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Aggregation of Battlespace Data

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Abstract: Joint All-Domain Command and Control (JADC2) is an initiative started by the Department of Defense (DoD) to connect input and communications from all five domains of the battlespace – air, land, sea, space, and cyber – into a single framework. Due to budget constraints and intensive communication needed, currently there is a disaggregated battlespace regarding the five domains. This shortcoming limits the DoD’s ability to effectively relay information through these shared sensors, which in turn hampers a commander’s decision-making capability to make decisions in combat operations. The research and tools presented in this technical report produces a dashboard to present to commanders to facilitate the JADC2 initiative and creates a platform for the influx of large amounts of data to be organized in an effective manner, providing a framework for evaluating alternatives.

Keywords: Department of Defense, Dashboard Design, Decision-making, JADC2, Lockheed Martin

1. Introduction and Background

The purpose of this research was to design a simulated dashboard to facilitate the flow of information between the five domains: air, land, sea, cyber, and space. The Joint All Domain Command and Control (JADC2) initiative attempts to integrate military platforms and systems to maximize the time a commander has to make decisions, enhance decision quality, and improve the overall use of data input. JADC2 requires four capabilities: “data handling and storage, secure processing, connectivity, and software applications that turn data into information” (Air Force Magazine, 2021). For JADC2 to be implemented effectively, the data needs to be processed and ready to use instantly. As JADC2 continues to develop, this dashboard and simulation will help filter and present the necessary data to provide insights and recommendations to the commander. Additionally, as the simulation scenarios get more complex, the dashboard will allow an easier presentation of information for the commander to digest.

There is currently a disaggregated battlespace relating to the five domains and it is critical for mission success that these five domains all share data to come to the most efficient solution together as one entity. The speed that data can be processed and presented in an effective fashion to military leaders will determine the level of decision quality. This will in turn lead to a more efficient military and defense system of our country. Thus, we can implement artificial intelligence to see how command and control within JADC2 can be made more effective using new technology.

However, to better utilize advancing technologies and tools, we also need to be cognizant of the cognitive ergonomics and limits that people possess. To decrease the cognitive loads for leaders, the inflow of data needs to be filtered. There are different types of cognitive loads military officers face while performing their jobs and various parts of the brain are activated due to the high stress levels associated with the life-or-death nature of their profession. All the while, it is important to note that a “healthy cognition” is imperative for soldiers to possess because it is critical that officers can make decisions without experiencing cognitive overload to achieve the best results (Batouli et al., 2020). Not only do cognitive straining environments affect individual decision makers, but they also possess harmful consequences that prevent organizations from being successful. JADC2 aspires to alleviate some of that cognitive load by presenting information in a more efficient way and reducing the cognitive straining factors placed on individual decision makers and organizations.

Given the challenges with the current JADC2 system, there was a need for further research into how to create a dashboard that will effectively present information while following the guidelines that help decrease the cognitive loads on those utilizing the dashboard. We conducted thorough research in the background and current state of JADC2 as well as the artificial intelligence and simulation research that will allow us to output data into our dashboard. After gathering, analyzing, and synthesizing our research, stakeholder analysis was performed, and we developed a functional hierarchy for our fundamental objective of providing battle commanders with multiple courses of action.

Decision support systems are information systems that help a business make faster and better decisions based on improved judgment, determination, and a sequence of actions. This information helps assist middle to higher level management programs within organizations by analyzing large amounts of unstructured data and gathering information that can solve the problem of making better decisions, faster (Corporate Finance, 2021). The main components of a decision support system include a model management system, which stores models that managers can use in their decision-making strategies. The user interface is another main component that utilizes tools to help the user to easily navigate through the system. The third and final main component is the knowledge base, which includes information from internal and external sources (Corporate Finance, 2021). The main five types of decision support systems include communication-driven, model-driven, knowledge-driven, document-driven, and data-driven. There are several advantages to using decision support systems. The main advantages include the increase in the speed and efficiency of making better decisions. Additionally, they promote more interpersonal communication and overall training within the organization. On the other hand, some disadvantages include the extensive information and cost that come with implementing and maintaining these systems (Corporate Finance, 2021). We intend to utilize decision support systems and tools in our project to ensure that our dashboard, model, and system are enabling commanders to make efficient and better decisions on the joint-all-domain battlespace. The goal of this project is to aid in the strength of command and control while utilizing advantageous technology and tools to filter, apply, predict, and model data in multiple joint-domain scenarios.

2. Methodology

We began with publicly available information about command-and-control operations and challenges to develop the scope and necessary elements regarding JADC2. Simultaneously, we conducted individual literature reviews to gather more information on JADC2. The four main areas of research for our literature reviews were Joint All-Domain Command and Control, cognitive ergonomics, artificial intelligence, decision support tools, and business analytical tools for big data and decision-making. The literature reviews were conducted independently and then synthesized to create a shared understanding of how all these different areas combine to improve and further the JADC2 initiative. The following sections dissect the most relevant sectors of research in developing the dashboard solution.

To further understand the project from the perspective of the client, a diagram was developed that outlines the basis of data flow for this product. Additionally, a functional hierarchy was developed to understand the important values of the information collected. The first phase of mind mapping was aimed at determining what the flow of data would look like for our specific project. This included specified information provided for one decision-maker that was filtered, modified, and derived from various data inputs. We determined that there needed to be a process that would help eliminate unnecessary data, and aid in evaluating what would be helpful data for that decision-maker. In Figure 1, three main functions were selected before developing further sub-functions. These three functions are the utilization of a simulation, the presentation of a dashboard, and the determination of the decision-makers' primary values for the data set.

2.1 Joint-All Domain Command and Control

The JADC2 system is a command-and-control structure that will allow our nation to communicate on the battlefield properly and efficiently. JADC2 falls under the umbrella of Joint All-Domain Operations (JADO), which has a main goal outlined by Khan and Thatcher (2020), namely evolving warfighting by synchronizing major weapons systems and crucial data sources with revolutionary simplicity. JADO allows commanders to quickly predict adversaries' next moves and disrupt and overwhelm them with a new level of precision. Although JADC2 is still developing every day, there is a clear goal for the project set by the Department of Defense, along with a strategy that will ensure JADC2 is developed in such a way that the goal is met. The challenges and failures of past projects have influenced the development of JADC2 and will lead to an improved command and control system for our armed forces.

2.2 Decision Support Tools

Decision support tools help bridge the gap between human intuition and data analysis by utilizing both technology and human thought to make the best decision. We saw trends in literature that implied the critical elements of a commander's decision cycle that are important for consideration. Although decision analysis tools can be very helpful, Johan Schubert, Joel

Brynielsson, Mattias Nilsson, and Peter Svenmarck's research in "Artificial Intelligence for Decision Support in Command and Control Systems," also shows that they are flawed as they do not always represent the best decision from an ethical standpoint. It may be better for a program manager to choose not to take any action at all than just take the lesser of two evils. It is apparent that there exist gaps in the literature here.

In conducting this research and review, we saw several trends in the literature we surveyed. Our analysis of the literature concluded emphasized the importance of optimization and efficiency when implementing decision support tools. This efficiency in the tool is critical to provide the commander with the most optimal alternatives to choose from when making that specific decision. It was apparent that nearly every source highlighted the significance of this. For example, when looking at our data, our specific variables such as vehicle type, mission type, and number of days, are what commanders would like to focus on to make the best decisions possible. Currently, decision support tools demonstrate how we integrate system model architectures and constraints across a diversity of decision support system research contexts – from military systems to management and businesses, among others. Ways of demonstrating contributions include providing a new theoretical understanding that helps to explain the previously confusing results.

2.3 Predictive Modeling and Learning Tools

In preparing further research to frame and aid in the analysis of the JADC2 project, we have determined that command and control capabilities, decision-making accuracy, and time are very valuable when developing improvements for the JADC2 framework. As technologies (to include artificial intelligence, virtual reality, machine learning, and augmented reality) increase, we see a common theme of faster decision-making times and more accurate data analysis and presentation; however, this ever-growing path for technology and self-learning tools can also run away from the user's control. The utilization gap associated with advanced Machine Learning (ML)/Artificial Intelligence (AI) and Virtual Reality (VR)/Augmented Reality (AR) can negatively affect the level of application and efficiency when handling and presenting data. As it applies to our research, our vision is to increase the user capability when ingesting data that has been compounded from various disciplines and domains. The team must consider that the use of artificial intelligence or machine learning pipelines can be known to operate at levels difficult for users to follow or control.

In conjunction with the use of advanced ML, artificial intelligence and augmented reality can rapidly increase accuracy and data availability for decision-makers leading to effective maintainability of command and control. Overall, there are extremely relevant and useful self-learning and simulation tools that we can utilize in our project to develop an accurate and specified flow of data for a decision-maker. Ultimately, augmented reality and simulation tools would prove most useful when developing programs to increase efficient data analysis for increased decision-making capabilities, however, aside from being a very useful tool, the process of data analysis has not been a focus. We use existing research to help frame what presentation style would be most efficient for a decision-maker to use. Maintaining command and control across multiple domains of the military is a good candidate for predictive modeling and learning tools, like ML/AI and AR/VR, to design better decision-making tools for commanders.

2.4 Cognitive Ergonomics

After looking at the current literature for cognitive ergonomics, there is an abundance relating to the military and commanders having to make decisions. Some of the current trends state that military leaders often have too much information, which can lead to cognitive overload, preventing them from processing the data efficiently. Especially when placed in life-threatening combat scenarios, commanders are more prone to have a tough time quickly processing information due to lack of sleep or increase in stress levels, meaning it is important to present the data to the commanders in a way that takes some of that load or pressure of their shoulders. This is where our proposed dashboard can be utilized effectively to display pertinent information in a manner that relieves the cognitive load and allows for quicker data utilization by the commanders to output necessary decisions more efficiently.

To better utilize the advancing technologies and tools, we also need to be cognizant of the cognitive ergonomics and limits that people possess. The limitations of cognitive loads for leaders are why the data needs to be filtered. There are different types of cognitive loads military officers face while performing their jobs. Various parts of the brain are activated due to the high stress levels associated with their profession. However, it is important to note that a "healthy cognition" is imperative for soldiers to possess because it is critical that officers can make decisions without experiencing cognitive overload to achieve the best results (Batouli et al., 2020). To prevent cognitive overload, successful training can lead to structural and functional improvements of the brain. It is possible to train the brain in receiving and filtering massive amounts of data to ensure the best results. Specifically in military officers, training is vital to the success of missions and the safety of soldiers because military officers "present a different brain activation in response to the threat" and "military training is positively associated with brain structure alternations" (Batouli et al., 2020).

Within JADC2, we aspire to alleviate some of that cognitive load by presenting information in a more efficient way and reducing the cognitive straining factors placed on individual decision makers and organizations. We identify existing different command and control problem characteristics as well as existing AI system solution capabilities to determine the potential for artificial intelligence systems in aiding military command from a technical perspective (Walsh et. al., 2021). Thus, being able to present information and coordinate information across the five domains alleviates some of the cognitive load placed on the commanders when having to make decisions critical to mission success. It is imperative that cognitive ergonomics is considered to fully understand the importance of JADC2 and the efficient synthesis and dissemination of information.

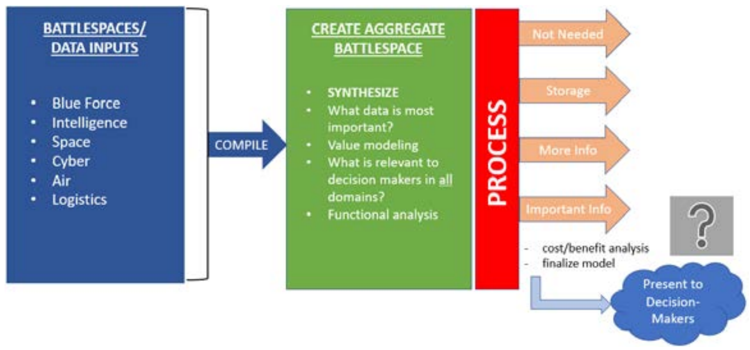

Figure 1. Initial Data Flow

The general idea behind our project is visualized in Figure 1. We determined that the flow of data is important to consider when multiple domains and battlespaces must be considered by a single decision maker. This flow chart demonstrates how collecting data from multiple sources and using various processes scrub and filter data can be a beneficial way to present it to the decision maker in a useful dashboard.

3. Solution Design

After defining our problem and canvasing relevant existing literature we embarked on creating a solution design and product development. In Figure 1, we conceptualize the flow of data from various inputs to include the multidomain operations levels and intelligence sources. This data is then compiled to aid in the understanding of an aggregate battlespace. From there, processing, data filtering, and data analysis is performed to allow for a narrowed output that more precisely meets a commander or decision-makers' needs. Once we determined our specific use-case to be a commander in a high-level or complex decision-making position, we decided to create a product that will deliver this aggregate data in a cognitive and effective manner.

As seen in Figure 2, we developed a preliminary functional hierarchy to outline the necessary functions of the dashboard that we will design. Our fundamental objective is providing the battle commander with relevant information to create cohesive and comprehensive courses of actions (COAs). In Figure 2, the primary functions underneath our fundamental objective included “Determine Leader Primary Values”, “Utilize Simulation”, and “Present Dashboard”. As we progressed into our solution design utilizing the program PowerBI and discussing the needs with our client, we determined to focus solely on the “Display Dashboard” in the solution design phase.

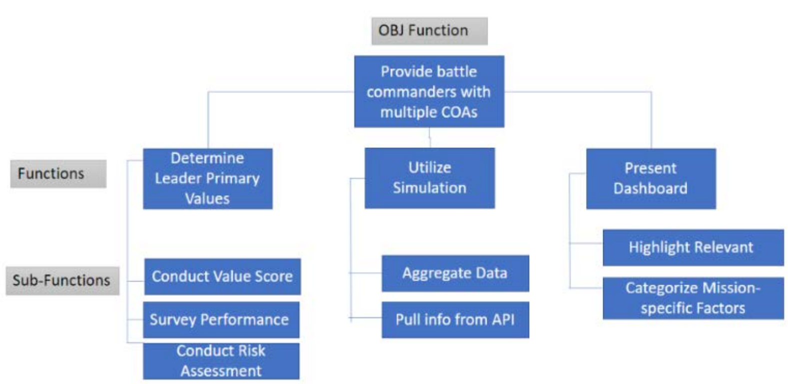

Figure 2. Functional Hierarchy

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Moving ahead with the specified scenario of developing a cognitively ergonomic dashboard that would present aggregate data from a JADC2 environment, our team heavily utilized the visualization program, PowerBI. PowerBI is a tool commonly used to display datasets in various formats. Working under the assumption that this concept can be extracted to a real-time scenario, our data is fixed data from a brigade combat team and their rotation through the National Training Center (NTC). Figure 3 displays a working snapshot of our current dashboard visualization. This dashboard pulls data directly from the NTC fixed data set which includes thousands of entries denoting time stamps, vehicle movements, asset and munitions deployment, and damage assessment categorizations. The map in Figure 3 displays any selected vehicle type and their location over a specified time. The middle columns to the right of the map allow the user to select the desired vehicle type and the designated date-time group to adjust the display. This allows for some adaptation and customization for the dashboard user. The toggle to the right outlines and defines the specific damage assessment categories applicable in the given date-time group.

In developing the dashboard layout, we applied aspects of cognitive ergonomic principles related to coloring and sizing to develop a digestible amount of data output. We focused on three design principles that are commonly used in dashboard design: consistency, simplicity, and the use of color. Consistency refers to the uniformity of formatting, terminology, positioning and placement of attention grabbers within the dashboard. We made sure to stay cognizant of what our dashboard should both look alike as well as act alike. Simplicity refers to displaying the data in a directly usable format for the user, meaning we grouped primary information on different displays which are the different layers present in our dashboard. We ensured the simplicity of the dashboard by eliminating information that was not pertinent to the commander. Finally, the use of color is most effective when displaying redundant information. The most obvious distinction to be made in the visualization in Figure 3 is the distinction between enemy and friendly vehicles (Nicol & Pexman, 1999). The use of contrasting colors, red and blue, are used to create an easy understanding of where and how those vehicles move and interact on the battlefield. The use of sharp colors helps grab the attention of the user and limiting the number of colors to three to seven allows us to decrease the potential cognitive overload on the user. Our dashboard also displays the contrast between the background and foreground to help display the data in a manner that is most digestible for the user (Alfredson et al., 2011).

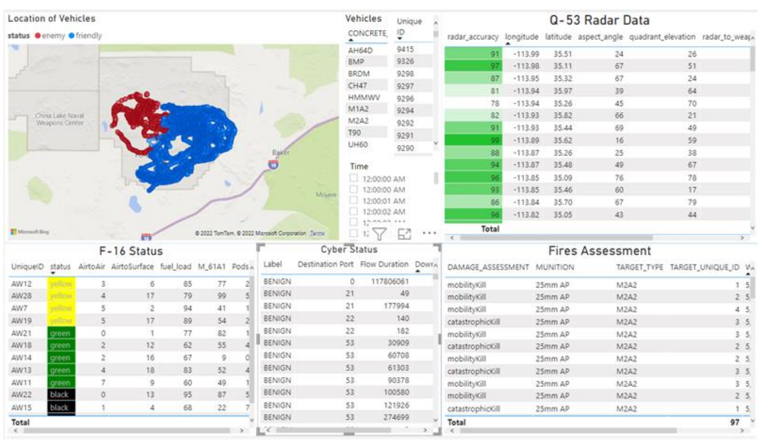

Figure 3. Dashboard in PowerBI

4. Significance of Our Dashboard

The main contribution of this research is the aggregation and display of data to allow the commander to make the best decision possible for a given mission. The research within our literature review topics gave our group a solid foundation for what we wanted to accomplish and framed our project around the JADC2 environment. Our coding team strategically chose what variables we wanted to analyze when it comes to the “combat scenario” displayed in our dashboard on. Our data is considered “live’ where the data is streaming in during a combat-scenario. Our dashboard will be scoped down significantly, looking at one mission over one day as the data flows live into the command center. The commander will then make his or her decisions based on our dashboard, which is already tailored to the qualities that are most important to them based on our stakeholder analysis.

5. Conclusion

In this report, we delve into the main components of JADO, analyzing how to integrate the systems decision process within our research and solution design of our dashboard display. The main components our research addressed were Joint All-Domain Command and Control (JADC2), cognitive ergonomics, AI in decision making, decision support tools, and business analytical tools for big data and decision-making. First, we introduce these topics and provide background on the various applications, relevance, and usability within the concept of data visualization and display. We then explain the methodology for research processes and development of a dashboard design. The dashboard is then oriented in accordance with the usefulness and application to commanding at a level specifically within a JADC2 environment, incorporating all five domains. The main body of this report investigates the significance of applying previous research to building the dashboard solution and extrapolating useful intelligence from the provided data using PowerBI. The figures displayed visualize an evolved understanding of the data filtering process and the application of the raw data taken in by our theorized "real-time" dashboard display. Utilizing the combined research, systems analysis, and PowerBI application, our group can develop a situationally relevant dashboard, our method of presenting data, for decision-makers within the JADC2 environment.

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