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A Systems Architecture for the Indirect Fire Engagement Process in a Dynamic Targeting Scenario

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Author Note: Cadets Abercrombie, Coates, Morriss, and Underwood are seniors at the United States Military Academy at West Point participating in a year-long capstone design course under the direction of their advisor, Dr. Gregory Graves. Upon graduation, they will all be commissioned as Second Lieutenants in the U.S. Army. The client for this project is the U.S. Army Combat Capabilities Development Command Armaments Center (CCDC AC) at Picatinny Arsenal, New Jersey.

Abstract: The targeting process, or kill chain, is the actions involved in engaging a target from when it first emerges as a potential threat through assessment of the effects on the target after engagement. The kill web is the network of systems and interfaces involved in performing the targeting process. As artificial intelligence (AI) becomes more prevalent and is applied to military operations, the Army seeks to incorporate AI-enabled information, tools, and systems into the kill web to enhance execution of the kill chain process. This research contributes to this effort by depicting the kill web using a systems architecture. Using a collection of different systems architecture viewpoints to illustrate these systems and interactions illuminates processes and systems where implementing AI can improve effectiveness. Additionally, the research led to development of a value model that will enable assessment of architectures for the current and future states of the kill web.

Keywords: Systems Architecture, Artificial Intelligence, Targeting Process, Value Model, Kill Chain

1. Introduction

The targeting process, often known as the kill chain, refers to the process of identifying and destroying or neutralizing a threat on the battlefield. There have been several different targeting processes throughout history, dating back to the Roman Era. However, with an increase in technological production and the implementation of artificial intelligence, there has been a significant decrease in the time spent at each phase within the kill chain process. The growth in sensor technology has allowed for integration of data and shortening of the kill chain process (Benitez, 2017). The current kill chain is a six-step targeting process: find, fix, track, target, engage, and assess (F2T2EA). This targeting process is predominately focused on dynamic targeting which is used to engage targets identified too late to be included in deliberate targeting (Department of the Army, 2015). Reducing the time in the kill chain process for Long-Range Precision Fires is one of the Army's top priorities.

Each step in the F2T2EA process is critical to quickly engaging dynamic targets. The first phase of the process is find which is the "act of rapidly locating targets." The find step is where threat capabilities, high-value targets, and threat models are accurately identified (Department of the Army, 2018). The output of the find step is "potential targets detected and nominated for further development" (Joint Chiefs of Staff, 2018). The second phase of the targeting process, fix, includes determining the location of the potential target for dynamic targeting. The fix phase leads to positive identification, accurate target location to engage with the target, and estimation of target time characteristics (JCS, 2018). Fixing on a location can be done through the use of Global Positioning System satellites or by imaging the area of interest and comparing it with earlier images providing a precise geo-location of a given target (Tirpak, 2000). The third phase of the F2T2EA process is track. During this phase, Army assets monitor the target's activity and track the target's movement (JCS, 2018). In the target phase, the fourth phase of the process, commanders make the decision to engage with the target in order to create desired effects. From this phase, the Army leaders validate the target, finalize the target data information in a format useable by the system that will engage it, and approve the target execution in accordance with the Joint Force Command (JCS, 2018). The fifth step of the F2T2EA process is engage. The outputs of this phase include issuing and passing of the engagement order, target engagement via lethal or nonlethal means, and engagement direction and control (JCS, 2018). The sixth and final phase of the F2T2EA process is assess. In this final phase, the unit assesses the status of the target, reports results, and provides re-attack recommendations (JCS, 2018). When the unit assess the status of the target, they are determining if the desired results have been achieved which requires more knowledgeable analysis (Tirpak, 2000).

The kill web is the network of physical systems, information systems, and interfaces that allow for the execution of the kill chain process. This project focuses on determining interactions in the kill web that can be improved or enhanced using artificial intelligence. The project client is the U.S. Army Combat Capabilities Development Command Armaments Center (CCDC AC) which is responsible for research focused on developing new weapons and systems to increase the efficiency and effectiveness of the Army. This paper presents results of efforts to create a systems architecture for the current kill web for indirect fire engagements using viewpoints specified in the Department of Defense Architectural Framework (DoDAF). For this project, indirect fire refers to artillery fires used to engage targets that are beyond line of sight for the firing unit.

1.1 Methodology

The methodology used in this research focused primarily on the tasks in the problem definition phase of the Systems Decision Process: research and stakeholder analysis, functional and requirements analysis, and value modeling (Parnell et al., 2011). Following client meetings to determine the needs of the stakeholders, initial research focused on the current state of the kill chain, how AI could be implemented into the process, DoDAF systems architecture viewpoints, and the future state of the kill chain. The initial research highlighted a need for a detailed representation of the current kill chain process and the systems involved in its execution.

The primary source of information on the current process was a series of interviews with Lieutenant Colonel Robert Kinney, the field artillery branch representative at West Point. His expertise and experience in division artillery operations at Ft. Bragg, North Carolina allowed him to provide the insight needed to depict the current kill chain process, the actors and systems involved, and the information exchanges that occur. After capturing this information, the project progressed to depicting the process and associated systems in a systems architecture using various DoDAF viewpoints.

The systems architecture considers the data, platforms, Command, Control, Communications, Computers, Combat Systems, Intelligence, Surveillance, and Reconnaissance (C5ISR), and network aspects of the kill chain. The analysis focuses on determining current factors of the kill chain that are important to its functioning. Further research on those factors will allow identification of possible improvements that involve artificial intelligence. The goal is to illuminate opportunities to introduce artificial intelligence that will improve the execution of the kill chain process. This project included multiple system architecture viewpoints to represent dynamic targeting indirect fire engagements. Finally, a value model was developed that can be used to determine which architectures of future kill web alternatives will be most effective in carrying out indirect fire missions.

2. Research and Stakeholder Analysis

Stakeholder interviews and research provided important information that would support the effort to make the kill chain more effective. The first finding is the kill chain over the years has been decreased from decades to years, to months, to days, then to minutes. The next step to improve the kill chain would be to decrease the time even down to seconds. With this in mind, this project sought to analyze each step of the current process to determine the steps that would be the best in which to incorporate AI to accelerate the process. This effort required accounting for the time each step currently takes and identifying the steps that require the most time and human interaction. The primary issue is the time it takes to identify and confirm the status, enemy or friendly, of the target, identify which assets to use, clear the air space, and assess the damage. Finding a way to increase the speed of these processes will impact the overall time of the process.

During his interview, Lieutenant Colonel Kinney explained the current kill chain process from finding an emerging target to the engagement itself. He identified the three main systems that were involved in the kill chain: the brigade tactical operations center (TOC), division TOC, and the field artillery battalion TOC. The main conclusion from this interview was that the brigade TOC is the nucleus of the current system, as the information is received at the brigade TOC and distributed based on the trajectory of the necessary engagement method. This process, also known as the clearance of fires, took the most amount of time in the kill chain because it required information to be sent to and from the brigade TOC to other entities like the field artillery battalion. This information determined a baseline for the Operational Viewpoint-1 (OV-1), which is a visual diagram that describes the mission as a whole while indicating unique interactions between the different systems as well as the environment. These findings not only informed the “as-is” OV-1 but also contributed the right scope on where the issue lies within the current kill chain process.

Further findings and conclusions were related to artificial intelligence. Using AI to aid military training is already occurring in the Army. In current training, AI is used to help aid a soldier’s decision-making process (Rasch et al, 2003).

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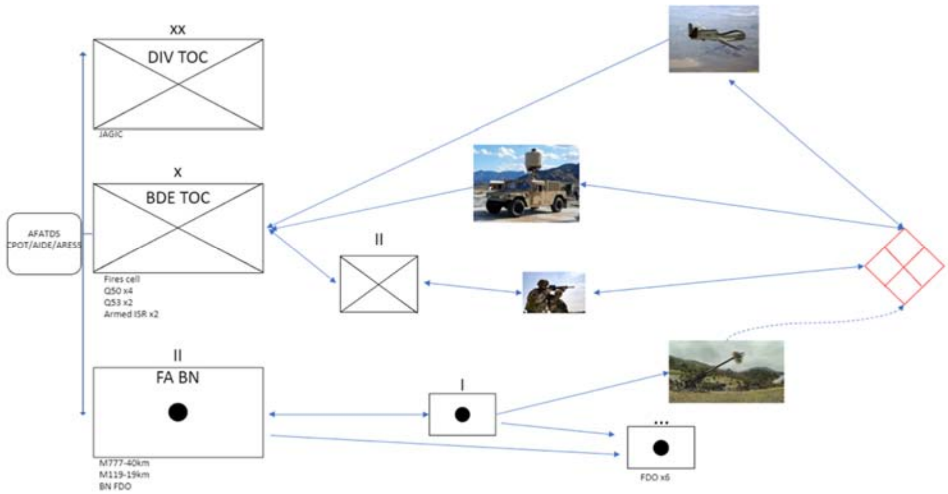

Figure 1. OV-1: High-Level Operational Graphic

Results from an experiment to determine how the decision-making process used by officers and non-commissioned officers is affected using Integrated Course of Action Critiquing and Elaboration System (ICCES) confirmed the use of AI decreases the time of decision making dramatically. Although AI is a great resource to speed up the process, there are issues to be considered with the integration of AI in weapon systems. The military follows a strict ethical code in war fighting. Including AI in weapon systems to create autonomous weapons violates this code. *The Commander's Handbook on the Law of Land Warfare* prohibits the use of blind weapons (Department of the Army 2019). A conclusion is that it is important to ensure the addition of AI in weapon systems align with the values and codes emplaced within the military. A recommendation is to start examining different ways to include AI in tasks such as risk assessment, air clearance, and fire missions using processes similar to those used in the ICCES experiment. By having preset responses with each of these tasks, the overall time will be decreased by avoiding variability in human processing times. Supervised AI would allow soldiers to be fully responsible for the weapons and systems they operate while employing AI in tasks less severe than pulling the trigger.

3. Systems Architecture

Of the architecture viewpoints developed in this project, only selected viewpoints are depicted in this paper. Those shown are overarching architectural descriptions to aid the understanding of how the kill web is intended to operate under battlefield conditions. Operational Viewpoint–1 is a high-level operational concept graphic that gives an illustration of the processes required in an indirect fire engagement. The operational viewpoint of the military systems involved, without the use AI, aided the effort to determine places where the integration of AI would benefit the overall efficiency of missions conducted. Operational Viewpoint–2 is a resource flow diagram. Applying this viewpoint to the battlefield in the context of indirect fire engagements led to identifying efficiencies in sharing or processing information that AI integration could provide. Capability Viewpoint–2 was used to identify the capabilities associated with the kill chain process and classify them according to warfighting function.

3.1 Operational Viewpoint-1 (OV-1): High-Level Operational Graphic

The overall design of the kill chain process is shown in Figure 1. This depiction highlights the key components and processes that accompany an indirect fire mission. This process begins with the identification of an enemy potential threat by some C5ISR asset. Once this occurs, the target information or imagery is transmitted to the brigade TOC. This command center is the most important system that operates within the indirect fire mission set because of its responsibility to funnel information above and below it to most efficiently carry out a fire mission. The next most important system within this operational view is the field artillery battalion fire direction center (FDC) because it calculates the maximum ordinal and distance needed to engage the target. Finally, the field artillery battery and platoon are important to this operational view because they possess and operate the howitzers that engage the target that was found with the C5ISR assets.

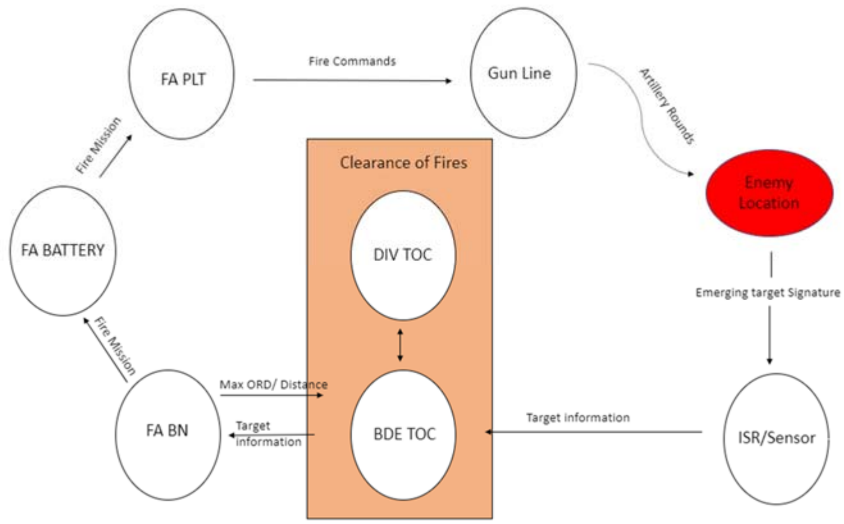

Figure 2. OV-2: Operational Resource Flow Description

3.2 Operational Viewpoint-2 (OV-2): Operational Resource Flow Description

The OV-2 graphic shown in Figure 2 complements the OV-1 graphic in terms of systems within the indirect fire mission; however, it depicts the flow of information and communication between them using arrows. Each arrow in this graphic depicts how one system communicates with another. Most importantly, it is possible to visually see the systems that interact and the frequency of interaction based on the number of arrows. Another aspect of this graphic is the different tasks that occur within the indirect fire mission. For example, the clearance of fires occurs between the brigade TOC and the division TOC.

3.3 Capability Viewpoint-2 (CV-2): Capability Taxonomy

The capability taxonomy represents a hierarchal flow of capabilities that the system has in order to complete its mission. In the case of the kill chain, the overall goal is to conduct the dynamic targeting process, F2T2EA. As shown in Figure 3, the five main capabilities that are needed to conduct this are intelligence, surveillance and monitoring, target acquisition, fires, and communications. These five capabilities are determined by grouping the tasks of the system components in the OV graphics with the communication needs of each. By leveraging these capabilities, the kill chain process can be timely and efficient. The lower level capabilities are the specific aspect of the F2T2EA process that the corresponding capabilities have in order to assess whether or not that capability is met within the system. This viewpoint will be crucial in the creation of candidate solutions for future systems because it bridges the gap between required system capabilities and how it does them.

4. Value Model

The value model is important for the project because it is the tool assesses performance of potential future state systems. This model uses qualitative measures to score each candidate solution in terms of four functions that each need to have: document enhanced capabilities, reflect process complexity, conform to doctrinal standards, and represent essential information interface requirements. The functions chosen were specific to what the stakeholders wants as they look to enhance the kill chain. These functions contain individual objectives that are assessed by maximizing, minimizing, or optimizing the performance measures in order to achieve this overall score. There are also performance measures that weight every aspect of a solution to formulate an overall score of its goodness and are denoted as less is better (LIB) or more is better (MIB). Figure 4 provides a visual depiction of the functions and their associated objectives and performance measures.

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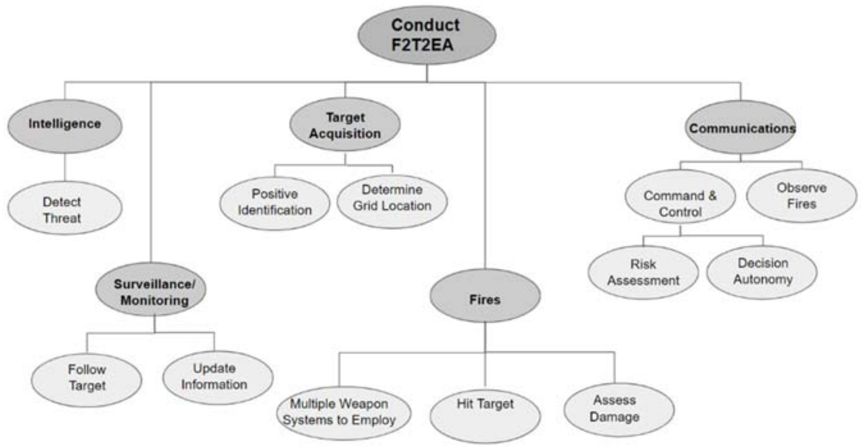

Figure 3. CV-2: Capability Taxonomy

4.1 Document Enhanced Capabilities

This function was chosen to show where and how each task can be enhanced whether it be with AI or some other aid to speed up the kill chain. The goal with outlining the capabilities of the kill chain is to identity task that can include AI along with ways to improve other tasks in F2T2EA the enhance the overall efficiency of the cycle. To enhance the F2T2EA capabilities, the primary focus is making more task electronic which limits the time it takes for humans to go back and forth from task to task. This allows there to be more AI enables system in the process to lower the workload of the human operators.

4.2 Reflect Process Complexity

The complexity of the system is important for creating candidate architecture solutions. It provides the information needed to be passed and the nodes needed to pass the information. We want to minimize the amount information interfaces the system utilizes and optimize the amount of system elements. This optimization addresses the fact that you cannot rid the process of a system entirely without providing a new technology or capability that can take its place. For instance, the Brigade TOC will not go away completely, but by providing the TOC's capabilities to an ISR, you can increase the modularity and reduce the number of elements needed in the process. The measurements used to assess the quality of an architecture for this function are amount of system elements on the same interface and the ratio of system elements to system modularity.

4.3 Conform to Doctrinal Standards for Targeting

The main goal is to reduce the complexity of the F2T2EA process. By mapping the kill chain process, we found that conforming to the standards for the targeting process would be best for improving the systems overall efficiency. The speed, accuracy, precision and effect on target will be maximized. In the targeting process there will be a focus on maximizing time and accuracy, minimizing discontinuity, and minimizing the risk involved.

4.4 Essential Information Interface Requirements

This project's goal is to minimize the amount of connections within the information interfaces and only have essential connections in order to decrease time spent in the kill chain. This can be easily represented in systems architectures like the OV-2 where there are multiple connections throughout the different domains. The fundamental objective is to minimize common operating picture (COP) and information nodes by aiming to put all the information and interfaces on one common operating picture and minimize the information nodes in general. These fundamental objectives are measured by the number of C2 networks and information nodes.

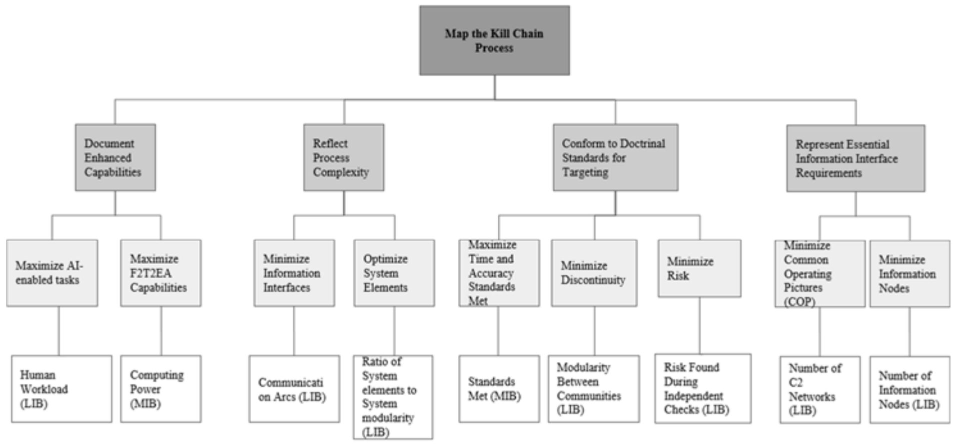

Figure 4. Indirect Fire Systems Architecture Value Model

5. Conclusion

This project, conducted on behalf of the Combat Capabilities Development Command Armaments Center, seeks to increase the efficiency and timeliness of the kill chain process. The creation of a kill chain with interconnected systems that involve the use of AI will provide a capability that Army leaders can implement to enhance lethality. As the nature of war evolves, so should the intelligence of the Army's weaponry. The integration of AI should not be used to create autonomous weapon systems. It is important to ensure humans remain involved in lethal decisions to maintain the foundation of moral and ethical decision making in the Army. Nevertheless, it will give commanders the tools to make more accurate, quick decisions within dynamic targeting multi-domain operative environments. Again, the goal is to decrease the time it takes to deliver indirect fires on the battlefield. This analysis outlines the framework to depict and assess future candidate systems architectures for indirect fire systems.

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