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Securing the Skies: A Value-Centric Approach to Modernizing the FAAD C2 System

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Abstract: In the evolving combat landscape, upgrading the U.S. Military's Counter-Rocket, Artillery, Mortar (C-RAM), and Unmanned Aerial Systems (C-UAS) defenses is essential. Central to this upgrade is the Forward Area Air Defense Command and Control (FAAD C2) system, which is vital for air defense and protecting assets. This study aims to refine the FAAD C2 interface, enhance user experience, and minimize operator burden with human-centered design and the Systems Decision Process. Collaborative feedback from FAAD C2 operators, the Integrated Fires Rapid Capability Office (IFRCO), Northrop-Grumman, and the Massachusetts Institute of Technology Research and Engineering (MITRE) Corporation has shaped a strategy for interface improvement. Recommendations focus on applying semiotic principles and optimizing user experience to maintain FAAD C2's efficacy in defending against current and emergent air threats, offering a focused approach to defense innovation.

Keywords: Air Defense, FAAD C2, Modern Warfare, Human-Centered Design, Interface Optimization, Counter-UAS

1. Introduction

The Forward Area Air Defense Command and Control System (FAAD C2) is a critical real-time software application that provides a unified digital air picture to support Counter-Unmanned Aerial System (C-UAS) and Counter-Rocket, Artillery, Mortar (C-RAM) missions. FAAD C2 has a successful track record, executing over 400 C-RAM intercepts without friendly fire incidents. Moreover, it has issued over 7,000 alerts related to incoming rockets and mortars, with minimal false alarms (USAASC, n.d.). The system aids weapon system engagements by monitoring friendly and hostile elements, including aircraft, cruise missiles, unmanned aerial systems, and mortar and rocket rounds, all detected by radar systems (USAASC, n.d.). Additionally, the FAAD C2 seamlessly integrates with modern directed energy and electronic warfare weaponry, such as the Maneuver-Short Range Air Defense or Phalanx (K. Reichmann, n.d.). In the dynamic domain of defense technology, Program Executive Office Missiles and Space (PEO MS) oversees the development, acquisition, and maintenance of precision strike systems and battlefield support systems for the United States Armed Forces. The PEO MS mission is to ensure these sophisticated systems enable the military to execute their missions precisely and efficiently. This research supports PEO MS objectives to improve fire response capabilities and enhance the delivery of fire support, specifically with recommended improvements to the FAAD C2 system. The primary research objective is to enhance the usability of the FAAD C2 system's interface design to improve user experience. By prioritizing user-centric design improvements, the aim is to make decision-making processes more efficient and reduce operator workload, thus increasing FAAD C2's operational effectiveness. This paper will outline the methods and analyses that form the basis of the usability enhancement recommendations for the FAAD C2 system.

2. Methods

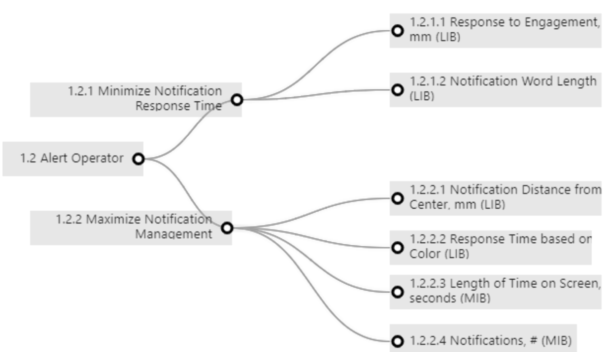
This project employs the Systems Decision Process (SDP), which encompasses four distinct phases: 1) Problem Definition: Identify and articulate the specific challenges that need addressing. 2) Solution Design: Craft potential solutions for the defined problem. 3) Decision-Making: Evaluate and select the most appropriate solution. 4) Solution Implementation: Put the chosen solution into practice. This research encompasses the first three phases — Problem Definition, Solution Design, and Decision Making. The Solution Implementation phase is outside the scope of this project. Agile principles were utilized throughout the phases to incorporate stakeholder feedback and continuously iterate on ideas. The following sections will summarize the work completed in each phase.

2.1. Problem Definition

The efficiency of the FAAD C2 system depends significantly on the interaction between the operator and the software (Missiles & Space, n.d.). To ensure that the system aligns with the needs and expectations of its users, extensive input has been gathered from various stakeholders, including Integrated Fires Rapid Capabilities Office (IFRCO) within PEO MS, FAAD C2 developers from Northrop Grumman (NG), human-centered systems engineers from The Massachusetts Institute of Technology Research and Engineering Corporation (MITRE), senior trainers for the FAAD C2 at Axient, and recently deployed FAAD C2 operators. It is crucial to acknowledge that feedback from certain stakeholders, such as deployed users and system engineers, may carry inherent biases, potentially skewing perceptions of improvement needs. This research team delivered impartial feedback on system enhancements. The team underwent basic FAAD C2 user training from Axient, the primary contract support for the system, totaling two six-hour blocks. The training is comparable to what Soldiers receive before deploying overseas to a combat zone. After conducting a detailed stakeholder analysis of FAAD C2 and the skills necessary to operate the system, the team began work on a value hierarchy.

To enhance the FAAD C2 system's interface, a value hierarchy is created to identify value-added elements of the human-machine interface (Parnell, Driscoll, & Henderson, 2010). This hierarchy comprises four key components that define the system's purpose and assess its performance: the fundamental objective, functions, objectives, and value measures (Parnell et al., 2010). The fundamental objective represents the FAAD C2 system's ultimate goal: to provide a unified air picture and enable actions on air targets. Functions are verb-object statements defining the specific tasks and roles the system performs. These include functions such as "Alert Operator" and "Enable Threat Engagements." Objectives provide a clear direction and purpose for the functions by outlining precisely what must be achieved to fulfill each function. Objectives are framed using terms like "Maximize," "Minimize," or "Optimize." Value measures are specific metrics employed to evaluate the success and effectiveness of the objectives. These measures help quantify and assess the extent to which the objectives are met. Value measures are categorized as "More is Better" (MIB) or "Less is Better" (LIB) to guide performance goals (Parnell et al., 2010).

This value hierarchy, partially depicted in Figure 1 within the "Alert Operator" function, is a structured framework for understanding the FAAD C2 system's mission, tasks, and the criteria used to gauge its performance (Sancadi, n.d.). The hierarchy offers clarity and direction for optimizing the system's functionality and ensures it aligns with its objectives.



Breakdown of "Alert Operator" Objective

Value Measure	Swing Weights	Global Weights
Training Time	100	0.100
Time to Fire Decision	95	0.096
Response to Engagement	90	0.092
Correct ID of Assets	85	0.089
Operator Satisifaction	80	0.080
# of UnIDed Threats	75	0.076
Recognizable Icons	70	0.071
Errors	65	0.066
#of IDed Tracks (Air/ Land)	60	0.061
Clicks to Launch	55	0.051
Response to Color	55	0.058
Size of Icons	50	0.047
# of Friendly Fire Assets	45	0.044
Length of Time on Screen	30	0.026
Notification Zone	30	0.028
Notification Word Length	15	0.015

Weighted Value Measures

Figure 1: Value Modeling

Based on stakeholder interviews, the value hierarchy, and the team's experience with the FAAD C2 system, the primary research objective is to enhance the current design interface, prioritizing user-centered improvements that emphasize user experience. The value hierarchy helps evaluate proposed interface changes across multiple domains and ensures a value-focused solution (Parnell et al., 2010). The team prioritizes two main functions in the complete value model: "Inform Air Picture" and "Enable Threat Engagement." Furthermore, there are seven objectives aimed at maximizing efficiency that stem from the main functions. Additionally, sixteen value measures are utilized to validate each objective's achievement. Accurately identifying and measuring these values for quantitative analysis is central to recommending solutions. The team used a swing weight matrix to determine weights based on each measure's importance and variation in the data. The final global weight for each value measure is depicted in Figure 1. Next, the team created value functions that translate raw data into the same measure of value to portray the *Baseline* and *Ideal* design of the FAAD C2 system. This approach provides a value representation of the current

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FAAD C2 system and brings to light how to resolve some of the issues present in the current system. The value measures generated in the Problem Definition phase give perspective on what is most impactful and highlight the most critical issues to address in potential solutions.

2.2. Solution Design

The Solution Design phase focused on generating value-centered ideas to refine the system's interface. The work done in this phase builds on the previous research generated by the team, the experiences of system experts collected through a series of interviews and continually pulling in feedback from the system as recommendations are tested. A key innovation in the project's approach was the incorporation of Agile development methodologies. Typically, this phase ends with developing multiple solutions to the identified problem. However, the research team chose to depart from this standard approach and refined the design strategy to focus on User Stories (USTs). USTs effectively communicate shortfalls in the system and provide key stakeholders with a clear understanding of a desired end state. This approach also enabled the team to gain a comprehensive view of the system's strengths and weaknesses through the perspective of project partners. This Agile design approach facilitated a rapid and iterative refinement process as feedback was collected, tested, and incorporated.

In the early stages of rapid development, preliminary feedback from USTs highlighted areas for potential interface improvements, specifically in iconography and notifications. However, it's crucial to note that these elements were not the project's central focus. Initial proposals suggested enlarging icons for incoming RAM threats for better visibility and moving the notification area to the upper left corner to align with English-speaking users' reading habits. While these adjustments aimed to boost situational awareness and operational response times, they were part of a broader exploration of interface enhancements. The collaboration with NG and subsequent prototyping with Axient aimed to identify various solutions to enhance the system's usability and performance. This phase involved testing various interface modifications to ascertain their practical impact on operational efficiency, ensuring that the focus remained on holistic system improvements rather than isolated changes to icons and notifications. Using the C-RAM Distribution System of System Simulation (CDS3), a simulation computer provided by PEO MS, scenarios were created to test and validate these user stories. The main scenario used to test the FAAD on the CDS3 is the "Symphony of Destruction," where various air threats attack a Forward Operating Base (FOB). Further Solution Designs were pursued based on user testing, emphasizing the project's commitment to developing a refined and effective FAAD C2 system. Given stakeholder feedback, ten USTs were created to improve the current FAAD C2 system. Through meetings with NG and Axient, the research team found that four USTs were already in development and the remaining six were chosen for further exploration (relabeled as UST1, UST2, etc...). Three user stories are described in depth below to explain the USTs with the highest impact to the improvement of the FAAD C2 system. The decision to implement these stories weighed heavily on improving the user's situational awareness and operator satisfaction when using the FAAD C2 system.

Story ID	User Story	Experimental Changes	User Feedback
1	As a FAAD C2 operator, I want the interface to show the hook bubble for the most dangerous air track automatically. This will help me swiftly recognize and prioritize targets when engaging.	If no other object is hooked, new hostile/suspect tracks will automatically be hooked. New track alert (top right corner) indicating when a track might be a threat (click alert to hook track).	Trouble with use- unable to have potential targets atuomatically hooked.
2	As a FAAD C2 operator, I want to receive notifications on the engagement window when ammunition for fire systems are depleted, so that I can maintain continuous operational readiness and switch systems without delay.	The Fire Order Menu now has graphic indicating notional inventory. Currently, the inventory per weapon type is fixed, but this demonstrates the idea of the rendering.	We recommend distinction between" % weapons" (lasers) and "inventory count weapons" (missiles), current build seems buggy and displays inventory count for coyotes. The layout of information is a sustain.
3	As a FAAD C2 operator, I want the notification bubble to be red to quickly grab my attention, enabling me to respond promptly to emergencies.	All "Urgent Alerts" that used to be rendered in orange (engagement authorizations) are now rendered in red. Additional, future research and iterations will look at color scheme changes for the category "Prioritiy".	Not seen very often while using system- only time seen was while utilizing the "Engage All" feature.
4	As a FAAD C2 operator, changed the default setting to include what radar is on the track (up to three) so that I can more quickly make a fire decision.	By default, the first three radars are now added to the information hook bubble and the rest of the information bubble is customizable to the operators needs and wants.	Sustain, engagement status included on hook bubble is also a positive change. Need clarification on ">,<" meaning.
5	As a FAAD C2 operator, I want to have all potentially engageable targets highlighted while using the CB3E so that I can more quickly create an effective and efficient engagement order.	This is addressed through and "Engage All" feature that allows the operator to engage all hostile targets simultaneously. The system dictates the best weapons to use and the engagement order.	Slow process from initiation of engagement to actual action, seems unable to launch and launch timer will run until negative at some points.
6	As a FAAD C2 operator, I want notification to confirm system shut down so that the system is not accidentally turned off during an engagement.	No confirmation, but single press of the power button will no longer do anything. Soft power button in the application will still have a confirmation and long press of the power button will work as a failsafe.	Sustain, helps remove the risk of unintentional shutdown during use.

Figure 2: Six USTs Developed by the Team

The user stories for the FAAD C2 system outline critical enhancements aimed at improving operators' operational efficiency. UST1 states: *As a FAAD C2 operator, I want the interface to show the hook bubble for the most dangerous air track*

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automatically. This will help me swiftly recognize and prioritize targets when engaging. When an aircraft enters monitored airspace, it initially appears in yellow, signifying an “unknown” status. This indicates that the aircraft has not yet been assessed by the operator and has not been assigned a more specific classification. To aid in faster threat recognition, the proposed solution involves automatically displaying the information of any air vehicle that exceeds a certain speed threshold and is heading toward a FOB. NG has addressed this UST by creating an automatic hook bubble to new hostile/suspect tracks in the airspace with the additional capability of notifying the operator of the threat level it may impose. This addition helps operators maintain situational awareness and reduce cognitive load when engaging air tracks, allowing them to focus on the highest threats.

UST2 states: *As a FAAD C2 operator, I want to receive notifications on the engagement window when ammunition for fire systems are depleted so that I can maintain continuous operational readiness and switch systems without delay*. By providing real-time notifications about the ammunition status directly within the engagement window, operators can maintain a constant overview of their available resources, enabling them to switch between fire systems swiftly. This improvement is expected to facilitate streamlined decision-making, optimize resource allocation, and bolster operator confidence by ensuring they are continually informed and ready to respond to any situation. NG has incorporated a “Fire Order Menu” tab that indicates an inventory of all fire systems at the operator’s disposal. This change reduces the number of clicks to reach the fires menu and lowers the operator’s cognitive load so they do not have to memorize the remaining ammunition per weapon.

Lastly, UST3 reads: *As a FAAD C2 operator, I want the notification bubble to be red to quickly grab my attention, enabling me to respond promptly to emergencies*. This system should distinguish between different levels of operational alerts, such as safety warnings, engagement authorizations, and urgent notifications, ensuring that each category is immediately recognizable and prompts appropriate action. NG has augmented the color scheme of these alerts to better suit the operator’s situational awareness. NG revised “Urgent Alerts,” which used to be rendered in orange (previously engagement authorizations) to now be rendered in red. Furthermore, IFRCO has given feedback mentioning the possibility of future research and iterations that look to revise the color scheme changes for the “Priority” category of alerts. Figure 3 is an example of UST1 and UST3 that highlights some of the current system’s limitations.

Figure 3: FAAD C2 Baseline Interface

The Solution Design phase of the FAAD C2 system enhancement project represents a holistic, user-centric approach to interface design. By focusing on key areas such as iconography and notifications alongside Agile methodologies and strategic submission of user stories, significant strides have been made in improving system operators' situational awareness and decision-making efficiency. This collaborative and evidence-based approach to development and testing ensures the effectiveness of the enhancements and closely aligns them with the operational needs of air defense, marking a pivotal advancement in the evolution of the FAAD C2 system.

2.3. Decision Making

In the Decision Making phase of the SDP, the team employed a structured and iterative quantitative modeling approach to weigh all potential recommendations against operational necessities and user feedback. All value measures were evaluated based on the changes incorporated in developing six user stories. The decision to implement these stories weighed heavily on improving the user's situational awareness and operator satisfaction when using the FAAD C2 system. NG provided an experimental software build with six changes that address the USTs. Of the six changes, two are in testing at Yuma Proving Grounds, which validates the Problem Definition and Solution Design completed by the team.

Leveraging stakeholder feedback, the team employed a rigorous quantitative analysis to prioritize recommendations, which involved an evaluation of each proposed UST solution's potential impact on system performance and operator efficiency (Parnell et al., 2010). Each experimental software change was evaluated through user testing, and raw data was collected for the value model. The team visually depicted the impact of each value measure on the system's performance while allowing for accurate comparison between each assessed value measure. The team evaluated the current fielded system, referred to as the *Baseline*, with a value rating of 56.53 out of 100. To progress towards an improved interface, the team utilized all USTs developed as a blueprint for implementing changes. The *All Changes* build encompasses all USTs merged into a single new experimental build. The *Ideal* build represents a theoretical solution where the system aligns perfectly with the developed value model, achieving an optimal state. The modifications resulted in noticeable enhancements across various value measures, including the Number of Identified Tracks (Air/Land), Time to Fire Decision, Click Rate, Operator Satisfaction, Response to Engagement, and Response to Color. The *All Changes* build improved the system value to 69.19. This led to an improved value rating of 69.19 out of 100. Figure 4 shows the *Baseline*, *Ideal*, and *All Changes* system solution, which enabled the team to comprehensively view the system's value growth.

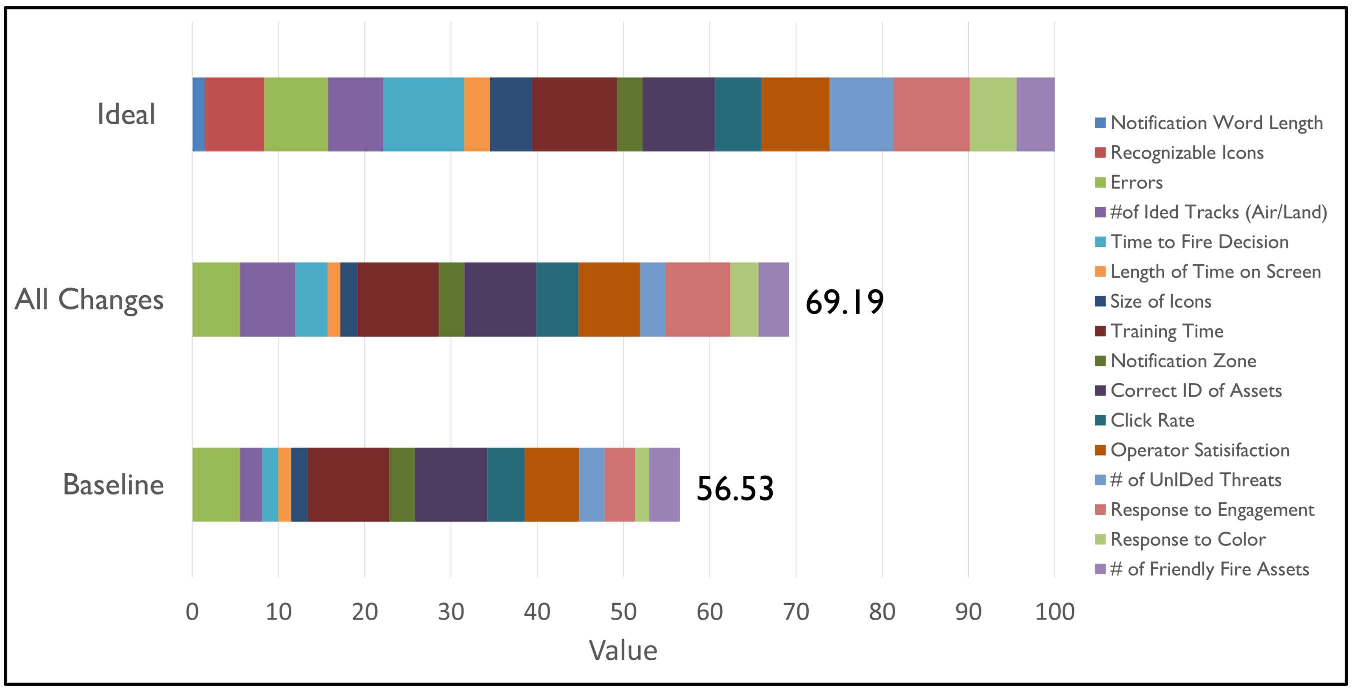

Figure 4: Stacked Bar Chart Comparison

The implications of the proposed recommended changes to the FAAD C2 system are far-reaching. The changes proposed will directly affect the interface's usability, the speed and accuracy of the operators' responses to threats, and the effectiveness of the air defense mission. In some instances, the team's recommended changes mirrored current design efforts by IFRCO, which validated the teams' ideas. Given this quantitative analysis, feedback will be given to IFRCO to recommend a more refined system.

3. Conclusion and Future Work

This research aims to improve the FAAD C2 system's interface, maintaining its critical role in modern air defense. FAAD C2 system enhancements, particularly in interface design and usability, signify a leap forward in how operators can more intuitively manage systems, regardless of their technical background. By simplifying the user experience and making critical information more actionable, these upgrades mean that Soldiers can respond to threats with greater speed and precision. Ideally, with changes implemented, the next step is to field test them at Yuma Proving Grounds. This would best highlight work that can be conducted in the Solution Implementation phase, and help give further feedback to researchers. As advances to the FAAD C2 system are made, its evolution will fortify current defense capabilities and serve as a cornerstone for pioneering future air defense technologies, ensuring a robust and responsive defense in the face of ever-evolving aerial threats. Currently, two of our user stories are being tested, and Northrup Grumman has also identified these as problem areas. Another four are being iterated by the research team and Northrup Grumman to be implemented into field testing in the future. The research was limited by the ability to conduct rapid software builds and the changes were not tested in a live field environment. Therefore, there could be some issues that we were unable to properly iterate out all problems. Given more time, the testing could have been more robust, and a more official build could have been coded to begin a complete testing phase.

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