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# Integrating Open Systems Architecture Models for Next Generation Cockpits: A Systems Engineering Approach

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**Author Note:** The authors of this project are cadets at the United States Military Academy at West Point, who are all pursuing degrees from the Department of Systems Engineering. Upon completion of their time at the Academy, they will all enter different branches within the Army. The authors would like to thank the Systems Department, their advisor, COL(R) Parrish, and SOAR for the opportunities and resources throughout the year.

**Abstract:** The purpose of this project is to determine how principles of the Army can incorporate Modular Open Systems Architecture (MOSA) into the next-generation cockpit project. A critical factor in implementing MOSA is creating a standardized system and set of requirements so that outside manufacturers can design their systems to be compatible. The problem-solving approach for this project is a modified systems decision process (SDP), comprised of three components: requirement and stakeholder analysis, value modeling, and alternative selection. Our research and analysis resulted in C4ISR/Electronic Warfare Modular Open Suite of Standards (CMOSS) being the existing alternative that most closely aligns with Army and ARSOA standards. Additionally, based upon project results, it is recommended that the Department of Defense write a new program that combines the best parts of each alternative for an ideal solution.

*Keywords:* Modular Open Systems Architecture, Systems Engineering, Value Model

## 1. Introduction

There are fundamental inefficiencies in the way the DOD, and by extension ARSOA, plan, acquire, distribute, and maintain its large-scale capabilities. Large defense contractors, motivated by profit, consistently design and sell the DOD systems that only they can produce and maintain. While this is beneficial for those companies by assuring a constant source of revenue and partnership, this prevents the DOD from taking advantage of any alternative solutions such as using COTS components that would save the organization time and money.

Currently, the United States Army and Army Special Operations Aviation (ARSOA) employ the Common Avionics Architecture System (CAAS) in their aircraft cockpits, a system that has been used by the Army since 1997 and has far exceeded its original scope (Clemente, Paul, and John Bergey, 2005). Both the Army and ARSOA are seeking a replacement for CAAS because of its inability to adapt and its closed system framework with Rockwell Collins, meaning they are the only ones who can update the system itself. The Army is looking for a system that implements a modular approach to allow increased adaptability and reduced cost so that SOAR aircraft can be rapidly updated to meet the needs of an ever-changing combat environment. This project explores the Modular Open Systems Architecture (MOSA) approach as a method of employing modular systems within the aircraft to increase adaptability and reduce the cost of upgrades. MOSA, according to the DoD, is "a technical and business strategy for designing an affordable and adaptable system. A MOSA is the DoD preferred method for implementation of open systems, and it is required by United States law (Department of Defense, 2020)." A key factor in implementing MOSA is creating a standardized system and set of requirements so that outside manufacturers can design their systems to be compatible not only with existing systems but with each other. The goal of MOSA is to allow our warfighters to make software upgrades in the field without having to wait on the manufacturers to make the changes. Other branches of the military have begun integrating similar systems such as the Future Airborne Capability Environment (FACE), which seeks to achieve similar goals of creating a low cost and high-speed system of integrating new technologies into aviation systems. The problem-solving approach for this project is a modified Systems Decision Process (SDP) (Parnell et al., 2011), comprised of three components: requirement and stakeholder analysis, value modeling, and alternative selection. Project research and analysis resulted in CMOSS being the existing alternative that most closely aligns with what the Army and ARSOA are looking for in their systems development. Additionally, the project result recommends that the Department of Defense write a new program that combines the best parts of each alternative for an ideal solution. This paper will discuss the background for the project, a brief overview of the project, the problem-solving approach, the methodology used, conclusions, and recommendations for future research. The purpose of this project is to determine how principles of the Army can incorporate Modular Open Systems Architecture (MOSA) into the next-generation cockpit project.

## 2. Background

The United States Army is currently in search of a next-generation update to the cockpit systems across all its airframes. As mentioned earlier, the CAAS has changed to a system unrecognizable from its original intention and has exceeded its useful life. This scope creep has made updates to both software and hardware increasingly difficult, slow, and expensive as the program is pushed further beyond its original design. The next-generation cockpit seeks to employ a highly functional and quickly adaptable replacement to CAAS. This system is necessary to meet the demands of a complex, multi-domain operating environment. Through the use of Modular Open Systems Architecture (MOSA), the military will have an approach to system development and acquisition that incorporates modular open development. Enhanced systems development will reduce the time and cost to acquire new systems and individual components, with the desire to incorporate components that are commercially off the shelf (COTS). MOSA helps to integrate legacy systems with enhanced technology better while reducing time and costs by creating a competitive market as well as a pathway for system adaptability. The next-generation cockpit project was at the generating requirements phase at the beginning of this research. Currently, the project has moved through initial research and focuses on idea generation and requirement analysis. In the future, the research done around MOSA will provide ARSOA with a better implementation strategy for the next-generation cockpit.

## 3. Project Overview

This project evaluates and explores the alternatives for the integration of open architecture software in an ARSOA context. Over the last several decades, inefficiency in the ability to upgrade military capabilities has plagued the acquisition department of ARSOA (Timmons, 2019). This project seeks to find the best modular approach for SOAR to implement based on their preferences to enable them to increase adaptability and reduce the cost of upgrades of aircraft within SOAR. Our research began with an intense search of the system approaches available across all branches of the military and ended with a comprehensive recommendation based on our clients' wishes. Conclusively, this project utilized the SDP to deliver an optimal solution of modular systems integration in the next-generation cockpit. The project incorporates three main areas of inquiry: requirement analysis idea generation, and alternative selection. Specifically, what the system is required to accomplish will be defined in requirement analysis. The purpose of the idea generation phase is to brainstorm ways the system can meet its overall objective and satisfy its requirements. In alternative selection, a quantitative method will be used to select an alternative, which will include alternative value scores and cost/benefit tradeoff analysis.

## 4. Problem Solving Approach: Systems Decision Process

The problem-solving approach for this project is a modified systems decision process (SDP), comprised of three components: stakeholder and requirement analysis, value modeling, and alternative selection. Figure 1 shows the full SDP (Parnell et al., 2011). This project does not execute the full SDP because it is not appropriate in the context of this project; however, there are still fundamental processes of problem-solving that apply. The limited application of the SDP is due to the scope of the project itself and the boundaries set by the client. The scope of the project focuses on alternative analysis, and because of the timeline, it does not allow for oversight or analysis of solution implementation. The development of a new modular open system is a multi-year project which is currently in its early stages. Through value-focused thinking and a quantitative model incorporating the stakeholder's preferences, the suitability of existing programs, the Department of Defense currently uses to integrate MOSA into projects, was analyzed.

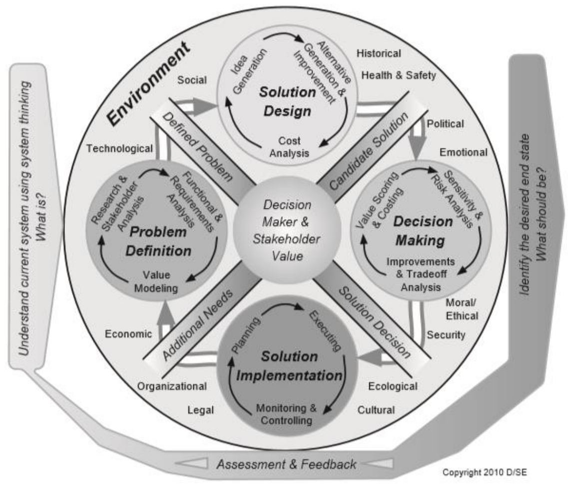


Figure 1. Systems Decision Process

## 5. Methodology

The first step taken to answer the question of how MOSA principles can and should be a part of the next-generation cockpit project was research. The research took the form of literature reviews where each member of a five-person team did in-depth research on different topics relevant to this project. This research enabled a better understanding of the intricacies of each program (each alternative) and directly affected the raw data inputted into our quantitative value model. Therefore, it was a crucial part of the project.

After initial research was conducted, a qualitative value model of the current cockpit system in a format similar to a functional hierarchy was created. This model could be useful in the future implementation of MOSA into the next generation cockpit by highlighting the different modules of the existing system. An understanding of how the current system is segmented allows one to determine where the implementation of MOSA can be more efficient. While this step of the methodology had no direct impacts on the results of this project, it is a valuable tool to provide the client since the next-generation cockpit project will continue long after the conclusion of this project.

The culmination of the question "how should MOSA be used in the next-generation cockpit project?" is answered in the quantitative value model (referenced in figure 2) to illustrate which of the existing MOSA programs best suits the wants and requirements of ARSOA. Below is the step by step process used to complete this model:

1. Value functions were the foundational output of research. To illustrate a simple example of these relationships, take the value measure security components. Our client views security as a good thing and would like the program they implement to be as secure as possible. Therefore, as the number of security components increases, the value of the program increases. The global weights of security components, as well as the other value measures, can be referenced in table 3. Each value measure is listed below with definitions as well as the scale used to measure them.
2. After creating value functions, the method of pairwise comparison was utilized to create weights because of the client's unfamiliarity with systems engineering. Even with a lack of experience, the client articulated which of the value measures are more critical compared with another. Additionally, the stakeholder confirmed the weights and functional relationships used in the quantitative value model. The most weight was placed on security as it is a common issue across all branches of the military. With the globalization of technology and cyber advancements, a more significant focus on security is crucial, moving further into the 21$^{st}$ century. Lastly, the least amount of weight focused on the rapid component interchange. Our client placed little emphasis on this value measure during stakeholder interviews. Tables 2 and 3 below show both the outcome of the pairwise comparison and calculation of weights.

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Table 1. Value Measures defined with the type of scale

| Value Measure | Type of Scale Used to Measure | Definition |
|---|---|---|
| Rapid Component Interchange | Constructed | The ability to swap components within the system. |
| Security Components | Natural | The number of layers and fail-safes dedicated to ensuring system security. |
| Accessibility | Constructed | The access the Army has to all system data. The inverse of proprietary data. |
| Compatibility | Natural | The number of other open architecture standards it is compatible with. |
| Ease of Operability | Constructed | Training required to transition from base case to a new system. |
| Defined Interfaces | Natural | The number of persistent systems within the cockpit. |
| Longevity | Constructed | The ability of the standard to accommodate new technologies. |
| Applicability | Natural | The number of aircraft systems encompassed by the open architecture |
| Functionality | Constructed | The current level of development of the standard. |

Table 2. Pairwise Comparison of Value Measures

**Comparison Matrix**

| | Rapid Component Interchange | Security Components | Accessibility | Compatibility | Ease of Operability | Defined Interfaces | Longevity | Applicability | Functionality |
|---|---|---|---|---|---|---|---|---|---|
| Rapid Component Interchange | 1.00 | 0.25 | 0.50 | 0.25 | 0.25 | 0.50 | 0.25 | 0.50 | 1.00 |
| Security Components | 4.00 | 1.00 | 2.00 | 4.00 | 4.00 | 2.00 | 4.00 | 2.00 | 2.00 |
| Accessibility | 2.00 | 0.50 | 1.00 | 1.00 | 2.00 | 1.00 | 1.00 | 1.00 | 2.00 |
| Compatibility | 4.00 | 0.25 | 1.00 | 1.00 | 2.00 | 1.00 | 1.00 | 1.00 | 2.00 |
| Ease of Operability | 4.00 | 0.25 | 0.50 | 0.50 | 1.00 | 0.50 | 0.50 | 0.50 | 1.00 |
| Defined Interfaces | 2.00 | 0.50 | 1.00 | 1.00 | 2.00 | 1.00 | 1.00 | 1.00 | 2.00 |
| Longevity | 4.00 | 0.25 | 1.00 | 1.00 | 2.00 | 1.00 | 1.00 | 1.00 | 2.00 |
| Applicability | 2.00 | 0.50 | 1.00 | 1.00 | 2.00 | 1.00 | 1.00 | 1.00 | 2.00 |
| Functionality | 1.00 | 0.50 | 0.50 | 0.50 | 1.00 | 0.50 | 0.50 | 0.50 | 1.00 |

Table 3. Weights Calculated for Value Measures Based Off Pairwise Comparisons

| | Rapid Component Interchange | Security Components | Accessibility | Compatibility | Ease of Operability | Defined Interfaces | Longevity | Applicability | Functionality |
|---|---|---|---|---|---|---|---|---|---|
| Weights | 0.046 | 0.254 | 0.113 | 0.115 | 0.070 | 0.113 | 0.115 | 0.113 | 0.063 |

3. Preferences from the client, along with information acquired during research, created raw data that was inputted into the appropriate value functions to create a raw value score for that value measure from 0-100. The raw value score was multiplied by its weight to create a weighted value score for each value measure of each alternative.

4. Alternatives were generated through brainstorming and evaluated for their feasibility based upon the established requirements above. Each alternative offers a different approach to MOSA. The most feasible alternatives were (1) HOST stands for Hardware Open Systems Technologies and were initiated by the Naval Air Systems Command to create a standardized hardware avenue of approach for upgrading aircraft (Conference 2020). (2) FACE stands for Future Airborne Capability Environment and aims to create a standardized software integration for the military (Conference 2020). (3) SOSA stands for Sensor Open System Architecture, and this alternative was initiated by the U.S. Air Force to create a standardized architecture for the life cycle management center (Conference 2020. (4)

CMOSS stands for Command/control Modular Open Suite of Standards and was initiated by the U.S. Army to create a modular open system's design for the electronics development and engineering center (Conference 2020). Each alternative gives a comprehensive approach to incorporate open system development for ARSOA and the client.

5. The weighted value scores were summed up across an alternative to create a total value score of the alternatives, and it was determined that CMOSS had the highest overall score, thus being the preferred platform. Figure 2 shows the results for the quantitative value model.

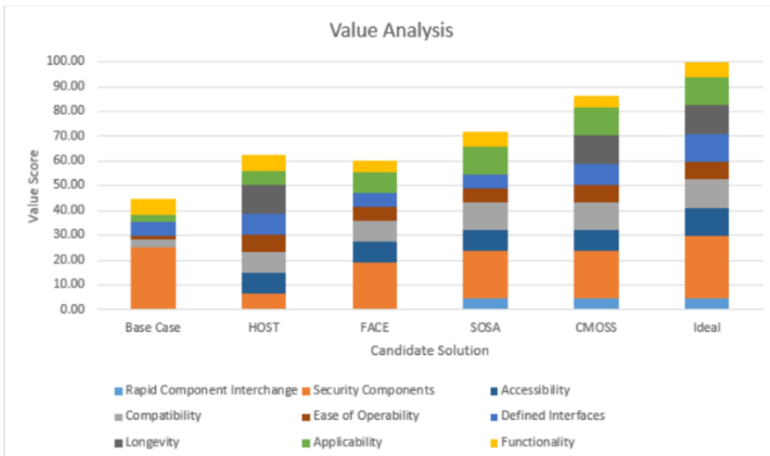


Figure 2. Qualitative Value Model on Alternatives

6. Sensitivity analysis was conducted by manipulating the weight of the security value measure by 25% and presenting the effects this had on the alternatives' overall value score. The security value measure was selected for sensitivity analysis because it weighed the most heavily in our original value model. The security value measure was selected for sensitivity analysis because it weighed the heaviest in our original value model. The ideal candidate solution is the combined, best-case scenario, which includes the highest value score from each of the different comparative characteristics. In a perfect world, the ideal candidate solution would be the desired solution; therefore, the ideal candidate solution is an excellent tool to compare competing solutions to make a better, more informed analysis and decision for other candidate solutions selection. After analysis, the model concluded that changing the significance of this value measure would not have an impact on the recommended decision for the decision-maker. Figure 3 shows the results of sensitivity analysis.

7. Typically, cost vs. value tradeoff analysis would be conducted to show the stakeholder which alternatives are dominated and the relationship between cost and value for an alternative. However, client guidance indicated cost was not a consideration in this project, and a modified SDP was selected.

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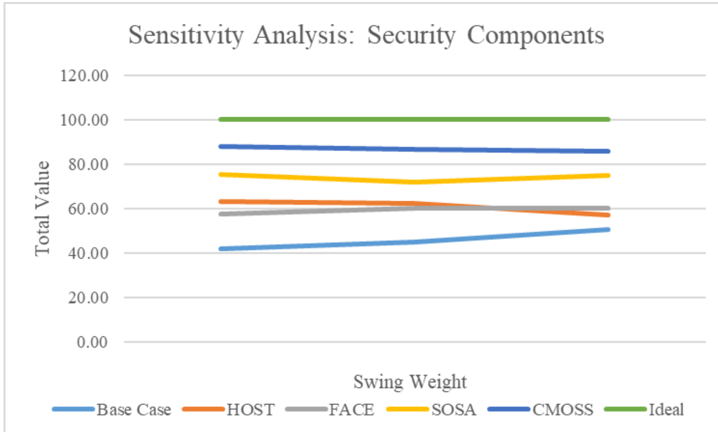


Figure 3. Sensitivity Analysis Conducted on Security Components

## 6. Results and Conclusions

Quantitative value modeling resulted in three significant results for stakeholders. First, the existing MOSA alternative that brings the most value to the stakeholder is CMOSS. Second, the worst (least value) alternative for the stakeholder is FACE. Third, the alternative that brings the most value to the stakeholder is CMOSS alternative depicted in our value analysis. The existing MOSA alternative that has the highest value score is CMOSS, with a value score of 86.45. CMOSS is fourteen points higher than the next alternative, which is SOSA. The lowest scoring alternative was FACE, with a value score of 44.75.

In conclusion, the model recommends that the client uses CMOSS for the next generation cockpit because it brings the most value when compared to other existing MOSA programs. The assumptions for this project are that all the systems fit the DoD security and standard requirements. However, the pitfall with these programs is that they are all slightly different. The major risk for the DOD is inadequate testing of the implementation of these systems. They are either used for different platforms or different branches of the military. These slight differences mean they lack the aspect of universal compatibility that MOSA aims at accomplishing. The perfect solution would be for the DOD to write a new program, which becomes the only standard that all DOD projects operated within. This perfect solution combines the best aspects, such as saving costs or improving security throughout the changes of each existing program. As the next steps beyond this project, the DoD can work on an optimal solution like the "ideal" alternative in the quantitative value model.

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