Proceedings of the Annual General Donald R. Keith Memorial Conference
West Point, New York, USA
May 2, 2024
A Regional Conference of the Society for Industrial and Systems Engineering

Modeling Combat Simulations in an Evolving World – Analysis to Provide Innovative Recommendations for Combat Simulations

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Author Note: CDT's Cox, Dellinger, Sackett, and White are first-class cadets at the U.S. Military Academy; LTC Gillespie is their advisor. The team would like to thank the support and communication from analysts at Fort Leavenworth (FLVN), White Sands Missile Range (WSMR), and Monterey. The views expressed herein are those of the authors and do not reflect the position of the United States Military Academy, the Department of the Army, or the Department of Defense.

Abstract: The U.S. Military Academy's Systems Capstone team was tasked to assess the Army's combat modeling and simulation systems and provide recommendations for improvement. Through stakeholder interviews, focus groups, questionnaires, and data analysis, the Capstone team identified several issues. First, due to different data sources within the defense acquisition systems, data challenges exist. It can be hard to sift through what is necessary and what can be discarded. Thus, current Army combat simulations must utilize more man-hours to clean data, which takes time away from other important operations. Second, Cyberwarfare and terrain degradation lack accurate representations due to limited data and combat application as opposed to other kinetic domains like armor and direct fire. Third, integrating modeling and simulation applications may improve process speed and reliability. It is also true that the number of Analyses of Alternatives (AoA) studies done has significantly decreased since 2018 due to mid-tier acquisitions. However, the number of studies overall has remained constant. Based on these findings, the team recommends improving data collection processes while utilizing artificial intelligence to clean data, exploring methods to better incorporate modern domains into simulations, and updating user interfaces to reduce the learning curve. Implementing these recommendations will serve the Army's overarching goal of providing timely, accurate analysis to inform the Army and DOD decision-making on combat systems and concepts.

Keywords: Requirements, Combat Simulation, Analysis of Alternatives (AoA)

1. Introduction

Combat simulation gives Army leaders insights to inform challenges in acquisition, force structure, and operational decisions in a resource-constrained environment. Combat simulations are challenging to make - they require data, models, time, and resources to build that are not always available. As part of the Army's innovation initiatives, combat simulations provide analysis to inform Department of the Army (DA) and Department of Defense (DoD) level decisions made with a complex network of stakeholders competing for resources. These decisions aid the United States Army in making large investments and procurements that have massive implications for national security. The Army's primary combat models that were looked at in this study are both over twenty years old. While still very useful in many regards, they are challenged to represent emerging capabilities in Multi-Domain Operations (MDO) and meet the volume and time demands of the Army's decision processes. Therefore, the desired end state for this project is the following: to provide recommendations on how to improve useability, interoperability, modeling, and simulation of combat scenarios to Army innovation initiatives.

This paper reviews combat simulation concepts to provide external feedback to future Army researchers. Firstly, the project's methodologies conducted including constraints, limitations, and assumptions along with study questions. Secondly, stakeholder interviews and questionnaire results provide initial findings taken from combat simulation developers. Thirdly, the requirements for the project are stated and elaborated on. Fourthly, the components of Multi-Domain Operations relevant to combat simulations are mentioned. Lastly, the tentative conclusions of this research endeavor, and what the West Point research team recommends for future investigation.

2. Methodology

2.1 Problem Statement and Study Questions

This project aims to provide requirements for combat simulations, enhancing their capacity to support the Army's analytical efforts in meeting future demands while assessing its current systems and investigating alternatives to prioritize the enhancement of simulation systems. The team analyzed an operational and tactical simulation, with alternatives being creating new systems, revising old systems, or exploring using different systems. However, the team did not research other systems as the focus was only on those two combat simulations, and some complications will be discussed later as to why a new system is not feasible.

Thus, this study focused on ways to improve current simulation systems. The team is concurrently investigating these ways with other study teams internal to the Army's research organizations. Tactics for collecting research include interviews, focus groups, questionnaires, and requirements analysis. To meet the Army's research objectives, the USMA team created study questions to note focuses for present and further exploration.

- *What combat simulation capabilities are necessary for the Army to answer its range of simulation-based study questions adequately?* This pertains to the specific capabilities needed to simulate the breadth of MDO and address the inherent limitations in answering specific study questions through simulations.
- *What combat simulation capabilities do the Army's research units currently have?* The study team assessed the Army's existing capabilities in representing different domains of MDO, identified appropriate quality measures for combat simulations, and understood the Army's proficiency level within each domain.
- *What capability gaps exist between what the Army currently has and what is necessary to answer its study questions?* By comparing existing capabilities with essential requirements, the study team aims to identify gaps and explore potential Modeling and Simulation (M&S) technologies or solutions within the Army's research framework to bridge those gaps.
- *How do the Army's combat simulations integrate into the existing infrastructure – specifically regarding technology, data, and organizations?* Researchers seek to understand the Army's current technology infrastructure, its applicability to new interfaces, data infrastructure requirements, and systems that can or cannot be implemented.
- *What are the important characteristics that allow easy operation of simulation systems?* Researchers want to identify valued characteristics from stakeholder experiences to understand what features should be retained or removed in existing systems for efficient operation in answering the Army's simulation-based study questions.

The methodology is also shaped by constraints, limitations, and assumptions made by the researchers. These are important factors to create research boundaries and broaden the researchers' understanding of the project. First, all data is dispersed into different Army locations. Second, communication and modeling of other DoD branches are not done through the Army's land-based scenarios used; this limits the applicability of most simulation scenarios. Third, all updates and research must be Secret-level classification or lower. Lastly, the project's scope only pertains to developing requirements rather than implementing new simulations. There are also several key assumptions and limitations to consider. First, like any organization, institutional bias may exist, necessitating the collection of opinions from multiple locations and combat model teams to mitigate potential biases. Secondly, researchers will only be able to perform usability tests on the Army's simulations indirectly, relying instead on researcher-created data analytics and historical work for quantitative research. West Point research team assumes that quantitative analyses will rely on historical study data and cannot utilize works in progress, thereby necessitating an analysis of trends rather than current data. Lastly, it is assumed that Army's research units' employee status and budgeting will remain unchanged beyond the research period.

2.2 Findings

The research team analyzed both operational and tactic-based simulations for this project. The operational simulation is a multi-sided model that regards relationships between units, makes maneuver and engagement decisions based on perception, and operates from a Brigade to the Corps level. The tactical simulation also regards interunit relationships and behaviors to exploit the information provided by the model's network. They work on operations analysis from Soldiers up to Brigade-level units. Other combat simulations were not thoroughly researched for this study.

A few findings were compiled from interviews done throughout the semester. For one, the line between when to create a new system or keep revising an old one was defined. Essentially, simulation personnel will only consider a new system entirely if it reaches the "tipping point" (Henderson, et al., 2024). The "tipping point" appears when situations that cannot be modeled become an area of significant strain (Henderson, et al., 2024). Currently, a situation called "Wet-Gap Crossing" is

causing developers and coders issues as current simulation systems cannot explicitly show damages to objects such as bridges, only units (Henderson, et al., 2024). In addition to not yet hitting the tipping point, a few more reasons why creating a new simulation is risky are the following: 1) New simulations can lose feature parity, which means that specific components experience reduced effectiveness; 2) It is easier and cheaper to rewrite parts of the coding of a simulation than to create an entirely new model, and 3) Trying to create a super combat simulation would be too complex (Henderson, et al., 2024).

The second main findings were on how data can be manipulated. Data processing and utilization take up the most time in running a simulation besides training personnel (Wade, 2023)(James Green, et al., 2023)(Robert Steele, et al., 2023). Thus, many theories on optimizing this process were the focal point of stakeholder conversations. The first aspect discussed was utilizing AI in one of the following ways: 1) AI can do quality control checks on lines of code to identify potential issues with the methodology, and give suggestions as to how the coder could fix it, 2) AI is included in the simulation to help with simple decision analysis of certain units, and 3) AI is used to create surrogate data if M&S teams cannot get the data from regular sources. However, the second and third suggestions were dismissed because of reliability issues since AI is known to make up results if it is not able to find the "correct" answer. A team interviewed also stated that it is better to keep using subject matter experts (SMEs) to cover gaps in knowledge than a computer (Fraka, et al., 2023).

Another aspect of data manipulation is the use of certain operating systems to model simulations. Currently, the operational simulation utilizes Linux (Henderson, et al., 2024). Linux tends to be more suitable for software personnel to work on it as it gives you more freedom and flexibility when coding (Henderson, et al., 2024). However, systems such as Windows are more commonly operated on by applications today and are user-friendly. The developers said that the tradeoff between either system seems to be insignificant (Henderson, et al., 2024).

An additional aspect of data manipulation was potentially using cloud computing to help facilitate collaboration (Powell, 2023)(Fraka, et al., 2023). However, there were a few issues with this suggestion, those being the following: 1) Taking the operational simulation off a closed network limits the freedom that employees have when creating a simulation as the network is monitored. This process can cause problems when trying to add certain features to the simulations, changing areas of it, and more. 2) Putting the program on the cloud adds extra steps when downloading and uploading information. This process increases the time exponentially and would fix the issue of running designs of experiments by switching to a more stochastic simulation process for more accurate results. However, downloading the information and utilizing the output is still the issue. 4) Finally, the bandwidth for transferring classified networks is extremely slow, and the Army's operationally-based combat simulation is currently a desktop system that runs locally, which also affects accessing the output (Henderson, et al., 2024). Thus, as it currently is, pursuing cloud networking would not be recommended.

The last aspect of data manipulation that was found hard to implement was creating a database (Welch, 2023). The idea was to put all the systems that go into creating a simulation into one database so that each one did not have to translate the code the previous system uses and information could flow more rapidly. However, this was identified as a minor issue that did not need to be addressed.

The third main finding is that including Multi-Domain Operations (MDO) in modeling is the new focus of many M&S systems (Wade, 2023). A significant challenge in representing MDO is Cyber. Domains like Cyber lack the measurement space to be modeled in a simulation, which means there is not enough information to define the capabilities' effects on the outcome. However, when considering the cyber domain, cyber should generally be focused primarily on intelligence gathering and counterintelligence (Farenbach and Farr, 2023).

The study team then created a questionnaire for 27 members at multiple research sites to complete (USMA Capstone Team, 2024). The numbers in the table below were calculated from personnel rating their perceived confidence and whether the capability should be done from 1-5. The percentage was found by taking groupings of ratings and seeing how many people fell into those groups. Thus, low percentages were derived from rating 1 or 2, 3 was a neutral value, and 4-5 were high values. The questionnaire revealed several challenges in modeling capabilities for combat simulations. A major issue is the difficulty of operating at the Secret level when much of the required information is classified as Top Secret. Restricted data access limits what developers can incorporate which affects useability and capabilities of the Army's research teams. Many cyber operations require higher security clearances, contributing to their underrepresentation in combat modeling.

Another challenge is the high-level aggregation in large-scale simulations. The lack of granular detail in the Army's operationally-based simulations makes it challenging to model soldier-level capabilities like small arms, CBRNE, logistics, and communications. Many stakeholders suggested having dedicated simulations for these aspects rather than combining them into one overly complex system. However, 22% believed Cyber should still be modeled in operationally-based simulations despite lacking confidence in their ability to model it.

Table 2.2 highlights key discrepancies between the perceived necessity of modeling certain capabilities and the confidence in doing so effectively. Notably, ammo/munition, intelligence, indirect fires, and small arms were deemed necessary to model by over 50% of respondents. However, confidence in modeling these ranged from 0-40%, with small arms at 0% confidence. This gap between importance and competence for critical capabilities underscores the need to improve combat simulation modeling, especially in the representation of MDO. Overall, the restricted data access, challenges of large-scale

aggregation, and lack of confidence in modeling key capabilities despite their importance reflect areas requiring further development for accurate, comprehensive combat simulations (USMA Research Team, 2024).

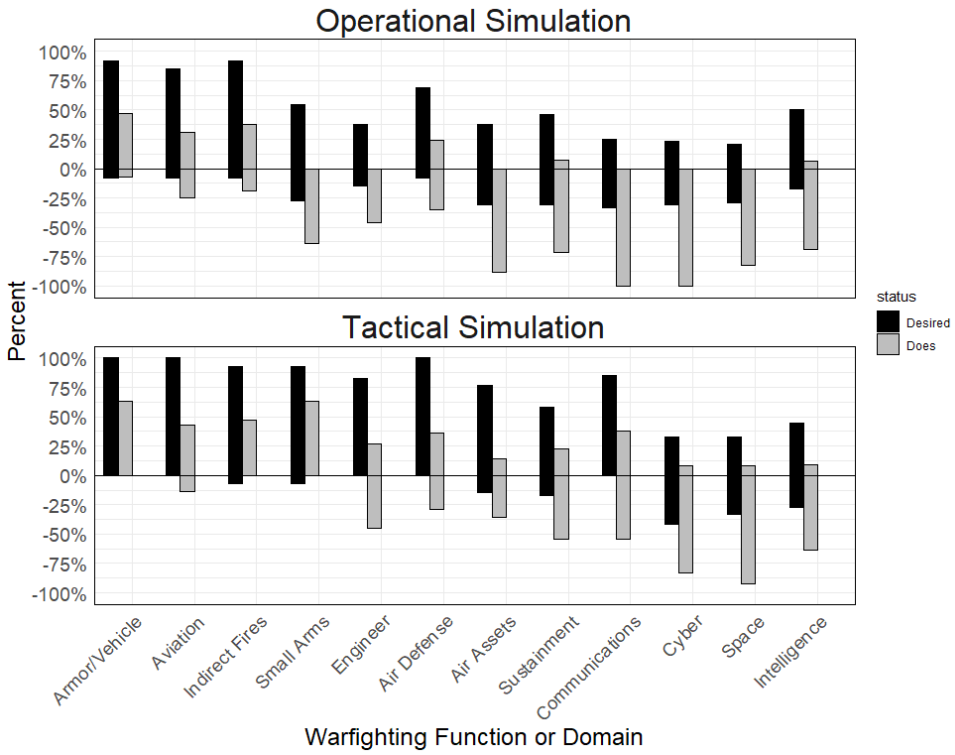

Figure 2.2: Questionnaire data showing Combat Simulation's desired capabilities versus its perceived capability.

3. Requirements

The first main requirement Army research units must accomplish is to improve the ease of use for new employees. Refining the interface and removing unnecessary software makes the simulation easier to use and can minimize training time for new employees to adapt to the system (Welch, 2023). Multiple stakeholders have suggested that their lack of time to create combat simulations stems from the lengthy process of training employees to use the simulation. By making the model easier to use, training time can be reduced and saved for more important matters like developing new weapon systems and operational tools.

The second main requirement Army research units must accomplish is to model more representative systems and capabilities. A holistic model will aid in representing all areas that can affect a military operation. Multi-Domain Operations are the Army's present and future and are necessary to be accounted for in combat simulations (Wade, 2023). While the West Point research team understands how to apply traditional domains, there are still domains proving a challenge to properly apply. Failure to model would reduce the accuracy of future weapons used in the operational Army.

The third main requirement Army research units must accomplish is to allow for interoperability across computing environments. The Army combat simulations value collaboration and cooperation in making their models. To improve interoperability, the Army should focus on the communication between networks, both public and private. Communication is essential since current local networks create significant inefficiency in database transfer (Welch, 2023).

The fourth and final requirement the Army research units must accomplish is incorporating data. Incorporating substituted (surrogate) and given data through collection, consolidation, and management should be well-defined and easily followed. The focus of incorporating useable data in combat simulations is considering how long it takes to run a simulation compared to the time taken during other components of creating AoA's.

4. Multi-Domain Operations

The Army is transitioning to Multi-Domain Operations to effectively address the complexities of modern warfare and maintain a competitive advantage against hybrid threats. While it seems that the Army's research initiative does a good job at modeling certain domains (i.e., ground and aviation maneuver, which most studies are geared to), there is a glaring weakness: the Cyber domain. Through interviews, West Point's research team heard that the current system is inadequate to model Cyber capabilities. It is also suggested that the Cyber domain is more important than ever (Farenbach, Farr, 2024). While the Army's research initiative shows the effects of Cyber, it cannot model and analyze Cyber capabilities. From this, it can be concluded that the need to figure out how to model Cyber is of the utmost importance as multi-domain operations (MDO) are a key focus of the modern battlefield. This has not been reflected in their studies as seen in Figure 4.1, as only one Cyber study has been conducted through the Army's research initiative since 2010. It is also important to note the difference between showing the effects of a domain versus modeling it. When showing the effect of something you can replace the actual effect with a substitute. For a large-scale simulation, this is sufficient if it is not what the overall study is looking at. Now if you were comparing two alternative chemical weapons you would need to collect data on how it affected the unit. This is where you would have to model it to collect that data, rather than just saying what the effect would do.

4.1 Cyber

When measuring Cyber research conducted by hours worked per year, the West Point research team noticed a significant decrease in emphasis on Cyber capabilities in simulations conducted by Army research units as previously mentioned. Figure 4.1, created by using data provided by Army research units, shows an even greater decrease in cyber focus (Army Research Units). In earlier studies, the West Point research team saw a consistent amount of man-hours put toward Cyber, but this has changed since 2015. Since then, there has only been a combined 142 hours put toward Cyber studies; mainly, this reduction is due to the unknown nature of cyber operations and their effects on the battlefield (Welch, 2024).

This decrease in 2018 is due to several factors, primarily the switchover of the Army's research units to be organized under Army Futures Command. The other potential reason is the introduction of Mid-Level Acquisitions. This bypasses the need for many AoA studies to be conducted as it allows for organizations to go with what they need from the private side, rather than going through government studies before. While the decrease is notable, it does not change the fact that the Army still needs to model AoA studies.

Additionally, all data in this section was given to the West Point research team in the form of logged hours on a study. The West Point Research team then concluded that the Man-hours worked was the best metric. This was mainly due to the accuracy of the proxy to determine what studies they spent the most time on. This data also provided us with the type and number of studies done (Army Research Unit, 2023).

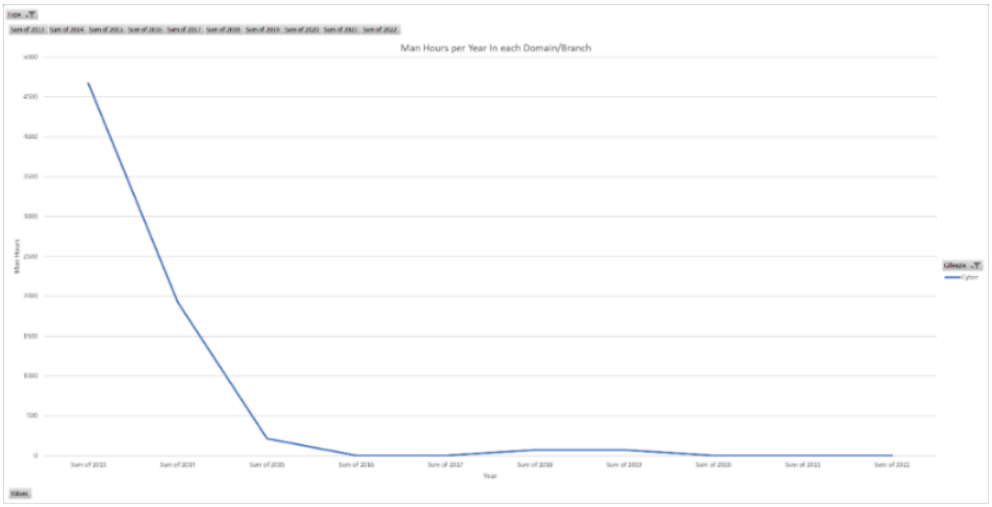

Figure 4.1: Man Hours per Year for Cyber

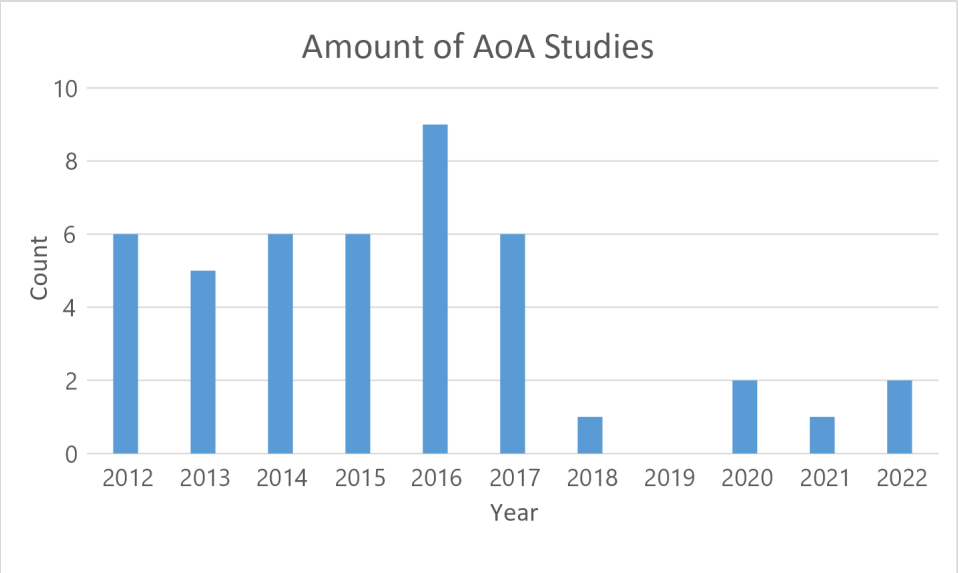

Figure 4.2: Number of AoAs by Year

5. Conclusions

From stakeholder interviews and data analysis, the West Point Capstone team has found that many of the Army's current systems are adequate at answering the study questions that they are asked to answer. It seems to be the case that it is adequate for analyzing traditional domains and branches like maneuvering and aviation. There does seem to be a capacity gap in some modern domains such as Cyber. One of the Army's research units' primary purposes is to provide AoA, but there has been a significant decrease in the amount of these since 2018. Through interviews, the West Point research team has determined it is still important for the system to have this capability. Another problem is currently, the system of receiving data is inefficient as it relies on different organizations. Even when they receive data, much of the data is missing and needs to be surrogated. While this may be outside of the scope of changes the Army's research units can make, it does create inaccuracy which potentially puts a whole study and simulation at risk from the beginning. Another gap that is causing the timeline of studies to be extended is the fact that it does take a lot of time to train new members, as 68% of members at Leavenworth and 52% of members at White Sands who completed the questionnaire identified this as a problem (USMA Research Team, 2023). the West Point research team can conclude that the training methods employed by the Army may be sufficient, but the systems complexity introduces a steep learning curve for the new employees and analysts. There exists a fundamental tradeoff between the complexity of the system and training time. Overall the Army's research initiative does a reasonable job of providing its stakeholders with answers to their study questions, but it could be improved.

6. Citations and References

Cordray, Haeker, Greene, Powell, Quinnell (2023, November 10). Operational Simulation Demo (A. White, Interviewer)
Bannister, Cozart, Pace, Steele, Urabe, Welch (2023, November 7). AWARS Focus Group (S. Sackett, Interviewer)
Farenbach, Farr (2024, January 30). Cyber Interview. (J. Dellinger, Interviewer)
Henderson, Lance, Maynes, Panzer, Payne (2024, April 5). Stakeholder Meeting (A. White, Interviewer)
Army Research Units. "Employe Data." *Microsoft Excel*. 10 Oct. 2023
USMA Research Team. "Stakeholder Questionnaire." *Microsoft Forms*. 26 Feb. 2024.
Wade, B. Dr. (2023, August 29). Intermideate Stakeholder Interview. (A. White, Interviewer)
Wade, B. Dr. (2024, January 23). Initial Stakeholder Interview. (J. Dellinger, Interviewer)
Welch, A. (2023, September 8). Stakeholder Interview. (J. Dellinger , Interviewer)