximizing its modularity (Zimmerman et al., 2018). Fundamentally, MOSA provides a framework that attempts to shorten the time required to develop new and upgrade existing technologies while reducing the overall cost of projects (Vogler, 2023).

2.2 Future Airborne Capability Environment

In 2015, the Department of Defense (DoD) released Instruction 5000.02, mandating the implementation of "a MOSA to the maximum extent feasible and cost effective." To demonstrate the need for MOSA, the DoD (2015) highlighted that "modular designs coupled with an appropriately open business model provide a valuable mechanism for continuing competition and incremental upgrades." The Future Airborne Capability Environment (FACE) initiative is an example of applying MOSA to the defense world, specifically within the aviation realm (Gaska, 2012). "The objective of FACE is to guide current MOSA [aviation] platforms toward a more unified next generation processing environment with additional improvements in open, modular, portable, partitioned, expandable, secure, and interoperable" systems (Gaska, 2012). One of the drivers of implementing FACE is the continuous emergence of new technologies reshaping Army aviation by enhancing operational capabilities and altering approaches to modern warfare. Great advancements in artificial intelligence, unmanned systems, and advanced data analytics anticipated between 2020 and 2040 should improve decision-making and operational efficiency (O'Hanlon, 2019). By relying on adaptable technology, aviators and the military can become better prepared for the uncertainties of future warfare.

2.3 Defense Industry Best Practices for Designing and Integrating Systems

To integrate Systems Engineering within SIMO, it is imperative to find both the best time and methods to use it. While integrating systems engineering ideally would happen throughout the whole life cycle of a project, cost, time, and resources are heavily limited within the Department of Defense and the defense industry. Traceable back to early decisions, many materiel/technological production issues with cost and schedule place a premium on size, weight, and functionality (Sanders & Klein, 2012). Additionally, one study found that 70% of the lifecycle costs are allocated by the time the conceptual design phase is complete, yet only account for 8% of the expected spending (Sander & Klein, 2012). This locks in costs early on with little money spent to ensure the conceptual design and requirements meet the actual needs of the stakeholders. With limited funding, time, and resources, it is evident that integrating systems engineering early in the project lifecycle provides the greatest opportunity to make improvements in producibility and affordability, as this is when initial requirements and supply chain concept establishment occur (Sander & Klein, 2012). The most notable systems engineering methodology currently practiced is the V-Model, shown in Figure 1, due to its "simplicity and straightforwardness" (Puik & Osch, 2023). The main benefit of the V-Model is that it allows for breaking complex problems down into smaller, more digestible parts (Sanders & Klein, 2012). Moreso, by creating a strong relationship between test activities and development activities, projects are more thorough in the design phase, saving copious amounts of time early on. The V-Model ensures projects maintain the initial requirements.

Although it creates a longer development phase, the V-Model achieves a highly efficient and reliable system by ensuring continuous improvement.

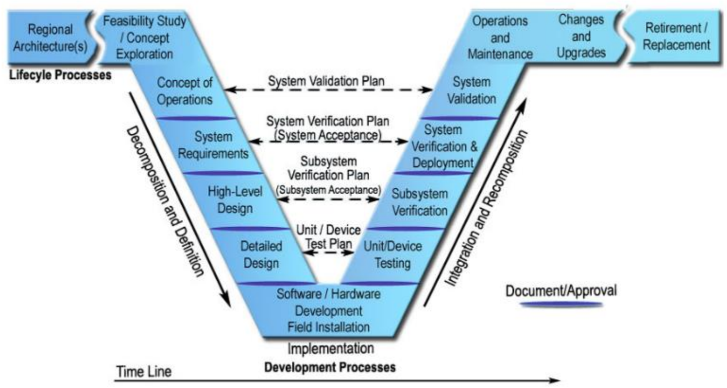

Figure 1: Systems V-Model (Bernal, 2022)

3. Methodology

To answer the problem statement, a framework employing two different models maximizes the ability to identify and exploit opportunities for systems engineering throughout the project lifecycle. The quantitative methodology sought to identify poorly performing components of a project early on, which can increase the implementation of MOSA and FACE principles based on integrating parts of a system from different manufacturers, while the qualitative model aimed to create a logical process that could bridge SIMO's gaps in systems engineering.

3.1 Quantitative Model

When testing out new capabilities, a predetermined set of Technical Performance Measures (TPMs) assesses the status of the technology (Office of the Under Secretary of Defense for Research and Engineering, 2023). Before testing, a TPM goal value is determined, which the actual performance values need to meet or exceed before the final stages of the project. The Department of Defense Systems Engineering Plan (DoD SEP) outlines eight stages a project must pass through before it is complete (Office of the Under Secretary of Defense for Research and Engineering, 2023). These eight stages are the System Requirements Review (SRR), System Functional Review (SFR), Preliminary Design Review (PDR), Milestone B (MS B), Critical Design Review (CDR), System Verification Review/Functional Configuration Audit (SVR/FCA), Milestone C (MS C), and Full Rate Production (FRP). Through the set of eight reviews and milestones, the planned value for a TPM builds towards the eventual TPM goal value. Based on the sample test data, a TPM meets the thresholds based on whether it is within 5% of the planned value (Office of the Under Secretary of Defense for Research and Engineering, 2023). However, there is potential to improve the process for assessing the success of TPMs by employing narrowing confidence intervals rather than a set percentage point. A measure that consistently falls outside of the acceptable range of values may be lacking in its integration with the rest of the new and existing system, thus not complying with MOSA and FACE standards. This could help provide an early warning and identify where systems engineers should focus their efforts, as failure to interface with existing systems could result in catastrophic failure for the new technology.

A table of sample test data can be found within the DoD SEP (2023). Each TPM measures a different component's performance and has a different value scale and units. Finding the percent change of each data point ensured that all values were on the same scale between -1 and 1. The formula used to find the percent error of each value can be found below as Equation 1.

$$TPM\ \%\ Change = \frac{new\ value - old\ value}{old\ value} = \frac{Actual - Plan}{Plan} \tag{1}$$

Although the sample data contains seventy-seven data points, three of these values required removal from the final dataset as they had a "Plan" value of 0, as this resulted in dividing by zero. The next step was to find the mean and standard deviation of the sample data. After finding the mean and standard deviation, applying Equation 2 to the data assisted in building the set of confidence intervals.

$$\bar{x} \pm z * \frac{s}{\sqrt{n}} \tag{2}$$

Utilizing a confidence level of 95% incorporated the 5% range of meeting the required threshold outlined in the DoD SEP (2023). Using the cumulative normal distribution, which relies on the assumption that the TPM percent change data will exhibit a normal distribution in the long run, the z-value used in Equation 2 to achieve a 95% confidence level is 1.96. In Equation 2, $\bar{x}$ represents the sample mean, s is the sample standard deviation, and n is the number of iterations. For each progressive milestone, increasing n by one reduces the span of the confidence interval.

3.2 Qualitative Model

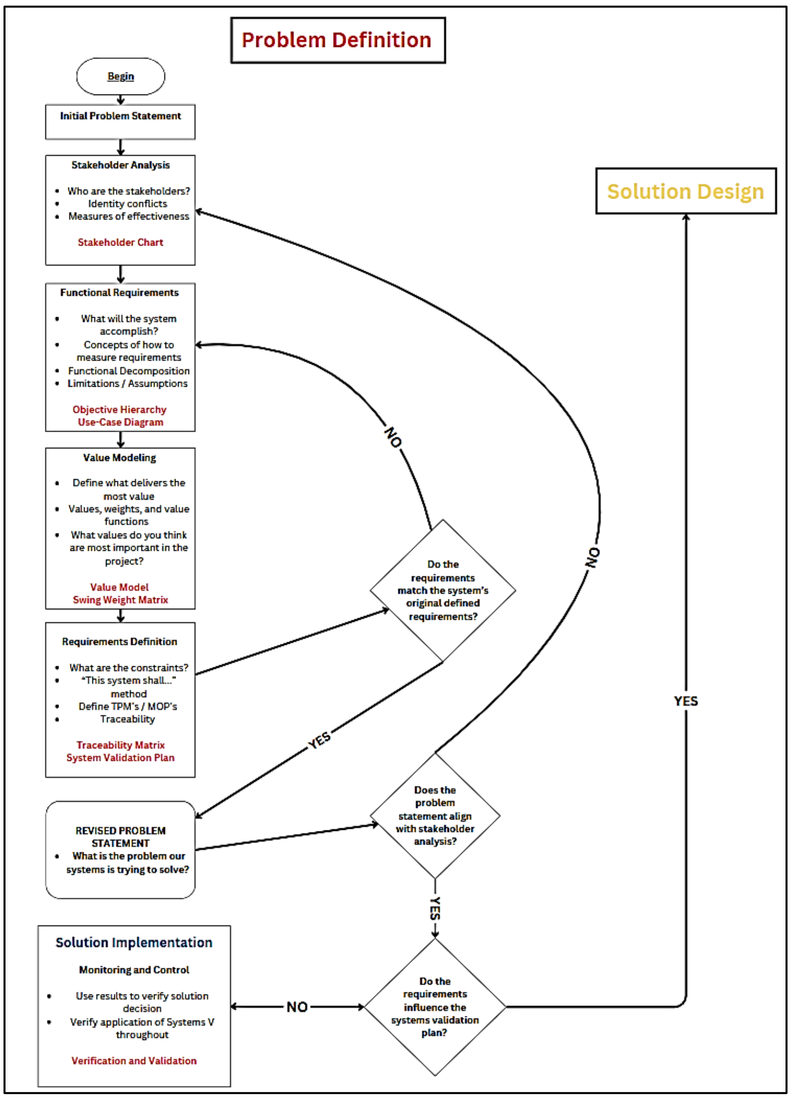

Figure 2: Excerpt of Flowchart Regarding the Problem Definition Section

To aid SIMO's incoming systems engineer, developing a flowchart, shown as Figure 2, served as a doctrinal guideline for all SIMO's projects. This flowchart drew inspiration from an in-depth flowchart utilized by NASA (2019) for flight and ground systems. While NASA's flowchart provided an example, SIMO requires a more generally applicable flowchart, using user-friendly language and models to ensure the optimization of systems engineering efforts. The Department of Systems

ISBN: 97819384969-9-8

Engineering at USMA currently utilizes the SDP as its doctrinal framework. The SDP is a value-focused methodology encompassing four phases (Problem Definition, Solution Design, Decision Making, and Solution Implementation), considering stakeholder priorities when assessing and deciding which alternative solution is optimal (Parnell et al., 2011). The flowchart created for SIMO aims to synthesize the four phases of the SDP with the Systems V-Model. The flowchart, broken down into four or five key sections, recommends deliverables for each phase (shown in red text in Figure 2). The process is extremely flexible, allowing for tailoring the necessary products to what the professional systems engineer on staff at SIMO deems necessary. To relate the SDP to the Systems V-Model, the flowchart relies on a strong relationship between developmental activities and test activities throughout each phase to verify that functional objectives, requirements, prototypes, and all other key decisions align with the final solution and test activities. Represented by decision nodes in Figure 2, these points serve as a feedback loop that repeats until verification of the need. It is highly recommended that these decision nodes are where SIMO emphasizes and employs Systems Engineering for each project. More importantly, these decisions in the problem definition and solution design phases are especially critical as they set the foundation for the rest of the project lifecycle.

The flowchart serves as an overarching set of guidelines and expectations for how and when to implement specific systems engineering practices, supplemented by a technical write-up that provides detailed descriptions of each section of the flowchart. Additionally, each phase comes with an example for each recommended deliverable following the Degraded Visual Environment Pilotage System (DVEPS) case study provided by SIMO. Using the DVEPS example for the proof of concept ensures the documents connect and demonstrate traceability back to one another through the narrative of a real-world example. This allows the user to visualize the leveraging of the flowchart, providing a holistic view of a single project. Additionally, it uses language and scenarios that all SIMO employees can easily understand and follow. This addresses the issue from the problem statement of "developing processes for when [and] how… systems engineering can be most effectively implemented throughout the project lifecycle." Ultimately, the final flowchart, accompanied by the write-up and proof of concept, provides SIMO with a set of doctrinal approaches that all team members can understand and apply.

4. Findings

The sample test data acquired from the DoD SEP (2019), comprised of 21 example TPMs for a notional project, had a mean of 0.059 and a standard deviation of 0.254. Using the 95% confidence level led to the production of a set of confidence intervals for each of the eight reviews and milestones (e.g., SRR, SFR, etc.), located in Table 1. These confidence intervals offer a set of acceptable percentage ranges a TPM can fall into, solving for the "Actual" value in Equation 1. By employing a confidence interval methodology similar in design to that of Cocks & Torgerson (2013), a more tailored range of acceptable values is available during each stage of a project. For example, the SRR confidence interval is [-43.80%, 55.69%]. Using a notional TPM goal value of 25, the range of acceptable test values for the SRR, after solving for the "Actual" value in Equation 1, is found to be [14.050, 38.921]. Using these same steps for the FRP, the acceptable range of values is [22.089, 30.882]. As shown, the confidence interval narrows as the project progresses through milestones, which satisfies the need for more accuracy in the later stages of a project. Additionally, this framework eliminates the need to devise a "planned" value for each review/milestone. Rather, the TPM goal value can be used with narrowing confidence intervals to add data-driven robustness when measuring the success of a project.

Additionally, the qualitative model aided in identifying challenges pertaining to systems engineering practices. The flowchart utilized placed more emphasis on the developmental process and thus enables the ability to pinpoint the steps that require the most attention from systems engineers. Following the outlined process facilitates adherence to the practices found through research, especially using requirements to inform the testing, evaluation, verification, and validation. Ultimately, the flowchart provides a doctrinal, systematic approach to implementing systems engineering practices that mitigate the risk of overlooking requirements early in the project lifecycle.

Table 1: Confidence Intervals for Each Review/Milestone

Review/Milestone	Lower Bound	Upper Bound
SRR	-43.80%	55.69%
SFR	-29.23%	41.12%
PDR	-22.78%	34.66%
MS B	-18.93%	30.81%
CDR	-16.30%	28.19%
SVR/FCA	-14.36%	26.25%
MS C	-12.86%	24.74%
FRP	-11.64%	23.53%

5. Conclusion

With the rapid advancement of modern technology, it is becoming increasingly important to employ a systems engineering framework for defense technical acquisitions. This ensures that all existing and new capabilities can interface effectively with one another. Especially during the test and evaluation of innovative technologies, failing to implement systems engineering practices could result in widespread issues throughout projects. Conducting extensive research led to the creation of quantitative and qualitative models aimed at aiding SIMO's systems engineering endeavors. The focus of the quantitative model was identifying where systems failed to comply with MOSA and FACE standards, while the qualitative model pertained to finding how and when systems engineering practices implementation can happen effectively. Together, these models tackle the issues facing SIMO, as outlined in the problem statement. For the quantitative model, further analysis should focus on examining when one-sided confidence intervals more accurately represent that a data point vastly exceeded the planned TPM value, rather than implying that too high or low of a value constitutes an out-of-control measure. Future work on the qualitative model could include creating an application to compile all deliverables to identify trends that are causing successes and failures across projects. Together, the quantitative and qualitative models provide SIMO with a way forward as it continues to accomplish its mission of "equip[ping] the soldiers with the most capable rotary wing aircraft and mission systems in the world" (United States Army Special Operations Command, n.d.).

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