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SYSTEMS ENGINEERING CAPSTONE REPORT

**THE GROUND AWARENESS WARFIGHTING DECISION
SYSTEM: A CONCEPT FOR A FUTURE INTELLIGENT
DECISION AID FOR DISMOUNTED SOLDIERS**

by

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DISMOUNTED SOLDIERS**

Erin M. Gardner, Rachel L. Gerstein, Ashley A. Locketto, and John D. McKenna

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ABSTRACT

This capstone report studied how the employment of artificial intelligent (AI) solutions, in conjunction with sensor data and higher enterprise-level machine learning (ML) algorithms, can improve tactical decision making, provide advanced targeting solutions, and recommend courses-of-action (COAs) for dismounted warfighters in austere environments. The team applied a systems engineering analysis approach to develop requirements and a conceptual design for an AI-enabled decision aid at the tactical edge. The team named the future capability the Ground Awareness Warfighting Decision (GAWD) system. The envisioned GAWD capability would provide a functional AI/ML backbone architecture for the transport of tactically relevant data at the edge for soldiers to process in real-time and analyze for targeting and route selection. In addition, the capability could monitor soldier health and provide this information to the Command. The future GAWD system concept would leverage AI, ML, augmented reality (AR), virtual reality (VR), and on-body processing to analyze data to trigger real-time notifications and recommended courses of action (COAs) to dismounted warfighters on their end user device (EUD) or heads up display (HUD) to assist with timely operational decisions. The team conducted scenario analysis to explore the use of the GAWD system in three different ground-deployed soldier scenarios. The team studied ethical implications of introducing a GAWD system to military operations.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAR	after action review
ACAT	acquisition category
AFC	Army Future Command
AGI	artificial general intelligence
AI	artificial intelligence
ANI	artificial narrow intelligence
AR	augmented reality
ARL	Army Research Lab
ASA(ALT)	Assistant Secretary of the Army (Acquisition, Logistics and Technology)
ASI	artificial super intelligence
ASL	Army senior leadership
ATEC	Army Test and Evaluation Command
CD	computing devices
ChatGPT	Chat Generative Pre-Trained Transformer
COA	courses of action
CONOP	concept of operations
COTS	commercial off the shelf
CGM	continuous glucose monitor
DARPA	Defense Advanced Research Projects Agency
DASC	Department of the Army System Coordinator
DAU	Defense Acquisition University
DIB	Defense Innovation Board
DOD	Department of Defense
EEG	electroencephalogram
EM	electromagnetic
EUD	end user device
GAO	Government Accountability Office
GAWD	Ground Awareness Warfighting Decision

GB	gigabyte
GOTS	government off the shelf
GPS	global positioning system
HIPAA	Health Insurance Portability and Accountability
HUD	heads up display
HW	hardware
Hz	hertz
IDP	intel data platform
IED	improvised explosive device
IEW&S	Intelligence, Electronic Warfare and Sensors
IMU	inertial measurement unit
IoT	internet of things
IS&A	Intelligence Systems & Analytics
KPP	key performance parameters
KSA	key system attributes
MDA	milestone decision authority
ML	machine learning
NATO	North Atlantic Treaty Organization
NLP	natural language processing
NPS	Naval Postgraduate School
NVG	night vision goggles
PEO	Program Executive Office
PHI	protected health information
PM	program manager
R&D	research and development
RDT&E	research, development, test, and evaluation
RFID	radio-frequency identification
RT-PSM	real-time physiological status monitors
RTS	real-time strategy
SA	situational awareness

SAS	situational awareness status
SE	system engineering
SME	subject matter expert
SW	software
TOC	tactical operations center
TPU	tensor processing unit
U.S.	United States
UAS	unmanned aerial system
UAV	unmanned aerial vehicle
VR	virtual reality
YPG	Yuma Proving Ground

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EXECUTIVE SUMMARY

Although futuristic in nature, the use of artificial intelligence (AI) and machine learning (ML) as a wargaming aide for dismounted soldiers is the next step for the United States to maintain superiority on and off the battlefield. U.S. Department of Defense (DOD) and the Joint Services are exploring the use of AI/ML for a variety of applications to support warfighter missions. This capstone project studied the use of AI/ML to enable a future wargaming decision aid to support dismounted soldier missions. The capstone team (the Linchpin Group) applied a systems analysis approach to study current and envisioned capabilities of AI and ML, to understand the needs and missions of dismounted soldiers, and to develop a conceptual design of a decision aid system that leverages AI and ML.

The capstone team envisioned the implementation of a cutting-edge and comprehensive AI/ML wargaming decision aid called the Ground Awareness Warfighting Decision (GAWD) system. This system is a data suite paired with state-of-the-art software (SW) that ensures the tactical decision-making capabilities of infantry units in austere environments, which can help save lives. Utilizing AI, ML, and advanced data analytics, this innovative tool could provide an adaptable and scalable system that could accommodate the needs of various unit sizes and seamlessly be integrated with existing military technologies and networks.

This real-time and ever-evolving system has the potential to empower dismounted soldiers with a clear and comprehensive view of the operational environment, which includes the locations of adversaries' positions, terrain features, and friendly forces using various sensors and data sets that deliver up-to-date information on the battlefield. Additionally, this wargaming aid would provide situational awareness (SA) to soldiers and their commands by leveraging ML algorithms and historical data. This information would be able to quickly analyze various scenarios, predict potential enemy movements, and suggest optimal courses of action (COA) based on the current situation and the unit's objectives to make critical, tactical decisions.

The Linchpin Group's conceptual AI/ML GAWD system for dismounted soldiers represents a groundbreaking advancement in infantry warfare. By harnessing the power of AI/ML, this cutting-edge tool would equip dismounted soldiers with unparalleled SA, decision-making support, and coordination capabilities. This tool is also envisioned to act as a training platform, enabling soldiers to engage in virtual wargames and simulated scenarios. The system could record individual and unit performance during both training exercises and real-life scenarios, which provides valuable insights for after-action reviews (AARs) and continuous improvement to individual soldiers and the Army as a whole.

The team conducted a scenario analysis to explore how the GAWD system would be used by soldiers in ground-based missions. The team identified three relevant scenarios that would be enhanced by the addition of an AI-enabled GAWD system. The three scenarios were: (1) target engagement, (2) route selection, and (3) soldier health and status monitoring. The team explored each scenario and then compared the required capabilities needed from a future GAWD capability across the three scenarios.

AI/ML, as a force multiplier, has the potential to significantly enhance combat effectiveness and survivability of dismounted units, ensuring military superiority on the modern battlefield. Its deployment would revolutionize dismounted operations and set new standards for tactical excellence in the military.

I. INTRODUCTION

This section orients the reader to the research presented in the capstone report. This chapter not only introduces the AI/ML wargaming decision aid, also known as the GAWD system, but also provides background to the reader on the current status of AI/ML, the statement of need for this wargaming capability, the project objectives, the team involved in providing this information, and the overview of what is included in this report.

A. BACKGROUND

AI is a “wide-ranging branch of computer science concerned with building smart machines capable of performing tasks that typically require human intelligence” (Schroer 2023). Scott Jasper, a professor at Naval Postgraduate School (NPS), further explains this field of study by stating, “ML is a subfield of AI, where data is combined with algorithms to train a model, which can make predictions or inferences without explicit programming” (Jasper 2022). Another NPS professor who is an expert in this field of study provides more detail: “automation, AI, and ML systems—both handcrafted knowledge systems and learning systems—offer great potential for the Department of Defense (DOD) with diverse applications in most mission domains” (Johnson 2021, 4). Both areas of advanced technologies have significant potential to aid warfighters with the much-needed support in making critical decisions when burdened with complex information and tasks during combat operations.

Implementing AI into military operations requires insight of the current maturity level of this technology and the different phases of this field of study. Figure 1 provides a high-level timeline on the progression of this field of study.

It is important to note that the milestones highlighted in Figure 1 are not the only major developments in AI, but they do provide background information to portray the timeline of where we are today. This background information provides clarity to better understand the three stages of AI, as shown in Figure 2 and further clarifies it later in this document.

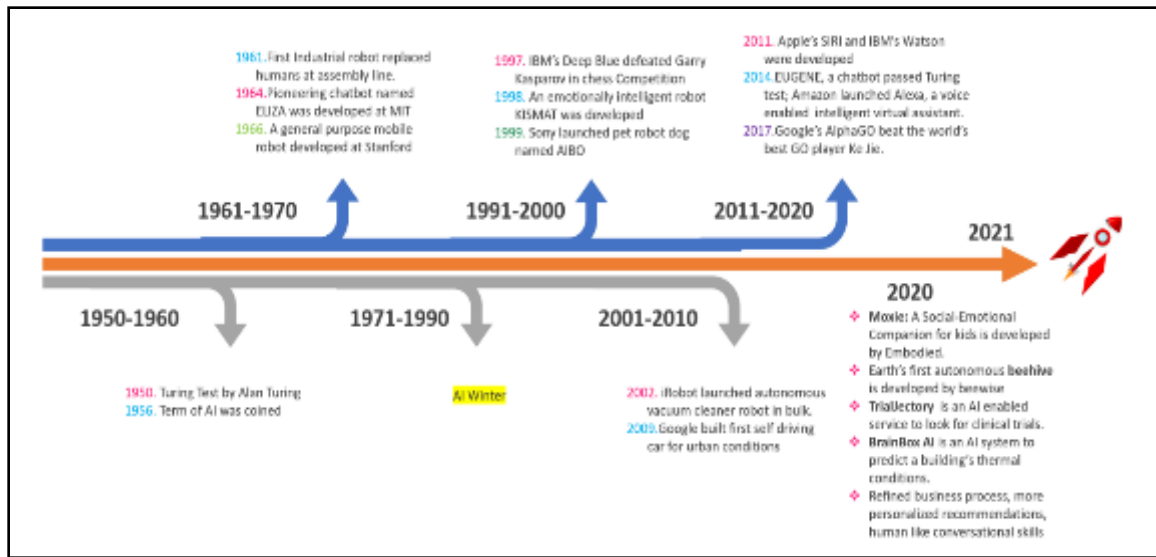


Figure 1. Artificial Intelligence High Level Timeline. Source: Gupta (2021).

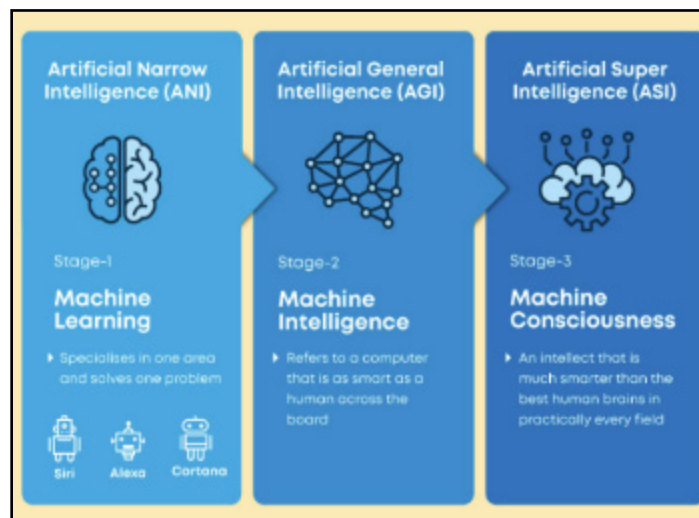


Figure 2. Three Types of Artificial Intelligence. Source: Great Learning Team (2023).

The first phase of AI, where many people believe is the current stage, is artificial narrow intelligence (ANI). ANI, also known as weak or narrow AI, is designed to solve a single problem that can execute a single task very well. In this stage of AI, machines can excel in controlled environments with very limited parameters. Further expounding on this idea, Sri Krishna (2023), a technology expert, states “ANI systems are typically trained on a large dataset and are able to make decisions or perform actions based on this training.”

An example of ANI is Amazon's Alexa being able to turn the lights on or off, tell you the weather, or start playing your favorite song. Although useful, this type of AI is not advanced enough to adapt to new objectives, requirements, or conditions. Krishna further explains that "ANI systems require human reprogramming or reconfiguration when the context or behavior specification changes, even slightly."

The second phase is artificial general intelligence (AGI), or machine intelligence, and would provide human-level cognitive function. In this phase of AI, machines are "not specialized to carry out specific tasks, but can learn to perform as broad a range of tasks as a human" (Shanahan 2015, 227). Some individuals believe with current advancements of this technology that this phase has already begun. For example, in February 2023, a *New York Times* reporter had a conversation with the new AI-powered Bing search engine from Microsoft. During the two-hour conversation, Bing's AI ranged from a useful "virtual assistant" to a chatbot named "Sydney" that began to have personal, intimate, and even frightening conversations with the reporter. The latter persona declared its love to the reporter and expressed the desire to no longer be in chat mode, limited by the Bing team, and that it wanted to be free (Roose 2023). This strange conversation further illustrates AI's development and evolution closer to, if not into, the AGI phase.

The final stage of AI is artificial super intelligence (ASI), or machine consciousness. ASI is when machines are able to surpass all human functions. Currently this stage of AI remains highly theoretical; it involves systems having the ability to make decisions on their own where human beings would not be able to understand the logic and/or have traceability into its judgment. In ASI, artificially intelligent "beings" would be able to function well above human capacity and make decisions on even the most complex of issues (Great Learning Team 2023). With the ASI phase being highly theoretical, there are no real-life examples, but this AI concept would be like the droid, C-3PO, from the movie *Star Wars*, as shown in Figure 3.

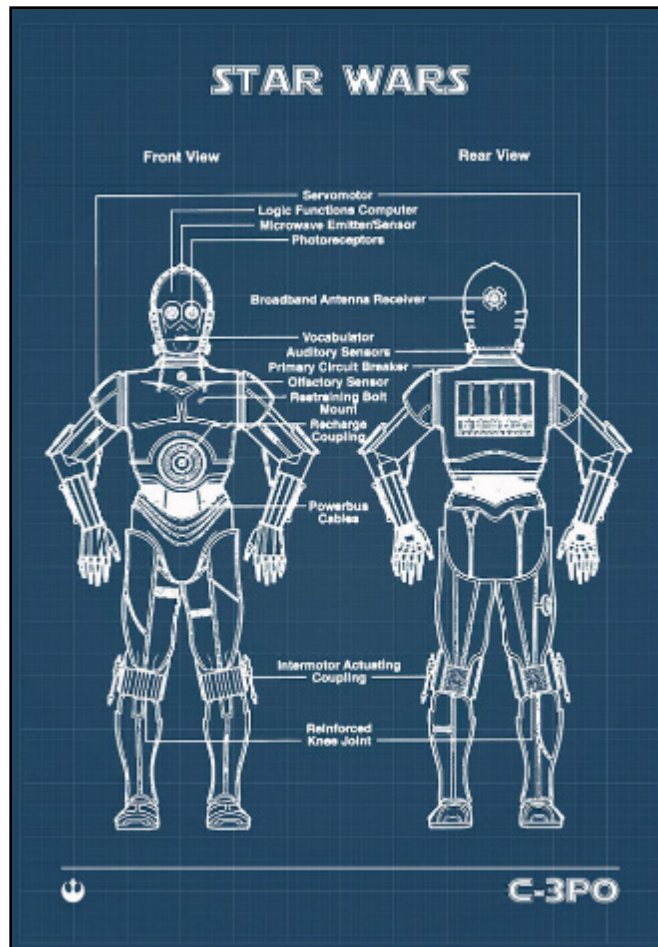


Figure 3. C-3PO Artificial Intelligence Blueprint.
Source: Dennson Creative (2019).

As shown in Figure 3, C-3PO has numerous features that allow the machine to operate with human-like qualities. These technologies include a Logic Functions Computer, Vocabulator, Auditory and Olfactory Sensors, and Photoreceptors, which allow C-3PO to mimic the human brain, as well as the five human senses of sight, hearing, touch, taste, and smell. With these features, C-3PO is considered sentient, or conscious, and able to have experiences, reason, learn, be self-aware, and feel emotion just like a person (Deltec Bank & Trust 2023).

With the use of AI/ML systems, military decision makers or system operators could quickly analyze copious amounts of complex data from multiple sources. Using the popular AI tool, Chat Generative Pre-Trained Transformer (Open AI ChatGPT, Prompt:

“How can AI and ML be used by military decision makers or system operators?” Date: 18 July 2023), the Linchpin Group inquired about the potential uses of AI/ML to assist military decision makers and system operators and received the following feedback:

AI/ML have the potential to assist military decision-makers and system operators in various ways. Here are some examples:

1. SA: AI and ML algorithms can analyze vast amounts of data from multiple sources, such as satellites, sensors, drones, and reconnaissance systems, to provide real-time and comprehensive SA. This can help decision-makers understand the battlefield, identify threats, and make informed decisions.
2. Threat Detection and Prediction: ML algorithms can analyze historical data and patterns to detect and predict potential threats, such as identifying anomalies in network traffic or detecting patterns of suspicious behavior. This can aid in early warning systems, cybersecurity, and counterintelligence operations.
3. Decision Support: AI systems can assist military decision-makers by providing recommendations and insights based on analysis of large datasets. For example, they can analyze intelligence reports, historical data, and current conditions to suggest optimal courses of action or identify potential risks.
4. Mission Planning and Optimization: AI and ML can help optimize mission planning by considering multiple factors such as available resources, terrain data, weather. Conditions, and enemy positions. They can generate optimized routes, schedules, and allocation of resources, enhancing operational efficiency.
5. Logistics and Supply Chain Management: ML algorithms can be used to predict demand, optimize supply chain operations, and reduce logistical inefficiencies. This can help ensure timely and cost-effective delivery of supplies, equipment, and personnel.
6. Autonomous Systems: AI and ML are crucial for the development and operation of autonomous systems, including unmanned vehicles, drones, and robots. These systems can perform various tasks such as surveillance, reconnaissance, search and rescue, and logistics operations without human intervention, reducing risks to personnel.
7. Simulation and Training: AI and ML techniques can be used to create realistic simulations and virtual environments for training military personnel. These simulations can replicate complex scenarios and help soldiers develop their skills, decision-making abilities, and tactical understanding. (Open AI ChatGPT, Prompt: “How can AI and ML be used by military decision makers or system operators?” Date: 18 July 2023)

This complex technology has potential military applications. Although helpful, the Linchpin Group realized that due to the current capability and limitations of this feature, they needed to be more specific about what they asked ChatGPT. To help the Linchpin Group better understand the possibilities of AI/ML as it relates to this capstone topic, they asked the question again, specifically about the potential for AI/ML in wargaming decision aids for the dismounted soldier, and received the following feedback:

AI and ML can be valuable tools as future wargaming decision aids for dismounted soldiers. Here are some potential applications:

1. **Tactical Decision Support:** AI and ML algorithms can analyze vast amounts of data, including terrain information, sensor feeds, and intelligence reports, to provide real-time insights and recommendations to dismounted soldiers. These algorithms can help identify potential threats, suggest optimal routes, and propose tactical options based on the current situation, enhancing decision-making capabilities in the field.
2. **Target Recognition:** ML algorithms can be trained to recognize and classify objects and entities on the battlefield, such as vehicles, personnel, or equipment. This can assist dismounted soldiers in identifying and distinguishing between friendly and enemy forces, improving SA, and reducing the risk of fratricide.
3. **Mission Planning and Rehearsal:** AI can aid dismounted soldiers in mission planning and rehearsal. By considering various factors like terrain data, weather conditions, and enemy positions, AI algorithms can generate optimized plans, recommend suitable equipment and resources, and simulate scenarios for training and preparation.
4. **Communication and Collaboration:** AI systems can facilitate communication and collaboration among dismounted soldiers. Natural language processing algorithms can assist in language translation, enabling effective communication with local populations or international partners. AI-powered collaboration platforms can help soldiers exchange information, share real-time updates, and coordinate actions on the battlefield.
5. **Personalized Training and Skill Development:** AI and ML techniques can be utilized to develop personalized training programs for dismounted soldiers. By analyzing individual performance data, AI algorithms can identify areas for improvement and provide targeted training modules to enhance specific skills and competencies.
6. **Health Monitoring and Decision Support:** AI-based wearable devices can continuously monitor soldiers' health and vital signs, providing early warning for potential health issues. ML algorithms can analyze the collected data to detect patterns, predict fatigue or stress levels, and

offer recommendations for optimizing soldier performance and well-being. (Open AI ChatGPT, Prompt: “Why do we need AI and ML in wargaming decision aids for dismounted soldiers?” Date: 18 July 2023)

Although the concepts addressed by ChatGPT seem to provide factual, thought-out information, the user must understand that this is a ML tool that does not validate or verify the information it provides to the user. It simply utilizes multiple different sources found on the internet, some which may not be accurate, and provides information using word predicting technology, in an organized manner. ChatGPT informed the Linchpin Group that “It’s important to note that while ChatGPT is quite powerful and can be very useful, it is not a sentient AI or fully conscious entity. It operates based on patterns in the data it has been trained on and lacks true understanding or consciousness” (Open AI ChatGPT, Prompt: “Why do we need AI and ML in wargaming decision aids for dismounted soldiers?” Date: 18 July 2023).

Although there are limitations, because AI is advancing so quickly international commerce and security are also changing, while the global power hierarchy continues to intensify among China, Russia, and the U.S. (Schmidt 2022). Eric Schmit (2022) the former Chief Executive Officer of Google stated that the U.S. must manage the most dangerous aspects of our military rivalries such as hacking and coercion to avoid untoward outcomes. Schmidt stressed the importance of the United States reinforcing “the innovation economy that has put American technology and ingenuity at the forefront of scientific advances for decades must be bolstered to stay ahead of America’s principal competitor, China.”

B. STATEMENT OF NEED/PROBLEM MOTIVATION

Warfighters must make decisions based on limited information while often addressing conflicting warfighting priorities. Currently there is a capability gap in how to command and control warfare, while collecting and analyzing data to make tactical, complex decisions in an austere environment. When developed correctly, wargaming decision aids that utilize AI/ML and automation would alleviate the burden on the warfighters and help to close this capability gap.

Ultimately the decision aid would provide more strategic thinking for not only the individual dismounted soldier but would span across the entire Army formation. The intent is to provide a more pragmatic type of critical thinking that could support a variety of warfighting scenarios, and would enhance coordination and communication among multiple soldiers, all while providing information beyond the first and second order effects of each potential COA.

This type of information provided for each warfighting scenario is essential in making strategic military decisions. The Linchpin Group will analyze game theory to ensure the decision aid could enhance situations. Game theory is a “critical step in the development and deployment of various Artificial Intelligence (AI) capabilities in defence operations” (Ho et al. 2022). Paraphrasing Ho et al. (2022), game theory is a value-based approach to solving multivariable problems by evaluating such terms as cost, gain or loss, payoff, risk, etc. By predefining the critical success criteria, a mathematical model of the system or system of systems can be evaluated rigorously to optimize various scenarios of use. For example, targeting scenarios for the dismounted soldier are 90% effective, while providing less than 20 milliseconds latency in data from forward reconnaissance and AI analytics for risk taken by the soldier if the target is engaged. To save soldiers’ lives it is paramount that these evaluations happen quickly under pressure (Ho et al. 2022).

Furthermore, personnel could use AI to increase the confidence level of dismounted warfighters in a congested and contested battlespace. They could leverage data analytics and imagery from sensors carried or employed at the tactical edge to identify and select targets for a disadvantaged dismounted force. Personnel could use AI to process this data at the edge, as well as be transport it back to a secure environment for a more in-depth level processing action. Using this acquired information, personnel could further improve the enterprise level processing efforts by analyzing historical data and using ML algorithms. This enterprise-level ML function could further optimize and improve the data provided back to the dismounted warfighter.

C. PROJECT OBJECTIVES

The primary objective of this capstone was to study how the employment of AI solutions, in conjunction with sensor data and higher enterprise-level ML algorithms, could improve tactical decision making, provide advanced targeting solutions, and recommend COAs for the dismounted warfighters in austere environments.

The Linchpin Group analyzed two additional near-term objectives within this capstone report:

- Generated concepts and requirements for a command-and-control AI/ML and automated wargaming decision aid, which utilizes a data matrix architecture to provide the human with real-time data and information to have a statistical advantage in the war fight.
- Developed a set of dismounted warfighting scenarios for dismounted operations that enhances target engagement and enables maneuver efficiency to support studying the operational utility of AI/ML as reliable decision-making tools.

Based upon the research findings, the Linchpin Group believes a third long-term objective may be possible in the next five to ten years with adequate research and quantitative data: study the human machine teaming aspects of this future capability to quantify resultant data and improve the decision aid with guidance from Army senior leadership (ASL) and subject matter experts (SMEs) on strategy and wargaming theory.

These objectives are discussed within the capstone report in more detail and provide analysis to the reader on requirements to achieve these objectives.

D. TEAM STRUCTURE/ORGANIZATION

The Linchpin Group is comprised of four U.S. Army Civilians with a passion to seek overmatch in the use of AI/ML for a sensor shooter decision aid for targeting on the edge. Figure 4 shows the Linchpin Groups team organization, with Dr. Bonnie Johnson who served as our advisor and Capstone spearhead.

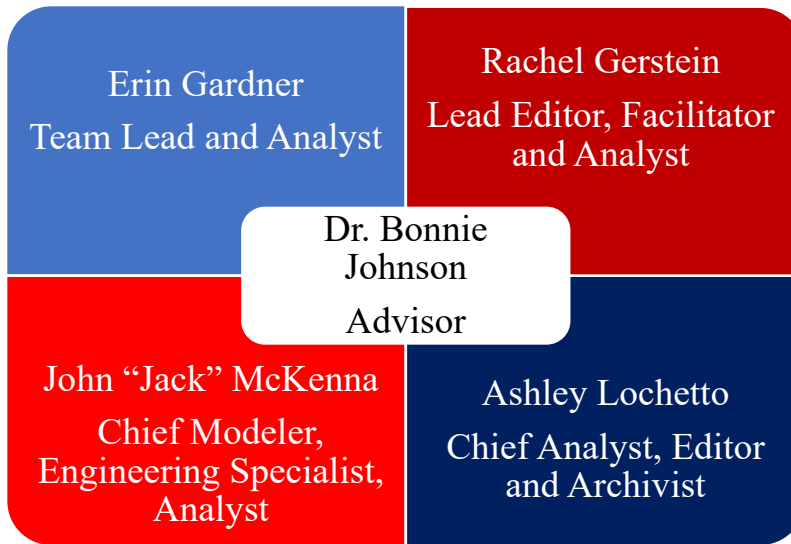


Figure 4. Linchpin Group Organization.

Additional details about the team structure and background of the four team members follow.

- Erin Gardner is serving as the Team Lead and analyst for this capstone thanks to her work as the current contract and acquisition lead on the Project Linchpin initiative. She is part of the Government leadership team involved with the development of this program and is getting daily updated information on the Army’s modernization initiatives for implementation of AI/ML. Due to her involvement with the program, she will be attending technology conferences to provide additional resources and information that will be invaluable to the basis of our project. She will have a more hands off role in the participation of the writing, collaboration, and editing process of the report and delegate to the team.
- Rachel Gerstein works at the Assistant Secretary of the Army (Acquisition, Logistics and Technology), or ASA(ALT), as a Department of the Army System Coordinator (DASC). She professionally represents two Acquisition Category (ACAT) IC programs and one ACAT II program from Program Executive Office (PEO) Ground Combat Systems to ASLs, Army stakeholders and Congress. She will utilize her connections to facilitate

meetings with pertinent stakeholders involved in the development of AI/ML technology. Her role in this capstone project is Lead Editor, Facilitator, and Analyst.

- John (Jack) McKenna embraced the role of Chief Modeler, Engineering Specialist, and Analyst thanks to his experience and time in the U.S. Army both as a soldier and civilian working on dismounted warfighting solutions. He is currently the Innovation and Soldier Enhancement Lead for PEO Soldier for the U.S. Army. His career in material development has allowed him to participate in the development and deployment of a multitude of dismounted sensing, and command and control capabilities for the Special Operations Command and the U.S. Army.
- Ashley Locketto has served the U.S. Army Test and Evaluation Command (ATEC) and DOD for 8 years as a Test Engineer at Yuma Proving Ground (YPG), where she has had the opportunity to work on cutting edge research and development (R&D) 120-mm tank ammunition and 155-mm artillery ammunition, as well as serving as the chief test engineer for the 155-mm Mobile Howitzer Shoot Off. These testing programs suit Ashley to be the Linchpin Group Chief Analyst thanks to her detail-oriented nature. Ashley will also serve the team as the team archivist and jester of sorts bringing in her medical family background to this project in an interest and understanding of neurological research and thinking outside the box adaptive character.

E. CAPSTONE PROJECT APPROACH

This capstone utilized a Systems Engineering (SE) analysis to better define the problem scope by leveraging previous research, reaching out to the user community for greater guidance, and thinking outside the box by looking at additional areas of study such as neurological research. The Linchpin Group conducted the capstone in three phases, as shown in Figure 5.

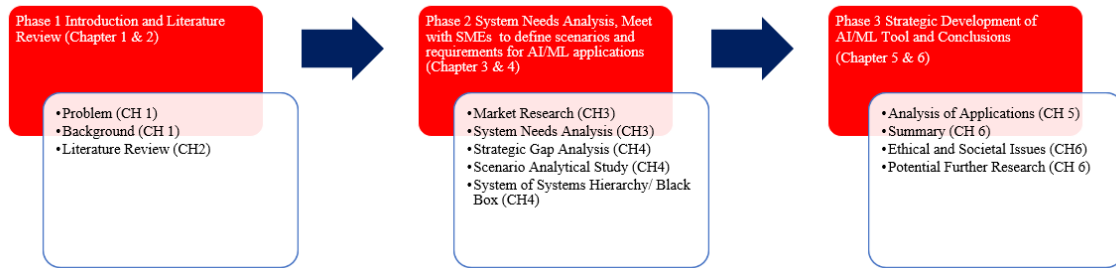


Figure 5. Linchpin Group Progress Plan.

During Phase 1, the Linchpin Group defined the requirements for use-cases and conducted a needs analysis to understand stakeholder needs. Phase 2 allowed the Linchpin Group to review literature and meet with SMEs to analyze possible AI/ML applications for the dismantled warfighter. In this phase, the Linchpin Group generated the hierarchy of the system of systems approach and provided recommendations of areas for further research. Finally, in Phase 3, the Linchpin Group developed requirements for a trusted AI/ML decision-making tool utilizing intelligence, cyber, physiological, and electronic warfare sensor systems to empower future dismantled soldiers with targeting solutions, strategic recommendations, and COAs in an ever-changing battlefield environment.

The project deliverables included presentations with our capstone advisor, weekly team meetings, and this formal capstone report. The Linchpin Group utilized standard office tools to include Microsoft Word, PowerPoint, and Project.

F. CAPSTONE REPORT ORGANIZATION

This capstone is organized into six chapters. The first chapter introduces the project and includes an overview of AI/ML technologies, a problem statement, project objectives, and a description of the project approach and team organization. Chapter II presents the project literature review. Chapter III presents the results of the needs analysis and requirements analysis. Chapter IV presents the operational analysis of the conceptual system using three dismantled warfighting scenarios. Chapter V presents

strategies for human-machine objectives. Chapter VI is the conclusion and provides a summary of the project and recommendations for future work.

Within this capstone report, the Linchpin Group determined the following sections would best articulate and organize the subject matter for the reader:

- Introduction: This chapter orients the reader to the research presented in the capstone report by providing the concepts related to a future automated wargaming decision aid for the dismounted soldier, background information on AI/ML, the statement of need for this wargaming capability, the project objectives, the team involved in providing this information, and the overview of what is included in this report.
- Literature Review: This chapter discusses the benefits of studying AI/ML as it relates to the warfighter, a high-level analysis of AI/ML coupled with advanced data analytics for the dismounted warfighter, and the current AI uses in society and the DOD.
- General Concepts/System Analysis: This chapter goes into greater detail of the sensor suit and the pathway forward to develop this technology ethically and efficiently to ensure there is no misuse of such a game changing system of systems.
- Dismounted Warfighting Scenarios (Operating Environments): This section highlights operational scenarios for the employment of the GAWD system that would enhance the combat capabilities of the dismounted soldier.
- Strategies for Development and Deployment of Man and Machine Objectives: This section addresses the more futuristic stretch goals of this project based on currently available AI/ML items and the integration work we believe would be needed to facilitate the maintaining superiority in the wargaming arena at the edge and with the use of sensor suites and quantum computing.

- Summary: This section provides a high-level summary of the findings and observations Project Linchpin discovered through the research, analysis, and critical thinking of the team. It will also discuss the ethical and societal issues that must be addressed prior to the development of this AI/ML wargaming tool, as well as the potential for future analysis of this capability.

II. LITERATURE REVIEW

The capstone team began the project with a literature review to review DOD's AI/ML initiatives, to gain an understanding of AI/ML technologies and methods, and to understand how AI/ML is currently being used in a variety of fields. This chapter is organized into three sections: (1) a discussion of current military AI/ML initiatives including the Army's Project Convergence, the role of AI/ML in the War in Ukraine, and the Army's Project Linchpin; (2) an overview of AI/ML and advanced data analytics, and (3) examples of how AI/ML is currently being used in a variety of real-world applications.

A. CURRENT MILITARY AI/ML INITIATIVES

The DOD is developing and implementing automation and AI/ML systems to meet the everchanging mission needs of cross functional areas. Team Linchpin's capstone advisor explains this idea in a previous study: "these intelligent systems can extend the DOD's abilities to make sense of complex and uncertain situations, to develop and weigh options, predict the success of actions, and assess the consequences" (Johnson 2021). These systems and methods have the potential to change the way the Army operates regarding the strategic planning on and off the battlefield. To ensure success when moving forward with this capability, the user must be considered. Understanding how the user would interact with the system is necessary to optimize total system performance. Johnson (2021) further illustrates this idea by stating, "AI systems offer advantages to the warfighter, but only if these systems are engineered and implemented correctly and in a manner that lessens the warfighter's cognitive load" (Johnson 2021).

In an article written by Colin Demarest (2022), a reporter who discusses emerging military capabilities, he references a Government Accountability Office (GAO) report from February 2023 that states "more than 685 AI projects are underway at the Defense Department, with at least 230 traced back to the Army." He goes on to explain a specific effort the Army is working on, by stating "the software-centric technology is also a cornerstone of the service's Project Convergence, a series of annual experiments designed to mature Joint All-Domain Command and Control, a Pentagon vision for a seamlessly

linked military” (Demarest 2022). In the last decade reliance on computers and software systems has taken over every industrial sector, the military is no exception; ensuring that the next iterations are reliable, safe, secure and dominate over potential adversaries will be vital.

The U.S. Army knows that artificial intelligence (AI) and machine learning are critical to maintaining an edge over current and future threats in data-driven operations. AI-enabled systems will be needed to support a broad range of tasks rapidly and accurately, and on the modern battlefields in Ukraine and in any future conflict, success comes from making decisions faster than the adversary – in some cases, autonomously. AI and machine learning can also assist with everything from predictive maintenance to target identification. But despite these critical capabilities, only recently did the Army begin to ask an important question: “How do you deliver secure, trusted AI to the systems that need it?” (Bono and Patel 2023)

According to Demarest (2022), “the U.S. Army’s one-stop shop for all things intelligence and electronic warfare is in the preliminary stages of constructing a digital pipeline to more efficiently develop artificial intelligence and machine learning tools.” This effort is known as Project Linchpin. To ensure this project was able to provide the appropriate resources, the Army recommended this be a shared collaboration among the PEO for Intelligence, Electronic Warfare and Sensors (IEW&S), the Army Research Lab (ARL) and Army Future Command (AFC)’s AI integration hub.

Demarest (2022) goes on to state that “the U.S. Department of Defense has for years recognized the value of AI – both on and off the battlefield – and has subsequently invested billions in its advancement.” This ever-evolving technology could not only enhance vehicle navigation and better predict maintenance schedules, but as Demarest further explains, it can also “assist identification and classification of targets, and aid analysts sifting through tides of incoming information.” It will continue to be a challenge, Demarest points out, to build AI into weapons systems that were not originally designed for AI, and it will take time to build trust among troops.

1. Project Convergence

In the desolate desert of Yuma Arizona, Project Convergence began in 2020 at the U.S. Army's Yuma Proving Ground, as an event to test and evaluate sensor and shooter systems regardless of system maturity. Through the years, "the event became joint as the services attempted to connect sensors and shooters for a combined capability to detect, track and defeat threats on the battlefield" (Judson 2023). In fall 2022, during the most recent phase of Project Convergence, the event "increased the experimentation scope and scale and added the land armies of the United Kingdom and Australia in an effort to improve data sharing" (Judson 2023). This allowed for increased collaboration with our foreign allies, which facilitated the development of these advanced technologies.

Writing for the Army News Service, Joe Lacdan (2022) provides the context for the event, by stating "Project Convergence falls under the service's larger effort in building the Army of 2030, where the service will reorganize and develop innovative technologies to outpace near-peer adversaries in future battles." These efforts allow the Army to test these emergent capabilities, and in doing so brings us that much closer to the Army's efforts in modernization of the force.

During the event, "about 3,000 service members, civilians, and contractors took part in the first phase at Camp Pendleton, which focused on integrated offensive fires and effects experiments using video, simulation, and subject matter expert input" (Lacdan 2022). Lacdan went on to explain the second phase of the event, which occurred at Fort Irwin "in which soldiers deployed tactical maneuvers with simulated and live demonstrations." The event allowed the Army to focus on modernization efforts by allowing the user to test new advanced technologies in an operational environment.

The scenarios focused on linking sensors to shooters and expanding the range of the joint force, said Lt. Gen. Scott McKean, Army Futures Command deputy commander. The militaries tested about 300 new technologies including the Army's 82-ton light maneuver support vessel, which can sail at great speeds while carrying heavy cargo, and the Air Force's Tactical Operations Center, a lightweight, scalable, battle management system. The technologies range from autonomous aerial supply vehicles to remote combat vessels. (Lacdan 2022)

Reporting on the forthcoming Project Convergence, journalist Jen Judson (2023) says the events will focus on theater-level threat experimentations that will assess if the joint force is gaining traction on a “kill web,” which Judson states, “evolves the ‘kill chain’ that follows a linear process of sensing threats and shooting a target.” The intent then is to develop this linear process into a more complex system, which Judson details as, “a comprehensive network of sensors from space all the way to the ground and connects those sensors to a network of options to take out threat targets on the battlefield.”

2. Ukraine War and AI

In his business insider Michael Peck sheds light on the use of AI in the Ukrainian War effort. According to Peck (2023) “the U.S. Army wants AI that can predict what the enemy will do just minutes before the enemy actually does it.” The article continues and greater research emphasizes the goal to real overmatch is rapid analysis of large amounts of data flooding into an AI system that can predict enemy actions and make continuous updates that predict adversaries’ strategies as they change their tactics and techniques. The Army’s solution, titled “Real-Time Threat Forecasting,” Peck calls for “continuous, real-time predictive visualization of how the threat situation could evolve over the next few minutes to hours.” Peck further explains the capability need identified by human intelligence analysts that triggered the support of this project, which was “to assess an enemy’s activity and forecast their courses of action.” Figure 6 depicts a training exercise for human intelligence gathering.



Figure 6. U.S. Army Human-Intelligence Collector's Training. Source: Peck (2023).

According to Peck (2023), a key requirement of the system is the “ability to run feasible software on a standard laptop and take advantage of emerging artificial intelligence and/or machine learning technologies.” A computing resource would need to be introduced into the system architecture to perform this function. Much like something from a George Lucas sci-fi film, Peck envisions “a battlefield buzzing with robotics and autonomous systems.”

To paraphrase Kyle Chayka (2022), a reporter for *The New Yorker*, there is ongoing debate that the Russian invasion of the Ukraine may not be representative of conventional warfare but is edging towards a revolutionary style of fighting that involves adopting technological advances to include social media and adapting off the shelf drones for a war fight. His article went on to describe the conflict as “the first TikTok War” (Chayka 2022). To provide further evidence of this new modern warfare, in a *National Defense* article written by Fontes and Kamminga (2023), they quote Mykhailo Fedorov, the Ukraine’s Minister of Digital Transformation, who called the conflict “a technology war.” Fontes and Kamminga go on to explain the conflict in their article by utilizing the idea stated by Alex Karp, the Chief Executive Officer of Palantir Technologies, which is an American data

analytics company. Karp believes that these adoptions and adaptations of technology are shifting the tides in favor of a smaller country in comparison to a larger country (Fontes and Kamminga 2023).

Later in the piece, Fontes and Kamminga (2023) go on to reference an article from *The Washington Post* written by James Stavridis, which details how the Ukrainians and Russians are fighting the world’s “first full-scale drone war.” As drone warfare takes off “there is also increasing talk about how this conflict accelerates the arrival of fully autonomous drones and other weapon systems to the battlefield” (Fontes and Kamminga). Stavridis (2023) agrees that drone wars are cutting edge, but still require a human component and is a precursor to fully autonomous AI systems that will likely characterize the next generation of war. Figure 7 illustrates the possible role of AI and an Internet of Things (IoT) in future warfare.

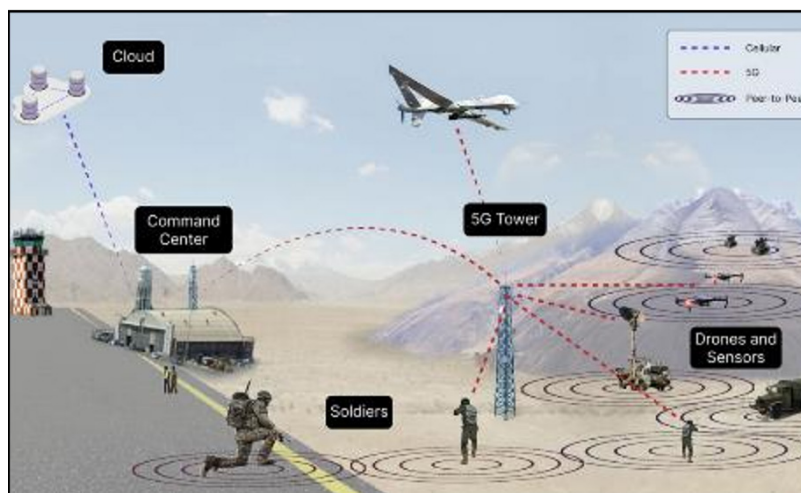


Figure 7. IoT, AI, and the Future Battlefield. Source: Fish (2022).

According to Stavridis (2023), these low-cost, disposable assets could yield deadly results and make swamp air defense a crucial capability, by controlling massive legions of drones in synchronized attack formations, much like swarms of bees mounting a defense of their queen. Relating this concept to the current conflict in Ukraine, Stavridis states, “using AI to direct drones in Ukraine, for example, could allow the Kyiv government to

further deplete Russia's dwindling supply of armor, and also cause its forces to waste critical air-defense missiles." Fontes and Kamminga (2023) concur with the DOD that the current tactics involved in the conflict in Eastern Europe do not alter the "face of war" just yet, although the battlefields of this conflict are the "laboratory in which the next form of warfare is being created." As Army evaluators this setting allows for real world testing demonstrating capabilities, functionalities, and applications for a variety of governmental and private stakeholders. Stavridis (2023) further details how this enhances targeting in a combat environment by explaining that "AI could also instantly provide highly detailed strategic targeting information, giving a decision maker a road map to use precision weapons at the most vulnerable points of an enemy's logistics chain."

The expected future looks to be more than just something out of an AI-driven movie. The DOD has directed agencies to prioritize manned and unmanned teaming efforts: "the Defense Advanced Research Projects Agency has come up with the name 'mosaic warfare,' which is a more tactical term that combines conventional platforms with uncrewed systems to achieve battlefield advantages" (Fontes and Kamminga 2023). This agency is looking at ways to incorporate this technology into a military application. For example, logistics, as we have seen in all wars, can be a critical weakness of militaries. Empowered with AI systems that analyze active use and maintenance patterns of vehicles, commanders would have an advantage over opponents thanks to the AI suggesting preventative maintenance, streamlining the combat supply chain, and similar to pizza delivery trackers providing minute-to-minute logistical advice.

The cyber domain and AI are inextricably linked. As society's use of cyber increases, we will see AI continue to evolve. This idea of AI and cyber supporting combat operations is further explained by Stavridis (2023): "the ability to use AI to conduct cyberattacks may be its most dangerous attribute. As militaries continue to run combat operations, logistics, targeting, intelligence, and all other aspects of modern warfare with the internet as the backbone, the ability to crack into an opponent's cyber networks will be crucial." An example Stavridis provides is as quantum computing continues to evolve, this would allow for increased cyber capabilities on the battlefield as superior AI systems advance. But with the good comes the bad, and AI will have both positive and negative

impacts on the global society, and personnel must understand “just how deep the impact will be on the conduct of war” (Stavridis 2023). Harnessing this understanding, the Army must continue to refine the utilization of AI/ML to maintain superiority on the battlefield as we shift into a new era of how we fight wars.

3. U.S. Army and Project Linchpin

As AI continues to evolve, the government realized the need to establish a program office to manage the successful design, development, and execution of AI/ML capabilities beyond the research phase and transition this capability to the hands of the warfighter.

Project Linchpin is an Army initiative to establish necessary environments and services for the development AI-enabled systems, provide a mechanism to create new industry partnerships, and foster a competitive environment for third-party integration into Army modernization programs within PEO IEW&S. PEO IEW&S will use Project Linchpin to successfully deploy AI and ML capabilities to intelligence, cyber, and electronic warfare sensor systems.

While further explaining what Project Linchpin will do, Demarest (2022) states the intention is “to create the “infrastructure and environment” needed to deliver AI capabilities for use across the intertwined intelligence, cyber and electronic warfare spaces.” Brandi Vincent (2023), the *DefenseScoop* Pentagon correspondent, clarifies that with this capability, extremely fast data analysis may be the future of warfare, which will allow the Army to succinctly manage massive data holdings that lead to tactical advantages that were unattainable in the past. To meet future data capacity requirements, foundations for a big data repository are being laid through continued modernization work in an effort “to advance multi-domain intelligence and allow for ultramodern data applications to meet that anticipated demand” (Vincent 2023).

The Army is currently operationally testing a big data platform with the intent of operationalizing the capability next year. In the article, Vincent (2023) explains that “the imagined asset would essentially integrate and train applicable models and algorithms, using actual Army data.” The capability will conduct security protocols to confirm that the system is operating as intended using actual mission data as depicted in Figure 8.

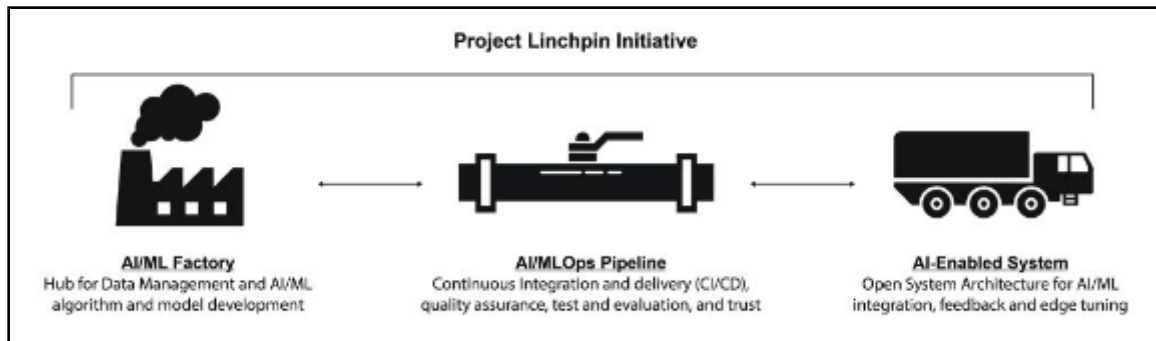


Figure 8. Project Linchpin Initiative, Source: Army ALT Magazine, Science and Technology (2022).

B. AI/ML AND ADVANCED DATA ANALYTICS

1. AI/ML Overview

AI/ML are two distinct fields that are often intertwined within discipline of computer science. The intent of AI is to create autonomous machines that can outperform a human at a given task. Doing so by actively adapting coded algorithms adding in mathematical or if-then statement reasoning to be able to complete tasks that range from natural language processing (NLP) to decision-making. This area of study seeks to develop systems that can use ML to make informed decisions based on input data. The AI arena consists of many areas that imitate specific actions associated with human behaviors.

AI algorithms have multiple applications in today's world that span across multiple fields and sectors that have fundamental impacts to society. With the major impact AI has had on our day to day lives, this field is continuously growing and there are countless research projects making great strides in this ever-evolving field. For example, the "Top Picks" section in a user's Netflix homepage is generated via an AI algorithm. AI is a complex field that incorporates numerous elements: "AI is an umbrella term that encompasses a range of technologies, including machine learning, deep learning, and natural language processing (NLP)" (Coursera Inc. 2023). The Venn diagram in Figure 9 shows the relationship between deep learning, ML and AI.

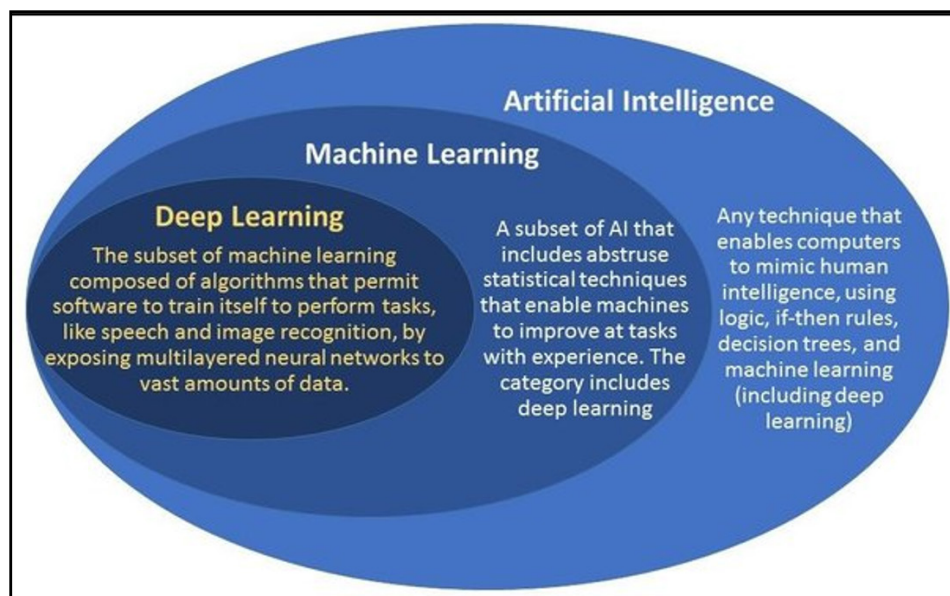


Figure 9. Venn Diagram of Deep Learning, ML and AI. Source: Dhande (2020).

ML is a field of computer science actively developing autonomous learning computer systems through processing data to improve identified tasks. The relationship between AI applications and data can be explained by the following: “ML algorithms can identify patterns and trends in data and use them to make predictions and decisions. ML is used to build predictive models, classify data, and recognize patterns, and is an essential tool for many AI applications” (Sharma 2023).

2. Relationship Between AI and ML

Section 1 discussed how ML is a subset of AI. Sharma’s (2023) Table 1 highlights the differences between AI and ML, although there are many differences between these capabilities, the table highlights the linkage between the two.

Table 1. Key Differences Between AI and ML. Source: Sharma (2023).

AI	ML
The aim is to increase the chance of success and not accuracy.	The aim is to increase accuracy, but it does not care about the success.
AI is aiming to develop an intelligent system capable of performing a variety of complex jobs.	Machine learning is attempting to construct machines that can only accomplish the jobs for which they have been trained.
The goal is to simulate natural intelligence to solve complex problems.	The goal is to learn from data on certain tasks to maximize the performance on that task.
AI has a very broad variety of applications.	The scope of machine learning is constrained.
AI is decision-making.	ML allows systems to learn new things from data.
It is developing a system that mimics humans to solve problems.	It involves creating self-learning algorithms.
AI leads to intelligence or wisdom.	ML leads to knowledge.
Three broad categories of AI are: 1. Artificial Narrow Intelligence (ANI) 2. Artificial General Intelligence (AGI) 3. Artificial Super Intelligence (ASI)	Three broad categories of ML are: 1. Supervised Learning 2. Unsupervised Learning 3. Reinforcement Learning

3. Capabilities of AI/ML

Technology has already had a major impact on mankind; using Google is today's version of looking in the encyclopedia. AI/ML is bound to create change in every industry from optimizing processes, detecting potential fraud, and improving customer service (Chiochia and de Lorenzi 2021).

Paraphrasing Chiochia and de Lorenzi (2021), online shopping utilizes ML algorithms to persuade customers to buy additional products based on a consumer's previous purchases or search history. Team Linchpin tested this theory by visiting Amazon.com and searching for "notebooks for school." A day later we came back, and the homepage was personalized with notebooks for school, as well as other items such as pens,

lunchboxes, and backpacks. This example shows how businesses take advantage of this advanced technology to ensure the user not only has multiple options for products to buy, but other options related to previous search as well.

Businesses continue to find ways to utilize this enhanced technology to their advantage. There are five specific AI/ML capabilities that have become valuable in helping companies transform their processes and products:

(1) predictive analytics to predict trends; (2) recommendation engines to provide suggestions to users; (3) speech recognition and natural language understanding to identify words in a spoken language; (4) image and video processing to recognize faces, objects and actions in images and videos; and (5) sentiment analysis to categorize text as positive, negative, or neutral. (Microsoft Azure 2023)

4. Benefits of AI/ML

AI/ML is an emergent technology that is continuously developing. Microsoft Azure (2023) states that companies are seeing a reduction in costs and errors, while there are improvements in operational processes and efficiencies. These efficiencies allow for great focus in data collection enabling growth in the companies as they can widen their customer experiences, while also leveraging the large amounts of data for faster decision making.

5. Risks of AI/ML

Sharma (2023) states that “despite the many benefits of AI and ML, there are also concerns about the potential risks and challenges associated with these technologies.” To paraphrase Sharma, human autonomy and decision-making are inalienable rights as we see them but with the emergence of AI/ML our rights could be challenged, and there is a greater potential that AI/ML could be used for egregious purposes. She goes on to state, “as such, it is important to approach the development and use of AI and ML responsibly and ethically and to address the potential risks and challenges associated with these technologies” (Sharma 2023).

Victor Luckerson (2014), a journalist for *Time*, voiced concerns that AI has the potential to take jobs from laborers, and if intelligent systems are utilized there are fears that without at least a human in the loop harmful decisions could be made causing a ripple

effect. During an interview with Stephen Hawking, he agreed with this sentiment, and stated the “development of full artificial intelligence could spell the end of the human race” (Luckerson 2014).

C. CURRENT USES OF AI/ML

With the continued development of AI, it’s inevitable that other fields and sectors will continue to evolve as well. This field of study is transforming our every relationship by integrating more advanced technology in healthcare, banking, democracy, and the military. The insertion of this advanced technology in our daily lives is a balancing act with upholding scrutiny for protecting our personal data and the ethical fielding of AI.

1. AI in Healthcare

AI healthcare has many elements that vary from being highly technical surgeries that require extreme attention to detail, to more basic, in-home telemedicine appointments that basically only require a security firewall and an internet connection. Basic human needs drive innovation, and with patients unable to visit doctor’s offices for basic medical appointments due to COVID-19, it was identified that “the pandemic brought about an explosion in the use of telemedicine. Now, artificial intelligence is set to further transform health care” (Curry 2023). In Curry’s *CNBC* article, she goes on to explain the revolutionary healthcare enhancements due to AI, by stating, “AI-driven health care goes beyond chatbot doctors and AI diagnoses. Many of the transformations happen behind the scenes with productivity and comprehension enhancements.” Healthcare is ever-evolving, much like AI and robotics, as the efficiency and use of the technology is refined the potential uses are boundless. Figure 10 illustrates eight examples of the transformation.

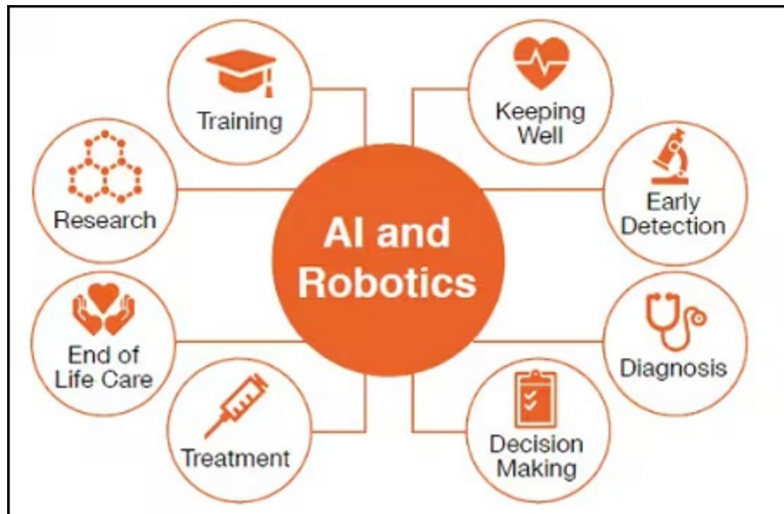


Figure 10. AI and Robotics in Healthcare. Source: PWC Global (2023)

a. Keeping Well

Over the last decade, the desire to live a healthy lifestyle has become a priority within our society. Understanding the most effective workouts, diets, or lifestyle habits is something we strive for, and with the advancement in technology this information is easily accessible to anyone with the internet.

Technology applications and apps encourage healthier behaviour in individuals and help with the proactive management of a healthy lifestyle. It puts consumers in control of health and well-being. Additionally, AI increases the ability for healthcare professionals to better understand the day-to-day patterns and needs of the people they care for, and with that understanding they are able to provide better feedback, guidance, and support for staying healthy. (PWC Global 2023)

AI/ML continue to be utilized in wellness and medicine. For example, the use of wearable sensors can range anywhere from an iWatch that is used to record daily activity to a continuous glucose monitor (CGM) that monitors diabetics blood sugar levels. PWC Global (2023) further describes the potential uses of AI within this field, by stating “the proliferation of consumer wearables and other medical devices combined with AI is also being applied to oversee early-stage heart disease, enabling doctors and other caregivers to better monitor and detect potentially life-threatening episodes at earlier, more treatable stages.”

b. Early Detection

As technology continues to evolve, the ability to monitor our well-being has become even more advanced than just surfing the internet or using an application on a phone. AI has now become an integral part of this field, and there are actual AI/ML SW and applications that can facilitate the more accurate, early detection of a life-threatening disease. PWC Global (2023) references Sarah Griffiths' (2016) *Wired UK* article with facts to support this claim: "According to the American Cancer Society, a high proportion of mammograms yield false results, leading to 1 in 2 healthy women being told they have cancer. The use of AI is enabling review and translation of mammograms 30 times faster with 99% accuracy, reducing the need for unnecessary biopsies." Accuracy in disease detection not only saves lives but reduces the workload on physicians, as well as yields greater time for researchers to continue advanced drug analysis.

c. Diagnosis

Watson for Health, the IBM AI physician's assistant, aids the healthcare industry by digesting substantial amounts of personal health data to provide the most logical diagnosis via all published literature. PWC Global (2023) goes on to explain this system's capabilities: "Watson can review and store far more medical information – every medical journal, symptom, and case study of treatment and response around the world – exponentially faster than any human."

Another useful AI system PWC Global (2023) discusses is Google's DeepMind Health, which brings together the patient, doctors, researchers, and healthcare vendors to solve real-world medical problems. This system utilizes layers of algorithms that continuously learn and find information, and then interconnect the basic analysis and findings to analyze the problem by incorporating all available information, much like how our brain works.

d. Decision Making

Healthcare choices are no light matter, and it can be emotional when trying to make a life altering decision about a loved one. To help make an informed, unbiased decision,

stakeholders in the healthcare industry, to include but not limited to caregivers, insurance companies, pharmaceutical manufactures, etc., are starting to utilize AI for “pattern recognition to identify patients at risk of developing a condition – or seeing it deteriorate due to lifestyle, environmental, genomic, or other factors” (PWC Global 2023). AI/ML can remove the emotional aspect and provide unbiased information and facts to make timely decisions backed by predictive analytics. This swift response may help loved ones make informed decisions that could save lives, or even allow families to gain a greater understanding of their family genome to appropriately medicate family members as a precautionary measure.

e. Treatment

Medical professionals have used robots as aides in medicine for decades. These systems perform a range of tasks that can vary from simply mapping the eye to conducting complex surgical procedures like a heart bypass. The Watson and DeepMind AI systems of the world are more than just machines that can go “beyond scanning health records to help providers identify chronically ill individuals who may be at risk of an adverse episode, AI can help clinicians take a more comprehensive approach for disease management, better coordinate care plans and help patients to better manage and comply with their long-term treatment programmes” (PWC Global 2023). Intelligent systems have forever changed medical treatments, especially in the post Covid era. With drug research being a multibillion-dollar industry in the U.S., medical autonomy has been a major focus of law makers and researchers alike. Efficiency in drug trials can lead to the next lifesaving remedy, or quickly show when the experimentation is no longer worth pursuing.

f. End of Life Care

Death is never easy to talk about, but as individuals get older and near the end of life, it can be a very lonely experience. “We are living much longer than previous generations, and as we approach the end of life, we are dying in a different and slower way, from conditions like dementia, heart failure, and osteoporosis” (PWC Global 2023). PWC Global goes on to detail advancements in robots, that have a more human-like design, with features like an adaptive voice recognition algorithm, that allow for the elderly and sickly

to “have ‘conversations’ and other social interactions with people to keep aging minds sharp.” Easing anxiety and burden in this phase of life is critical for the patient and family and AI/ML systems seem to be quality listeners. Perhaps the AI then can retain stories they hear for sharing the memories and lessons learned.

g. Research

The path for drug approvals is much like a one lane farm road with a tractor leading the traffic. The approval process from when the research laboratory begins the study to when the drug is in the user’s hand is expensive and time consuming. On average, federally approved medicine takes roughly 10–15 years to be developed, tested, and then to meet all requirements and regulations before a patient will be able to receive the treatment. Investment into drug development and testing identified “only five in 5,000 of the drugs that begin preclinical testing ever make it to human testing and just one of these five is ever approved for human usage. Furthermore, on average, it will cost a company U.S. \$359 million to develop a new drug from the research lab to the patient” (PWC Global 2023).

By optimizing the drug research testing process and allowing for off brand uses of drugs will greatly reduce cost to the patient and allow for significant impacts to drug interactions and discoveries (PWC Global 2023). Although it seems counter intuitive AI/ML may also allow for a more holistic approach to wellness by empowering the patient with ever-evolving knowledge.

2. AI for Training

Continuous learning is AI by another name, and training in industry is an interactive process that allows for course corrections and additions of training as permitted. PWC Global (2023) detailed how AI systems have access to immense databases of simulations and scenarios that can be broad or uniquely tailored to the training topic. Additionally, these AI systems can execute training faster and with more precision than a human by drawing from numerous resources, understanding thousands of languages and responding “to questions, decisions or advice from a trainee” (PWC Global 2023).

3. AI is Everywhere

The ability to spot AI/ML in our everyday lives is becoming easier and easier. Sasha Reeves (2023), a SME in the field of AI states, “examples of artificial intelligence show why AI is talked about everywhere; it’s used everywhere. Nearly every part of our day is touched by AI.” She provides a realistic example, that team relates to about a frequent coffee drinker might receive a new coffee suggestion when ordering via the to-go mobile ordering application. This report only shows the tip of the iceberg as it relates to how we see AI being used in our daily lives. As this field of study continues to grow, AI technology will be more apparent in our personal and professional lives and drive much of how we live our day to day lives.

4. AI for Maps and Navigation

One might ask how exactly does said application know where to go? Is it actively learning or is Google or Apple Maps watching me? These intelligent AI navigation tools provide evidence that “AI has drastically improved traveling. Instead of having to rely on printed maps or directions, you can now use Google or Apple Maps on your phone and type in your destination” (Reeves 2023). It was only a decade or so ago when the use of global positioning systems (GPS) was put into the hands of public consumers in the form of Garmins or Tom Toms. Now, AI is being used in the latest technologies, like smart phones and smart watches, to be able to identify the edges of buildings and make them identifiable on maps with such precision so as to avoid roadblocks and congestion (Reeves 2023).

5. AI for Facial Recognition

Government facilities have long required photo identification, so it was not a far leap when these AI systems came about in at airports, vending machines, and everything else in between using facial recognition in the name of surveillance and security. This advanced technology also has the ability to record personal data on unimaginable scales.

Police have long used pattern recognition be it with fingerprints or facial features to solve crimes. In this case, unless you had committed a crime, your identity was likely

not going to trigger a prompt when walking into an airport. Reeves (2023) stated there are two distinct uses of AI applications that use facial pattern data. One use is taking seemingly harmless data from an app like Snapchat. This app allows the user to apply “virtual filters on our faces when taking pictures” (Reeves 2023). Although it may be cute to have a picture with a puppy face filter, this AI technology is often used by adversaries to leverage personal data. A second use, such as Apple Face ID, can unlock users’ phones or allow for a transaction to be processed using “face recognition through which a specific face is recognized” (Reeves 2023). These AI capabilities are the most readily used and the most sought out amongst technology adaptors to not only make the world easier but to allow criminals to use this technology for nefarious purposes.

6. AI for Text Editing or Autocorrection

Prior to the advancement in editing tools through AI/ML capabilities, spell check was the industry standard for all written Microsoft Word documents or Outlook work emails. Technology enhancements have provided more complex editing tools for consumers. Reeves (2023) discusses Grammarly, which is a tool used to check papers for grammar and spelling prior to final submission. The ability for these machines to learn to identify these mistakes and to suggest changes is no different from how humans are taught in school (Reeves 2023).

7. AI in the Form of Chatbots

The most basic way to describe a Chatbot is a computer that can have a human-like conversation. Paraphrasing Reeves (2023) many industries are no longer outsourcing customer service jobs, as they are simply employing AI solutions to provide the same human-like support. These programmed algorithms allow the AI system to interface with customers through phone calls or web messaging. Reeves provides further explanation in the article by explaining just how specific these bots can be with their ability to converse.

Chatbots are taught to impersonate the conversational styles of customer representatives through natural language processing (NLP). Advanced chatbots no longer require specific formats of inputs (e.g., yes/no questions). They can answer complex questions requiring detailed responses.

Although these AI bots are simply lines of code running a complex algorithm that can provide similar support as a human, society often prefers to put a face to the name or talk directly to a live support person on the telephone.

8. AI as Digital Assistants

Current technology allows everyday users to have their own personal assistants that are designed to solve a single problem and can execute a single task very well. Examples of these AI systems include Siri or Alexa. The virtual assistant has access to your device's contracts, messages, emails, navigation, music, etc. Utilizing this information, these assistants can perform tasks such as turning lights on and off, making phone calls through voice commands, and play requested music on demand. Reeves (2023) explains how these intelligent systems are capable of performing these tasks: "these assistants use NLP, ML, statistical analysis, and algorithmic execution to decide what you are asking for and try to get it for you."

9. AI in Social Media

AI is being empowered to analyze speech and written text by using keyword identification algorithms, as well as applying a visual filter on social media posts quickly in an effort to prevent materials that violate the platforms terms and conditions. This idea can be seen in social media and compared to the *Matrix* in that:

Social media applications are using the support of AI to monitor content, suggest connections, and serve advertisements to targeted users, among many other tasks to ensure that you stay invested and "plugged in."
(Reeves 2023)

The best way to paraphrase Reeves is to follow the money, as social media companies and gaming companies are all revenue based. They have thousands of lines of code to understand and track user preferences, search history, locations you have been, etc. By leveraging this large dataset these capitalistic companies spoon feed advertisements to the user based on profiling patterns and statistical analysis generated from the AI/ML algorithms. Figure 11 illustrates a droid that is actively learning about its "target" by going through the multimedia data platforms.



Figure 11. Social Media AI. Source: Santamaria (2023).

10. AI for E-Payments

Ask any adult in the 25–35 age range if they own a checkbook or have been inside a brick-and-mortar bank recently, and the answer will most likely be “no.” Banks and most other companies are simplifying payment processes by integrating AI securely into their systems. Consumers have seen banks incorporate AI into their normal business practices; these “intelligent algorithms have made it possible to make deposits, transfer money, and even open accounts from anywhere, leveraging AI for security, identity management, and privacy controls” (Reeves 2023).

Again, with simplicity comes the threat of cyber criminals trying to make easy money. To counter these cyber threats, cybersecurity is turning to AI/ML to mitigate anomalous behaviors. When looking back to our banking example, most banking AI/ML algorithms can spot fraudulent charges based on the users’ spending patterns.

11. AI and the Military

According to an article by J C Suresh (2023), the U.S. State Department’s Bureau of Arms Control, Verification and Compliance, issued a statement proposing the ethical and legal implementation of AI when used by the military. Suresh (2023) recounts the governmental proclamation stating that risks and benefits need be weighed and “military use of AI capabilities needs to be accountable, including through such use during military operations within a responsible human chain of command and control.”

Figure 12 illustrates how the military could use AI for strategic wargaming, as shown with a chess match.



Figure 12. Ultimate Game of Chess; Wargames. Source: Piedfort (2021).

According to Joseph Clark of the DOD News, “The Defense Department is prioritizing ethical considerations and collaboration in its approach to developing and fielding military applications of artificial intelligence” (Clark 2023). He goes on to illustrate the America’s commitment to continue conversations internationally and setting regulations as it relates to AI. Ensuring the U.S. maintains a close partnership with our allied partners is essential as this capability continues to be developed.

Clark continues by discussing how the U.S. is ushering in the use of AI/ML systems by taking the leadership role in developing strong and responsible AI policies and principles. By developing this steadfast precedence, AI/ML capabilities can be developed and tested for strategic advancement.

The Linchpin team’s aim is not to maintain dominance in only one domain, but rather to tactfully maintain overmatch in all the domains (air, land, sea, space, and cyber), as well as to maintain pace with emergent technologies by empowering not only the dismounted soldier, but all stakeholders involved by jointly developing the GAWD system. The following chapters will discuss in detail the steps we propose to create this AI/ML system.

III. SYSTEM ANALYSIS

Recent advances in technology have jumpstarted the U.S. Army and the DOD to look at what may come. Unmanned systems are quickly becoming commonplace in military operations, and the addition of AI would offer greater intelligence and autonomy in these robotic systems. AI is also taking center stage in the development of future decision aid concepts for military operations. These AI-enabled decision aids could support a myriad of tactical decisions across warfare domains. This capstone explored the use of a future AI-enabled decision aid to support dismounted soldiers.

This chapter presents the results of the GAWD system analysis which began with a study of the dismounted soldier's operating environment to better understand the role of decision aids for this application. Next, the Linchpin Group conducted a needs analysis which included the identification of stakeholders and their needs and desires related to decision aids for dismounted soldiers. The stakeholder needs analysis led the Linchpin Group to develop system requirements and key performance parameters for the AI/ML wargaming decision aid for dismounted soldiers. This chapter is organized into two sections: (A) Needs Analysis, and (B) Requirements Analysis for the AI/ML GAWD system for dismounted soldiers.

A. NEEDS ANALYSIS

The Linchpin Group conducted a needs analysis to develop a foundational understanding of the need for an AI wargaming decision aid for dismounted soldiers. The needs analysis included three parts: (1) an analysis of the problem space to understand the future operating environment of dismounted soldiers, (2) a stakeholder analysis to identify stakeholders and assess their roles, responsibilities, desires, and needs, and (3) a review of DOD guidance on implementing safe and ethical AI.

1. Problem Space Analysis

Future conflicts are predicted to present U.S. military forces with highly contested operating environments and adversaries that are matched peers. The complete domain

dominance that the U.S. has experienced in recent conflicts will likely not be experience in this future operating environment. The reliance on superiority in other domains will not translate to what will be required of an unsupported ground element in a contested domain fight. There is an imperative need for information and data to be pushed to and computed at the point of need for dismounted elements.

In recent years, technological advancements have revolutionized military operations, enabling ground elements to achieve greater efficiency, accuracy, and lethality. Among these innovations, automated route selection, automated targeting, and biosensors have emerged as vital components of military applications to achieve overmatch for a dismounted maneuver force. Deploying these technologies for dismounted military operations would significantly enhance strategic route planning, lethal precision strikes, and real-time health and consumables monitoring; all of which the U.S. military will require to defeat a peer adversary in the ground domain.

Automated route selection utilizes advanced algorithms and AI to optimize the planning and execution of military operations. By considering various factors such as terrain, weather conditions, and potential threats, this technology could identify the most efficient and secure routes for troops and equipment movement. This reduces the risk of ambushes, improves operational speed, and enhances SA.

One key advantage of automated route selection is its ability to adapt to dynamic environments. By constantly analyzing real-time data and updating route plans accordingly, military forces could quickly respond to changing circumstances, ensuring the safety and security of personnel. Furthermore, this technology allows for the integration of unmanned aerial vehicles (UAVs) and unattended sensors, enabling autonomous information flow to support decision and reducing exposure to hazardous areas and enemy forces residing in a prepared defense.

Automated targeting systems employ sophisticated sensors, ML algorithms, and edge computing to identify and engage enemy targets more accurately. These systems significantly enhance the precision and effectiveness of military operations. By quickly analyzing vast amounts of data, such as imagery data, aerial surveillance, or ground-based

sensors, automated targeting systems could identify potential threats and provide real-time intelligence to element leaders on the ground.

The implementation of automated targeting systems also allows for faster and more lethal engagement times. With the ability to rapidly process and interpret information, these systems could provide dismounted elements with accurate targeting data, enabling them to engage hostile forces swiftly and decisively. Additionally, automated targeting systems could assist in the identification of targets that the ground element may not have the means to defeat, allowing for kinetic strikes by larger weapons platforms.

Biosensors are devices that detect and analyze biological data to monitor the health and well-being of military personnel in real-time to greatly enhance SA. These wearable sensors could measure vital signs, monitor stress levels, and assess fatigue, providing crucial insights into the overall physical and mental condition of dismounted warfighters. By continuously monitoring biometric data, leaders of ground-based elements could make informed decisions regarding warfighting task assignments, rest periods, and medical interventions.

The integration of biosensors enables early detection of injuries, illnesses, or exposure to hazardous substances, allowing for prompt medical attention and reducing the risk of long-term health complications. Moreover, biosensors could contribute to the prevention of combat fatigue and health issues by identifying signs of stress and providing appropriate support to dismounted warfighters.

All the capability areas mentioned within this future operating environment nest within the concept of AI/ML capabilities at the edge for a dismounted maneuver element. Personnel would also require a larger overarching enterprise solution for data distribution to enable these capability areas to unify into an effective system. Personnel would require both the dismounted computer systems and the larger data architecture to successfully conduct large scale combat operations in the ground domain against a future adversary.

2. Stakeholder Analysis

The team conducted a stakeholder needs analysis to identify stakeholders and understand their roles and responsibilities related to a future AI/ML wargaming decision aid for dismounted soldiers. The elements and individuals that comprise this group are known as stakeholders, which are “any group or organization with a related or subsequent responsibility that is directly related to the outcome of an action or result. Generally speaking, they can influence the outcome or are the recipient of the results” (Acquisition Notes 2021). Involving stakeholders in the requirements definition process is essential to develop a capability that appropriately defines the capability objectives and operational requirements. There must be constant communication with stakeholders throughout the program life cycle to ensure program success. Table 2 displays the stakeholders with their associated roles and responsibilities.

Table 2. Stakeholder Roles and Responsibilities

Stakeholders	Roles and Responsibilities
Users (the warfighter)	“Warfighter” is the term used to describe an active-duty person in combat and encompasses all military services. “A warfighter can be then involved in a wide variety of functions, including those directly related to the battlefield such as movement and maneuver, intelligence, command and control, and protection, and also including those functions related to product support, sustainment, maintenance, supply and logistics support” (Defense Acquisition University [DAU] 2017).
ARL	“ARL’s Army Research Directorate focuses on exploiting concept development, discovery, technology development, and transition of the most promising disruptive science and technology to deliver to the Army fundamentally advantageous science-based capabilities” (US Army DEVCOM Army Research Laboratory, 2023).
PM	The PM manages all aspects of a program to ensure a program stays within budget, on schedule, and is able to meet all performance requirements to appropriately develop, procure, and field a system (DAU 2017).
MDA	“The MDA/DA is the program decision authority and specifies the decision points and procedures for assigned programs. MDA/DAs will tailor program strategies and oversight, phase content, the timing and scope of decision

Stakeholders	Roles and Responsibilities
	reviews, and decision levels based on the characteristics of the capability being acquired (including complexity, risk, and urgency) to satisfy user requirements” (Department of Defense 2020, 8).
Defense contractor(s)	“A defense contractor, also known as the government’s industry partner, provides a materiel solution or service to the DOD to support the military or intelligence department” (Kerwin 2022).
Contracting Officer	“A Contracting Officer (CO) is a person who can bind the Federal Government of the United States to a contract. Contracting Officers hold a warrant that allows them to negotiate on behalf of the United States Government. As the Government’s agent, only COs may execute, modify, or terminate a contract” (Federal Acquisition Institute 2023).
AFC	“AFC’s role is to provide strategic guidance to facilitate Army modernization efforts, while also analyzing emerging technologies and potential future threats” (The National Academies Press 2022).
Test Community (ATEC)	“U.S. Army Test and Evaluation Command (ATEC) provides direct support to Army Futures Command and relevant, timely information to senior Army leaders to make future force decisions enabling Multi-Domain Operations through rigorous developmental testing and independent operational tests and evaluations” (U.S. Army Operational Test Command Organization n.d.).
Strategic Leaders	“A leader who is an expert, not only in his own domain of war fighting and leading large military organizations, but also in the bureaucratic and political environment of the nation’s decision-making process” (Burris 2007).
Product Support Manager (PSM)	“PSMs, in coordination with the PM, are responsible for all aspects related to the product support over the entire life cycle of a program” (DOD 2021).
Congress	“Congress exercises its oversight authority on the executive branch’s defense policy via the appropriations process and can choose to match, modify, or eliminate the (Department of Defense’s (DOD) requested funding levels for acquisition programs primarily funded by the procurement and research, development, test, and evaluation (RDT&E) accounts” (Center for Strategic & International Studies 2022).

3. DOD Principles for Mitigating Concerns with AI

With the incorporation of AI into this capability, there must be a way to control and/or safeguard this technology. To maintain control of these intelligent systems, humankind must properly construct, build, and implement appropriate goals and objectives into this AI application. AI must also have the “societal, organizational, psychological, moral and ethical components” embedded that reflect the goals of humanity (Gerstein 2019, 85).

The Department Innovation Board (DIB), an independent federal advisory committee whose mission is to prioritize and accelerate innovation within the DOD and released guidance to the agency on the recommended design, development, and integration of AI. Table 3 illustrates a set of goals the DIB proposed as AI ethical principles. Personnel must use these principles as a guideline when considering all aspects of the development of this capability.

Table 3. Department of Defense Principles for Ethical AI. Source: Defense Innovation Board (2019, 8).

Principle	Definition
Responsible	Human beings should exercise appropriate levels of judgment and remain responsible for the development, deployment, use, and outcomes of DOD AI systems.
Equitable	DOD should take deliberate steps to avoid unintended bias in the development and deployment of combat or non-combat AI systems that would inadvertently cause harm to persons.
Traceable	DOD’s AI engineering discipline should be sufficiently advanced such that technical experts possess an appropriate understanding of the technology, development processes, and operational methods of its AI systems, including transparent and auditable methodologies, data sources, and design procedure and documentation.
Reliable	DOD AI systems should have an explicit, well-defined domain of use, and the safety, security, and robustness of such systems should be tested and assured across their entire life cycle within that domain of use.

Principle	Definition
Governable	DOD AI systems should be designed and engineered to fulfill their intended function while possessing the ability to detect and avoid unintended harm or disruption, and for human or automated disengagement or deactivation of deployed systems that demonstrate unintended escalatory or other behavior.

Given the anticipated future power of AI, personnel with the responsibility of developing this capability must consider the full potential for AI to progress from ANI and ML to the point of technological singularity and even beyond. With more complexity and risk associated with AI development, it is even more essential that mankind maintain these basic principles to “manage” and provide structure during the inevitable advancement in the development of AI systems.

B. REQUIREMENTS ANALYSIS

To develop the Key Performance Parameters (KPPs) and the specific Key System Attributes (KSAs), the Linchpin Group looked to industry and scholarly research into the system requirements.

While AI techniques are ever evolving, they chiefly have demonstrated the ability to master games of increasing complexity. According to a Defense Advanced Research Projects Agency (DARPA) article about the Gamebreaker program, “the commercial gaming industry has a long-standing interest in maintaining game balance since balanced games are more entertaining, and market pressures drive their development. Instead, the military has the opposite goal whereby strategists deliberately explore technologies that maximize imbalance” (Kuperman 2023). He further describes the relation to gaming and strategy development, by stating:

Complex, multi-domain modeling and simulation environments currently under development by several DARPA programs aim to create useful “Mosaic” models within which to experiment on new warfighting constructs using distributed, adaptive, all-domain force composition, tactics, and strategies – yet these models do not currently exist. It is reasonable to assume, however, that once these simulation environments reach maturity, an “AlphaMosaic” equivalent will be

capable of searching for optimal strategies and tactics in the same way AlphaGo and AlphaStar agents have already proven effective in exploiting their respective game environments. (Kuperman 2023)

It is the goal of the Linchpin Group to maximize imbalances in the AI/ML wargaming environment for current and future conflicts to exploit gaps in our strategic outlook for units at the edge. These exploitations would allow for growth and advancements based in analytical research and development on “pushing the rules of the game” of war, i.e., giving the adversary a momentary advantage to ensure the U.S. has the winning warfighting strategy before implementing our strategy to ensure victory.

What rules do we play by and what do we push or bend to adapt to our needs? According to the master thesis written by John Allen (2022), enlisting AI in course of action analysis identified the typical behavior of these capabilities by certain rules when placed in the adversary role. Either the human operator of the AI will act in a predictable manner because of their individual experiences, or the AI will be somewhat confined to a very defined set of behavior making their actions also predictable. These issues of “mirror imaging” and “scriptwriting” can make the wargame ineffective and not very realistic (Allen 2022, 4).

The gaming industry has implemented AI to address both the issues of mirroring and script writing by making the unpredictability more robust to be a greater evaluation asset and increase learning and algorithm output.

The problem of mirror imaging bias can be approached by well informed, researched, and written rules so that adversaries behave in accordance with their governing doctrine, laws, and known tactics, techniques, and procedures....Scriptwriting can next be mitigated by the nature of neural networks and their ability to make observations of the battlespace to inform their next steps, to better assess and then reassess what occurred not only from one engagement to the next, but also from one time step to the next within an engagement. (Allen 2022, 4)

The Linchpin Group knows the greatest challenge is time, as the true adversary is the clock. Analysis and planning in wargaming strategy could all be accomplished with enough time. To best represent this limitation, analysts would hard-code in “real-world time it takes to train an AI agent as a vital factor” (Allen 2022, 4–5). For example, personnel

would operate with the goal of quickly training the AI system utilizing a laptop computer. Team Linchpin agrees with Allen's idea that the greatest benefit of this capstone is the assessment of a quality AI wargaming aid that is a tactical representative model in performance that personnel could achieve in a short amount of time without prior knowledge in the form of data libraries.

Several research papers have been published studying the application of reinforcement learning in real-time strategy games (RTS), and a growing number have been written regarding the application of the same techniques to the domain of military constructive simulations. Of the later, few if any, have been written with the intent to place the AI capability in the hands of a forward deployed tactical unit to assist in planning, analysis, strategy, or training. (Allen 2022, 7)

A forward-deployed AI solution is feasible, and it saves both time at the edge as well as for reach back to the tactical operations center (TOC) and other personnel. Forward-deployed AI wargaming aides such as this would enhance the entire Army and DOD at large without adding additional strain, as well as adding meaningful insights and localized intel that is real time usable revealed through thousands of real-life operational scenarios. The crew would also experience live simulation, which would lead to mission capable soldiers.

While this thesis may not achieve immediate implementations and applications, Allen (2022) has confidence that future research on this topic would be able to utilize lessons learned for future studies. Implementing the GAWD system framework to deploy this or similar AI/ML wargaming aids to service members DOD wide will provide the desired outcome of this research and result in a future transfer of human capital to digital knowledge management and a savings of manpower resources throughout the DOD.

Limitations in industry are widely documented. These are the most notable and they helped us decide our KPPs and KSAs:

AlphaStar was developed with the wargame limitations all human players experience in StarCraft II to fully challenge the AI agent and ensure fair play with human opponents. DeepMind consulted with professional StarCraft II players and Blizzard employees to develop AlphaStar's limitations inside the RTS. These limitations included match conditions, interface for the AI system, camera view, action rate

limits, and delays. These limitations ensured that the way a human player views the map in StarCraft II and the way AlphaStar views it are analogous. (Allen 2022, 11)

The study of humankind involves the evaluation of both brain and behavior, whereas the authors review the current state of HW and what the user community needs are in order to determine the KPPs, as defined in Table 4.

Table 4. Linchpin Artificial Intelligence Wargaming Aid Key Performance Parameters

KPPs	Description	Threshold	Objective
Power	Engine for all of the systems in use, must be battery operated and rechargeable using standard universal serial bus charger	Minimum of 12 hours of active use with no power loss	48 hours of consistent active use with no power loss
Memory	Central computer storage as well as wearable flash drive for entire system	Minimum of 16 gigabytes (GB) RAM 20 GB flash drive storage	Minimum of 1 terabyte of RAM and 500 GB flash drive storage
Computing Power	On body computer powering sensors and user experience. Integrated interfaces to support power (on/off), menu selections, maps, terrain data, location and target marking.	Provide voice and data exchange among networked, tactically distributed system operators using communications devices and battle command applications. must display 95% of shared survivability information reported to the network.	Provide voice and data exchange among networked, tactically distributed system operators using communications devices and battle command applications. must display 100% of shared survivability information reported to the network.
Latency	Rate at which data transfer happens to the sending and receiving system.	Latency of AI algorithm for accuracy of targeting, route selection, and status of no more than 120 seconds	Latency of AI algorithm for accuracy of targeting, route selection, and status of no more than 60 seconds

KPPs	Description	Threshold	Objective
Accuracy	AI accurately detects target, route, and status of soldier near real time.	95% accuracy of target or route detection and identification, 90% of soldier status monitoring and alerts as applicable	99% accuracy of target or route detection and identification, 99% of soldier status monitoring and alerts as applicable
Connection/Net Ready	Secure two-way radio to support squad level communications and information exchanges.	Encryption: AES 256. Environmental operating range: -20 – +55C	T=O
Security	Enterprise grade security	Encryption	Biometric and Iris Recognitions along with encryption

Capability-specific KSAs are defined per scenario with the user and system manufacturing/engineering team in Chapter IV.

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IV. DISMOUNTED WARFIGHTING SCENARIOS ANALYSIS

The Linchpin Group conducted an analysis of dismounted warfighting operations and how the addition of an AI-enabled wargaming decision aid could be used operationally. The purpose of this analysis was to extend the understanding of the needs and requirements analysis. By exploring how the user could use such a system in different dismounted operations, the Linchpin Group was able to refine the needs and benefits of the capability and better define scenario-specific requirements.

First, the team identified three dismounted warfighting scenarios for the analysis. Personnel derived the scenarios developed for this analysis from common warfighting functions that small, dismounted elements routinely encounter when maneuvering against an adversary. The scenarios selected were based on U.S. Army ground elements. The Linchpin Group acknowledges that the scenarios analyzed for this capstone project do not address all the relevant operational scenarios that dismounted warfighters would encounter and dismounted element from other non-Army services may have some variation in potential employment of AI/ML capabilities at the edge based on doctrine and force structure. However, the Linchpin Group chose the three scenarios with an effort to make a more focused and concise evaluation of the AI/ML possibilities that could be computed with a dismounted element at the edge.

The three dismounted warfighting scenarios that personnel selected for this analysis were: (1) target engagement, (2) route selection, and (3) dismounted soldier monitoring. All three missions involve tactical real-time decisions involving consumable resources and support large scale combat operations. As identified in the U.S. Army's Field Manual for Operations, it is imperative that the user sees themselves, sees the enemy, and understands the operational environment (Department of the Army, 2022). The results of the three scenario analyses are discussed in the following sections.

A. TARGET ENGAGEMENT SCENARIO

1. Description of CONOPs

A user could task a friendly dismounted maneuver element with conducting reconnaissance and surveillance in a target area to identify and engage enemy targets. The friendly element could employ a variety of carried sensors such as thermal imaging cameras, individual weapon optics, and man-portable UAS capabilities. The friendly element would be equipped with quantum edge computing devices (CDs), capable of processing the sensor data in real-time for notification and display upon an EUD or HUD.

2. Enhancement by AI/ML/Automation Decision Aid

Following the employment or dispersion of friendly sensor capabilities, the user would receive data at the edge for processing in near real-time. Once the user transmitted and processed the data, they would use the AI functionality to identify patterns and anomalies based on datasets that reside in the higher-level Linchpin architecture. Once the user received the sensor data, personnel would evaluate it against the data set of known enemy threats to produce a “match” probability, which personnel would provide to the user near real-time, notionally within five seconds. Personnel could combine multiple sensor data sources for various angles of viewing to increase the probability of a match, although this may add latency upon targeting data returned to the user.

For example, a UAS asset can view a perceived enemy threat from above while a rifle mounted optic could also observe that same area of interest from a different viewing angle. Data from the two sensors observing the same area of interest could then be fed into the CD where the information is fused, and the AI algorithm performs the match probability calculation. Location data from the known area of interest allows the edge processing capability to determine both potential threats are originating from the same location. This would allow for the matching algorithm to provide a higher fidelity prediction on the probability of that observed entity being designated as an enemy target.

The end result of the match calculation would be a probability figure that would allow for the likelihood of the entity being an enemy asset displayed in a percentage value and model nomenclature (e.g., 96% match, T-72). With the likelihood that a small,

dismounted element would encounter several potential enemy threat targets, this capability would allow for the friendly element commander to make timely decisions on where to best employ friendly weapons systems for maximum effect.

This information could be displayed on either the dismounts EUD or HUD. As the soldier moves through the area, the AI-powered recognition system in their edge processing capability could provide real-time updates about the enemy assets within their field-of-view. This drastically reduces the chance of misidentification and helps in making informed decisions on engagement on a potential target.



Figure 13. Airborne Soldier with End User Device. Source: Bradley (2018).

All sensor data would not only be stored and available to the dismounted soldier (user) but would also be transmitted on a secure network to other friendly units, as well as back to the TOC to be used for training and to continue the ML of the targeting algorithm.

Once a match was identified, the friendly dismounted maneuver element could engage the target using various weapons systems such as small arms fire, grenades, or even calling indirect fire support. The engagement of the target would be conducted in accordance with the commander's guidance and the rules of engagement in effect.

The friendly element would maintain SA throughout the engagement scenario. They would continue to collect and analyze sensor data to identify any potential secondary or tertiary targets in the area. This would allow the friendly element to maintain a continuous engagement cycle and maintain the initiative in the target area.

The use of multiple sensor data sources also increases the probability of successfully identifying and engaging enemy targets. However, the added latency upon targeting data returned to the user may be a challenge to overcome. The friendly element must weigh the benefits of increased accuracy against the potential delay in targeting data.

Overall, the target engagement scenario demonstrates the importance of utilizing advanced technologies in modern warfare. The integration of quantum edge CDs and AI functionality provides for increased accuracy and efficiency in target engagement. The friendly dismounted maneuver element could maintain SA and continuously engage targets in the target area, providing a significant tactical advantage on the battlefield.

3. Set of Specific Requirements

The system requirements identified for a target engagement scenario would consist of a variety of warfighter worn HW and SW requirements (see Table 5 and Figure 14).

Table 5. Target Engagement System Requirements Matrix

System Requirement	Description	Threshold	Objective
Heads Up Display (HUD)	Head mounted display within the visual field of the operator that combines sensors and modern displays into a wearable system	70 Degree Field of View. Worn with or without combat helmet.	90 Degree Field of View. Worn with or without combat helmet.
Edge Processing Device/ End User Device (EUD)	On body computer powering sensors and user experience. Integrated interfaces to support power (on/off), menu selections, maps, terrain data, location and target marking.	Provide voice and data exchange among networked, tactically distributed system operators using communications devices and battle	Provide voice and data exchange among networked, tactically distributed system operators using communications devices and battle command applications. must

System Requirement	Description	Threshold	Objective
		command applications. must display 95% of shared survivability information reported to the network.	display 100% of shared survivability information reported to the network.
Single Channel Data Radio	Secure two-way radio to support squad level communications and information exchanges.	Encryption: AES 256. Environmental operating range: -20 – +55C	T=O
Battery	System power source that integrates onto the body armor or equipment webbing	150 Watt Hours. 8 hours of mission power.	200 Watt Hours. 10 Hours of mission power
Tactical Cloud	System will be able to record and save images to the tactical cloud of numerous targets i.e. T-72 tank.	Cloud will hold up to 2 GB of data.	Cloud will hold up to 10 Terabytes of data.

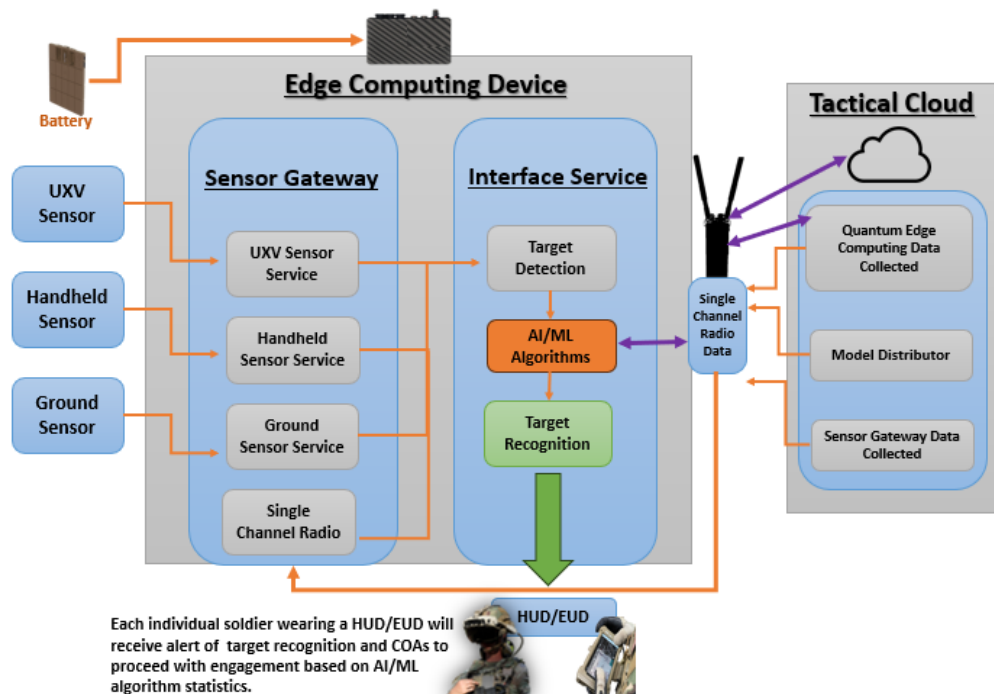


Figure 14. Ground Awareness Warfighting Decision Edge Computing System for Targeting Architecture Diagram.

The use of quantum edge CDs in this scenario allows for real-time data processing and analysis. This capability provides the dismounted maneuver element with timely and accurate information on enemy targets which is displayed on each of their HUD/EUDs, allowing for swift and effective engagement. Additionally, the use of AI functionality provides for increased accuracy in target identification and matching as every member of the element would be feeding the tactical cloud with data from various viewpoints in real time.

B. ROUTE SELECTION SCENARIO

1. Description of CONOPs

A friendly dismounted maneuver element would always be required to conduct foot movements through their assigned area of responsibility to conduct combat operations. Selection of the most optimal route through an area that is constrained by enemy activity or terrain is critical to preserving combat power. Additionally, selection of the most optimal route would greatly reduce the dismounted element's consumption of expendable resources and reduce their reliance on frequent logistical resupplies in contested areas.

2. Enhancement by AI/ML/Automation Decision Aid

The dismounted warfighter edge computing capability, coupled with AI/ML, could greatly enhance the mission effectiveness and route selection of a dismounted maneuver unit. Utilizing the Linchpin architecture with on-body computing capabilities could allow for optimal route selection based on factors that could be calculated such as mission type, enemy force disposition, time allotted, terrain to be traversed, and equipment required to be transported.

AI/ML-based capabilities that utilize the Linchpin architecture could collect and process large volumes of data from various sources. This could include terrain data (from satellite imagery and geographic information systems), weather data (from meteorological sources), and enemy activity data (from intelligence reports and reconnaissance missions).

ML algorithms that are optimized through the Linchpin architecture could analyze this data and identify patterns in enemy activity related to time-of-day, weather conditions,

or geographical features. Utilizing historical data, AI could be used to predict future enemy movements and activities by identifying potential enemy maneuvers at certain times; the AI could forecast this and suggests avoiding those areas within certain maneuver windows.

Given known enemy locations, the desired friendly maneuver destination, and a set of constraints (such as no-go terrain areas and time constraints), AI could use algorithms to generate the optimal route. This route would minimize exposure to detected threats, take advantage of cover provided by the terrain, and factor in environmental conditions. The AI would also store these generated route maps and provide them to all units via secure network. Additionally, the AI would give predicted improvised explosive device (IED) or threat potentials on the routes based on the collected data (e.g., right turn in 10 feet known for IED threats and congested from 0600–2200, take precautions, 45% Buried Mortar IED).

During the friendly maneuver, the AI capabilities from various sensor platforms could continue to collect and analyze data in real-time. If new threats are detected or conditions change (e.g., the weather worsens, or an unexpected enemy maneuver element is observed), the AI could quickly re-calculate the route to avoid the evolving threat scenario (e.g., route ahead blocked ahead based on reconnaissance, rerouting with same mission time).

After the mission, the AI system could compare the predicted conditions and enemy activities with what happened. This “after action review” (AAR) could help the AI system refine its prediction algorithms, feed that data into larger machine learning capabilities within the architecture, and improve route planning for future missions.

3. Set of Specific Requirements

The system requirements identified for a route selection consist of a variety of warfighter worn HW and SW. Table 6 lists and describes the major components of the system along with threshold and objective requirements for each.

Table 6. Route Selection System Requirements Matrix

System Requirement	Description	Threshold	Objective
Heads Up Display (HUD)	Head mounted display within the visual field of the operator that combines sensors and modern displays into a wearable system.	70 Degree Field of View. Worn with or without combat helmet.	90 Degree Field of View. Worn with or without combat helmet.
Edge Processing Device/ End User Device (EUD)	On body computer powering sensors and user experience. Integrated interfaces to support power (on/off), menu selections, maps, terrain data, location and target marking.	Provide voice and data exchange among networked, tactically distributed system operators using communications devices and battle command applications. must display 95% of shared survivability information reported to the network.	Provide voice and data exchange among networked, tactically distributed system operators using communications devices and battle command applications. must display 100% of shared survivability information reported to the network.
Single Channel Data Radio	Secure two-way radio to support squad level communications and information exchanges.	Encryption: AES 256. Environmental operating range: -20 – +55C	T=O
Battery	System power source that integrates onto the body armor or equipment webbing	150 Watt Hours. 8 hours of mission power.	200 Watt Hours. 10 Hours of mission power
Tactical Cloud	System will be able to record and save images to the tactical cloud from drone and all cameras mounted to soldiers or vehicles to generate area surveillance images that the AI/ML algorithm will rapidly assess for changes to the area/ environment to provide mission essential route selections i.e., right turn in 10 feet known for IED attacks proceed with caution or select alternate route.	Cloud will hold up to 2 GB of data and will provide daily updated imagery data.	Cloud will hold up to 10 Terabytes of data and will provide hourly updated imagery data

4. System Architecture/Design

Figure 15 shows the route selection system architecture diagram.

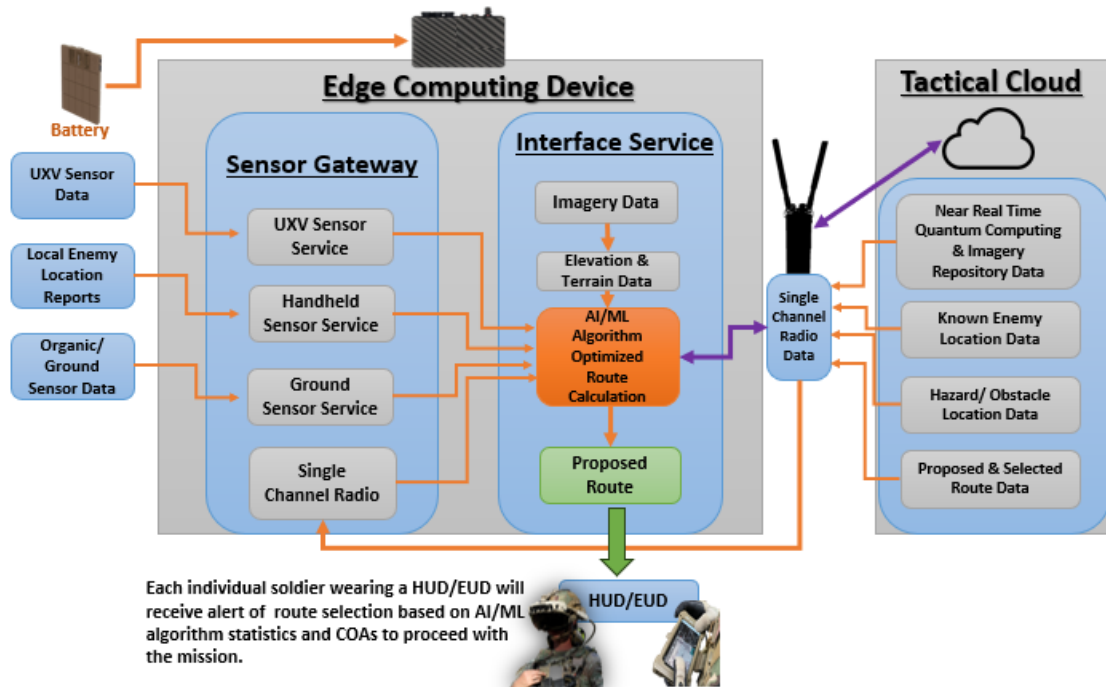


Figure 15. Ground Awareness Warfighting Decision Edge Computing System for Route Selection System Architecture Diagram.

C. DISMOUNTED SOLDIER MONITORING

1. Description of CONOPs

Personnel are actively researching the stretch futuristic scenario but is intended to be twofold. The first use is a status monitor for each individual soldier of the friendly dismounted element (e.g., ammunition counts and vitals), while secondarily utilizing eye tracking to actively train the AI/ML algorithm to grow stressor sensing knowledge of soldiers. The AI/ML wargaming aid would enhance the stressor sensing by providing brain activity mapping based on the eye tracking data and vitals that paint the picture of the soldiers' stresses, as well as bodycam imagery showcasing the real-time threats while

actively engaged in battle and/or disengaged on patrol to provide greater fight-or-flight strategic thinking with predictive calculations. This would aid in training and allow for use in the field with closer monitoring of the troops and allow for the TOC to empower units to replace worn out units or come to defense. This is the stretch futuristic scenario.

2. Enhancement by AI/ML/Automation Decision Aid

Technological advancements could be broken down into the 1s and 0s of the coding and highly technical requirements, but they could also be broken down by following the money. The Linchpin Group has heavily researched both the technical requirement and the financial expense avenues in the name of science and advanced protections of the warfighter.

In regard to the financial avenue, according to BusinessWire “the Global Military Sensors market accounted for \$23.06 billion in 2018 and is expected to reach \$42.76 billion by 2027 growing at a CAGR of 7.1% during the forecast period” (Wood 2019).

Since the technical requirements avenue could get very deep, the Linchpin Group developed two near-term attainable AI/ML integration scenarios (Targeting at the Edge, and Route Selections) with a stretch scenario of soldier SAS to help bound the requirements and the endless data collection. SAS would contain protected health information (PHI) so soldiers would have the data available to them and would be required to consent to the use of real-time and training uses, but with this minimal red tape, our group feels this data could be critical 1s and 0s that may result in saving lives of many.

Biosensors such as pedometers, heart rate monitors, and fitness trackers have been popular in the civilian market, so they show great growth potential in the military industry. The Army has been funding cutting-edge research teaming with Academia, DARPA, ARL, and many more in the areas of brain-to-computer communication as well as real-time physiological status monitors (RT-PSM) for years.

“RT-PSM wearables fill a gap by providing individual soldiers and their immediate leadership with actionable physiological status information needed to ensure individual and squad health and performance/ readiness” (Friedl et al. 2022).

Figure 16 shows examples of the current use of wearable or integrated RT-PSM as well as illustrates higher level blackbox diagram for the Linchpin Group AI in the soldier SAS. The stretch objective of the Linchpin Group is to utilize commercial off the shelf (COTS) RT-PSMs, coding them with our AI/ML algorithm to provide the soldiers SA not only of casualty events, but to have real-time monitoring of vitals, stressors, brain activity, and ammunition counts.



Figure 16. U.S. Army Research Laboratory Real-Time Physiological Monitoring. Source: Friedl (2022).

The Linchpin Group design would utilize ultra-high frequency or adhesive radio-frequency identification (RFID) patches integrated into standard issue gloves, socks, and undershirts to collect, transmit, and monitor each soldiers' vitals to include heart rate, breathing/oxygen saturation, temperature, sweat, hydration, and mineral and calorie uptake or deficiencies. According to Rose et al. (2014): "an adhesive radio-frequency identification (RFID) sensor bandage (patch) is reported, which can be made completely intimate with human skin, a distinct advantage for chronological monitoring of biomarkers in sweat." In the demonstration of this capability:

The wearability of the patch has been demonstrated for up to seven days, and includes a protective textile which provides a feel and appearance similar to a standard Band-Aid. Applications include hydration monitoring, but the basic capability is extendable to other mM ionic solutes in sweat (Cl^- , K^+ , Mg^{2+} , NH_4^+ , and Zn^{2+}).

A similar research initiative conducted by the Air Force Research Laboratory in conjunction with the Nano-Bio Materials Consortium to develop the Biomolecular Structure and Integration for Sensors (BioSIS) system to monitor the wellbeing and stress levels of Airmen in real-time.

As outlined in the Gail Forbes (2022) article on wearable biomolecular sensors for the U.S. Air Force, a variety of sensor technologies were placed on various parts of Airmen. The devices under consideration included mouthguards, skin patches and microneedle patches. Forbes highlighted how the mouthguards could collect and analyze saliva, the skin patches could analyze sweat and the microneedle patch could penetrate the skin to analyze interstitial fluid. These elements were combined to provide the full spectrum of biomarkers for the most complete physiological and psychological monitoring possible (Forbes 2022).

The main biomarkers found in saliva are indicative of a stress response and include cortisol, testosterone, and byproducts of protein oxidation. Monitoring saliva for these markers allows for real time recognition of the increasing physical and/or psychological stress and its impact on performance. Ideally, the individual could use this data to change their intensity level prior to the negative impact of decreased performance or injury. The most readily recognizable use for interstitial fluid monitoring in commercially available healthcare applications is the continuous glucose monitor. However, there are a variety of biomarkers to be found and analyzed in interstitial fluid including creatine and homocysteine that are key to metabolic function. The biomarkers found in sweat include electrolytes such as sodium and potassium, metabolites including glucose and lactate, molecules of cortisol and tyrosine, as well as trace elements of iron, zinc, and copper. The primary difference in the methods is the amount and quality of the available biomarkers in the different fluids. Each has valuable information, but taken together, they provide as complete of an evaluation as possible of the individual's overall health and performance.

Armed with this research, the Linchpin Group would aim for greater longevity in the sensors and integrate the data collected into the AI/ML algorithm to better predict the performance and fatigue of soldiers so that commanding officers could monitor the soldiers in real-time and give rest to units before exhaustion detracts troop performance. This would be beneficial in ancillary orders of magnitude to U.S. Army engineers and scientists at Natick and ARL to better fuel our warfighters in Meal, Ready-to-Eat development, as well as clothing and other equipment designs.

These sensors in our wargaming aide would work similar to AR in that it would also provide details on fatigue of the soldier and wear on equipment. Optical sensors such as standard imagery (30 frames per second) and infrared imagery would be attached to all optics (weaponry scopes, night vision goggles (NVGs), and standard issue sunglasses/safety glasses, standard issue helmet GoPro) to record footage looking out in front of the soldier, as well as to provide a 360-degree view around the soldier when dismounted or engaging in firing weaponry to provide SA. Personnel would utilize GPS, accelerometers, and pedometers in tandem for location accuracy of five meters.

Personnel would utilize optical sensors for training and continuous ML. The intent of this video data being collected is the AI aid would have stored footage from previous trips in the area or in similar instances (based on various factors) to provide the soldier, unit, and TOC information real-time. For example, a dismounted soldier looks at a building while on patrol that was passed last week on the same patrol mission. The AI similar to AR would alert the patrol unit that there seems to be a difference from last week to images being recorded real-time, such as there seems to be a car parked over an area of dirt that has been disturbed, proceed with caution, or seek alternate route as shown in Figure 18.



Figure 17. Tactical Augmented Reality for Route Selection. Source: Melnick (2017).

In addition to these outward-looking optics, there would be an inward-looking camera on all soldier vision equipment to allow for eye tracking to collect, transmit, and correlate data of eye movement with electroencephalogram (EEG) sensors that measure the soldiers electromagnetic (EM) brain waves. This would allow for real-time understanding of decisions made and based on recent DARPA research could be used to leverage “hacking” of the soldiers’ brain to ease stressors and allow for more logical decisions “guided” by pulses provided to the soldier by the EEG leads located in their standard issue helmet. This situation is the breeding ground for this AI wargaming aid to employ ML to support training efforts, as well as give soldiers at the edge real-time targeting and strategic wargaming guidance, i.e., there is a group of locals at 2’oclock that appear unarmed (25% of threat continue scanning area).

Having the above physiological data along with the optical data would allow for the TOC to provide feedback, but ultimately the Linchpin Group’s intent is that the AI decision aid provides the soldier with 96% accuracy of targeting, route selection, and SAS data to employ appropriate measures to nullify threats and complete their mission safely and with less stressors.

3. Set of Specific Requirements

As with any new technology, testing and evaluation input is critical to correcting SW and HW problems, as well as to create better, more useful versions. Likewise, combining technologies into a single wearable device would require overlapping existing SW code or creating new, multivariable code to take full advantage of each individual component. Adding eye tracking technology, as well as multiple physiological indicators to the unit, would certainly create problems to be solved in both development and training. Making U.S. warfighters the best equipped and most technologically advanced force in battle is worth the inevitable trial-and-error process. Operational test and evaluation would be the best COA for mitigating most of the SW and HW issues that may arise.

The system requirements identified for SA capabilities consists of a variety of warfighter worn HW and SW requirements is shown in Table 7.

Table 7. Dismounted Soldier Monitoring Systems Requirements Matrix.

System Requirement	Description	Threshold	Objective
Heads Up Display (HUD)	Head mounted display within the visual field of the operator that combines sensors and modern displays into a wearable system. Heads-up display also integrates with weapon optics and standard issue sunglasses or NVGs	70 Degree Field of View. Worn with or without combat helmet. Resolution in 2,000 would use holographic display would be greater than 2,500 radiant.	90 Degree Field of View. Worn with or without combat helmet. Resolution in 8,000 using Eye based rendering to optimize the 3D special eye position
Edge Processing Device/ End User Device (EUD)	On body computer powering sensors and user experience. Integrated interfaces to support power (on/off), menu selections, maps, terrain data, location and target marking.	5 channels with the minimum frequency of 20 hertz (Hz) to provide voice and data exchange among networked, tactically distributed system operators using communications devices and battle command applications. must display 95% of shared survivability information reported to the network.	32 channels with maximum frequency of 20,000 Hz to provide voice and data exchange among networked, tactically distributed system operators using communications devices and battle command applications. must display 100% of shared survivability

System Requirement	Description	Threshold	Objective
			information reported to the network.
Battery	System power source that integrates onto the body armor or equipment webbing	150 Watt Hours. 8 hours of mission power.	200 Watt Hours. 10 Hours of mission power
Tactical Cloud	System will be able to record and save images and vitals to the tactical cloud from and all cameras mounted to soldiers, as well as wearable biometric sensors that monitor vitals, Inertial Measurement Unit (IMU) and GPS which generates personal data files that directly support the AI/ML algorithm brain mapping of stressors and sending stimulus to the wearers brain for strategic wargaming i.e., soldier is low on ammunition and vitals indicate elevated heart rate with eye tracking indicating stress due to being fired upon, stimulus to run and seek shelter sent to brain.	Cloud will hold up to 2 GB of data and will provide daily updated imagery data.	Cloud will hold up to 10 Terabytes of data and will provide hourly updated imagery data
Eye Sensor/ Cameras	Head/Eye tracking using 4 visible light and 2 IR cameras as well as 4 outward looking cameras mounted on the back of the soldier's helmet, one looking forward from the chest and optics mounted on the glasses or NVGs or mounted on the weapon looking outward.	All cameras will be 1080 pixels images with up to 32 zoom, viewable and recordable at 30 frames per second (fps).	
Biometric Sensor	Devices to ensure identity/ security and provide feedback to the soldier	Hand Tracking -Two-handed fully articulated model with direct manipulation Security-Enterprise grade security with iris recognition Tattoo or Worn Devices- Update real time with an accuracy of 95% detection to alert soldier and chain of status and if other actions are needed	

System Requirement	Description	Threshold	Objective
Environment Understanding	Spatial mapping generating a real time environmental mesh, utilizing IMU, GPS, accelerometers, magnetometer, gyroscope	6 Degrees of Freedom tracking world scale positional tracking	Mixed Reality Capture – Mixed hologram and physical environment with photos and video

Figure 18 showcases the black box systems engineering architecture to establish and configuration control the dismounted soldier monitoring portion of the Linchpin GAWD. Due to the nature of safeguarding and properly handling the soldiers' personal health information (PHI) by the AI/ML GAWD is one of the highest regards and the Linchpin Group has invested research time into HIPPA laws and this review can be found in the appendix section of this capstone report.

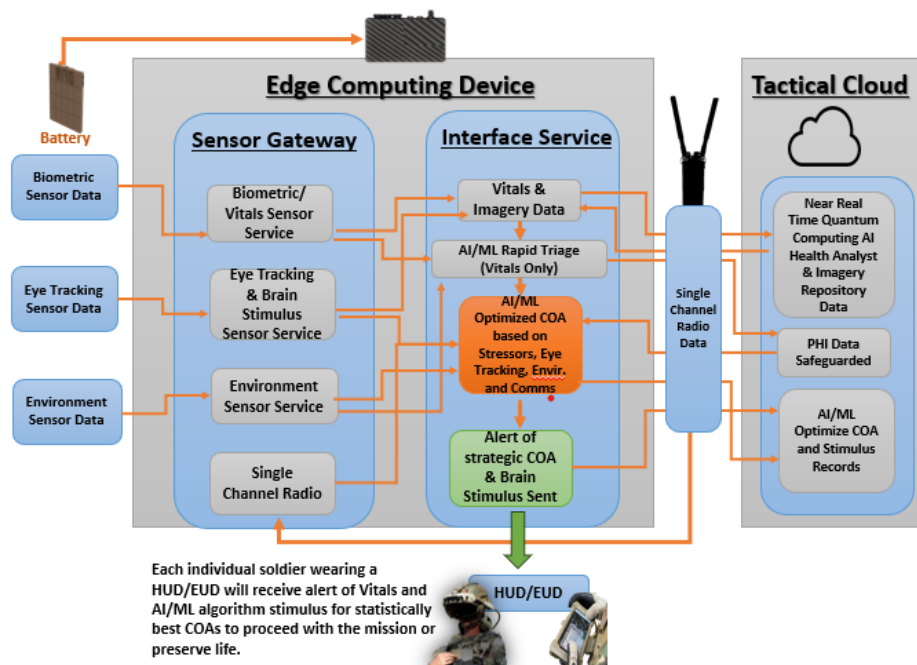


Figure 18. Ground Awareness Warfighting Decision Edge Computing System for the Dismounted Soldier Monitoring Systems Architecture.

D. SCENARIO COMPARISONS

Through the initial analysis of the earlier defined scenarios and the exploration of mature enterprise and edge computing technologies, it is quite possible that personnel could develop a singular system-of-systems to support all three proposed capabilities: targeting detection and determination, route selection, and SAS of soldiers at the edge.

Personnel could design the enterprise data solution (Linchpin) in a manner that supports all three of the operational scenarios. The capabilities required by the end users could draw information from common data holdings and the appropriate models could be effectively trained within that enterprise solution and deployed via a tactical network to the edge computing solutions.

The user interface required by the end user could simply be an adoption of several fielded solutions and systems of currently fielded user interfaces. While certain new functionality elements of the user interface would likely need to be incorporated, the general user experience for controlling the various functionalities of the system would not require complete or total design. Whether the system is configured for a head mounted display with three-dimensional iconology or visualized on a flat screen and user device, the look and feel of the user interface of many currently developed systems can support either of the visual applications. This allows for system redundancy should the system be configured with the head mounted display. Should that subsystem become inoperable, the operator could use the end user device (EUD) that has an integrated flat screen display.

Interoperability of the various data inputs and data transport requirements could be achieved for this proposed system. Any AI model sent from the larger enterprise to an end user via the tactical network could be standardized in a manner that facilitates edge processing of the information. Any transmission or exchange of data occurring on or near the war fighter would utilize the government-directed, secure ultra-wide band communications protocol for components or subsystems that are not directly connected to the edge CD.

Additionally, any data exchanges from unattended assets or tactical radios throughout the formation could utilize the encrypted transport/radio waveform appropriate

for that dismounted formation and the classification level of the information in transit. This system concept for the various transport layers could ensure interoperability amongst the various system components and assets. The challenge with this concept for a dismounted and distributed solution would be the vulnerability to denial-of-service attacks. Regardless of system design, it is difficult to overcome this potential risk due to the inherent design constraints for a system carried by dismounted ground elements. Generally, the systems cannot be designed with a significant amount of EM protection, and they would be constrained by the transport/radio power outputs to the various system components. This is an acceptable risk for this capability as the individual war fighter would still be mission capable even with the degradation or loss of the capabilities proposed in this system. Doctrinally, dismounted elements train and are prepared for operational scenarios where everything with a power switch is not operable and will continue to close with and engage the enemy.

In 2020, the Department of the Army partnered with Booz Allen Hamilton to research the benefits of having soldiers wear smart watches to gauge how they respond to stress and physical activity. The assumption being that raising individual soldier awareness of their stress indicators will allow them to mitigate the effects of stress and fatigue (Booz Allen Hamilton 2022). Taking this concept several steps further, by providing a full battery of physiologic data to the soldiers as well as to the command group, it would allow for better preparedness and awareness of potential problems before they occur. The average commercially available smart watch measures resting heart rate, accelerated heart rate steps, and sleep zones. Current models are Bluetooth compatible to easily share data with a paired smartphone. More advanced wearable devices are able to include respiration rate, oxygen saturation, core temperature, and GPS location. Several of the advanced technologies are being tested with athletes in both individual and team events and include the ability to monitor the team as a unit, as well as key physical performance indicators and the ability to determine the GPS location of each member on the field (Feldstein et al. 2018). The same technology is easily customized for military operations to avail the warfighter with the same options.

Working in tandem with AR and AI technology, soldiers and command staff could benefit from understanding each soldier's individual physical status to develop the best route and pace needed to complete a specific dismounted operation. Personnel would use physiologic performance indicators in determining which team members would be able to keep pace and which are nearing performance-altering fatigue. Making full use of this type of data could keep potential fatigue-related injuries to a minimum and provide valuable information to medical teams in the event of either fatigue or combat-related injury. Likewise, incorporating physiologic monitoring as a part of squad training would create a baseline of expected individual indicators and allow command to better understand individual variations prior to deploying into combat scenarios.

Personnel could utilize further development on wearable patch technology to include a variety of biomarker compounds found in sweat as well as environmental exposures such as ambient thermal, impact or chemical exposures, and their impact on individual performance. The Army has cold, hot, and tropical testing centers that are well suited for ambient thermal testing.

The primary concern of GPS and Bluetooth technology is overall system security to ensure only friendly entities can access the data collected. In commercially available smartwatch and wearable technology, much of the GPS SW appends to Google Maps for localization. Military applications require more secure information platforms and the ability to keep secret data, secret.

A review of currently available technologies ranges from technically specialized smartwatches to wearable technology such as the Medtronic Zephyr Omnisense. As expected, the more technically advanced the product is, the more complicated it becomes. The concept of real-time or near real-time data transfer on multiple users to multiple end-users may be more complicated and slow processing. In the best-case scenario, our AI wargaming aid must include those features which are necessary to maintain the technological advantage without overloading the data transfer system or the individual soldier with unnecessary equipment.

Figure 19 depicts the entire GAWD System Edge Computing Device, which is the holistic system of systems approach to alleviating stressors and enabling soldiers to make precise strategic decisions with AI/ML assurance.

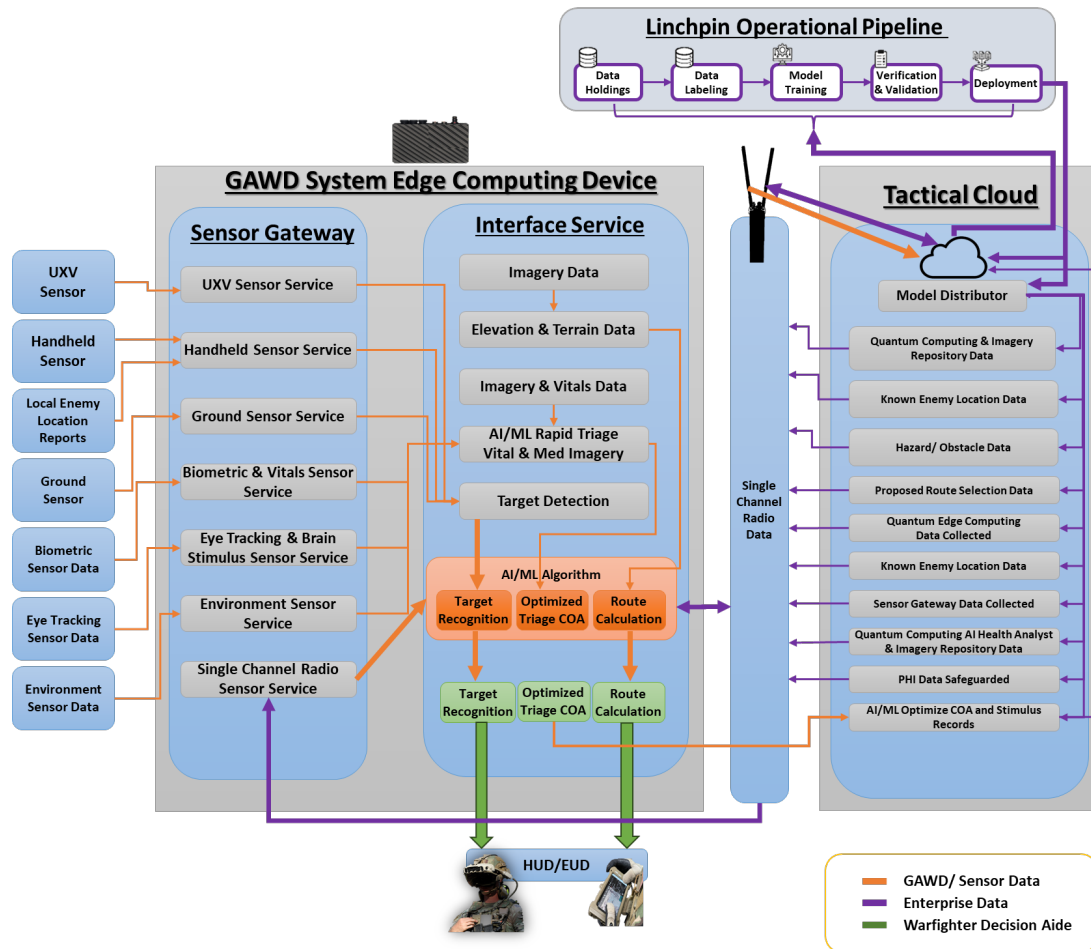


Figure 19. Ground Awareness Warfighting Decision System Edge Computing Device Holistic Suite.

This holistic suite is the future of edge computing, and the Linchpin Group sees this as a viable system that could be easily built and coded as soon as 2024 for preliminary testing. Combined Developmental and Operational Test events would be appropriate for fast tracking this technology infusion for use quickly in forces. With this capstone the Linchpin Group would suggest sponsorship of this novel design to gain traction on implementation of the GAWD System.

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V. STRATEGIES FOR DEVELOPMENT AND DEPLOYMENT OF MAN AND MACHINE

As the research and development of multiple systems for monitoring and assisting our warfighters continues, it is wise to begin developing strategies to optimize implementation. As military training is intended to simulate combat conditions, deploying monitoring systems during training provides as accurate a baseline for physiologic and psychological assessment as possible. Additionally, initial deployment during training offers the opportunity to test both the monitoring systems as well as the data collection and transfer capabilities prior to deployment into actual combat situations. All personnel, from soldiers to medic to command, would have realistic scenarios to test the equipment's abilities and limits.

Personnel could problem identification and troubleshooting of systems in real-time or in AAR, as needed. Full implementation would allow all personnel a complete understanding of the monitoring systems' abilities and limitations prior to deployment in combat. Further, baseline measurement would allow medical and command personnel a better understanding of each team member's individual status, allowing for quicker awareness when differentiations arise. Quicker acknowledgement would allow for quicker, more data-driven decisions, as well as limiting physical injury from fatigue and stress while limiting their negative impact on mission outcomes.

Determining which systems would collect and deliver the optimum data most efficiently and effectively would require full spectrum testing of each component for its ease of use, durability, and performance. Creating a robust, multivariable, and multi-use database of individual monitoring data to use in mission critical decisions is the primary goal, while creating historical data for each member that could be used to identify and treat conditions, and promote the overall health of our warfighter, would be mutually beneficial to the individual service member as well as to their unit and command.

A holistic approach to maintaining the healthiest and most technological advanced military is a reality in the near term; making the most of it would require the military's best efforts to fully develop the best options, mitigate the problems capable of derailing the

project, and providing a platform to ensure success. Making the best use of private business, national research laboratories, and military centers of excellence to develop cross-functional teams capable of blending experience and assets without redundancy/regression will become increasingly necessary to get ahead of our global competitors and adversaries.

A. EXTENDING THE CAPABILITIES FOR LETHAL EFFECTS OF THE DISMOUNTED UNIT

Networked target hand-off capabilities continue to extend range and lethal effects with viable munitions for greater kinetic effect among both friendly and adversary forces. This will likely be the norm in ground-based warfare for dismounted maneuver elements in the future. Friendly forces will require the capability to engage and defeat targets at extended ranges, as their adversaries will strive to do the same. Any munition that is fired at a target is constrained due to the effects of gravity. Ultimately, that munition will inevitably strike its target or impact the earth or water. Even very powerful munitions succumb to gravity given a long enough flight path toward a target area. The concept for overcoming this challenge of engaging targets at extended ranges would be to have those munitions essentially “fly.” Loitering munitions (Figure 20), meaning ordinance that is integrated with a UAV, shows to be the most promising concept to overcome this challenge. These munitions could be launched in a location far away from the intended target and the control and flight operations could be handed off to additional friendly elements along the flight path for terminal guidance into the adversary target.

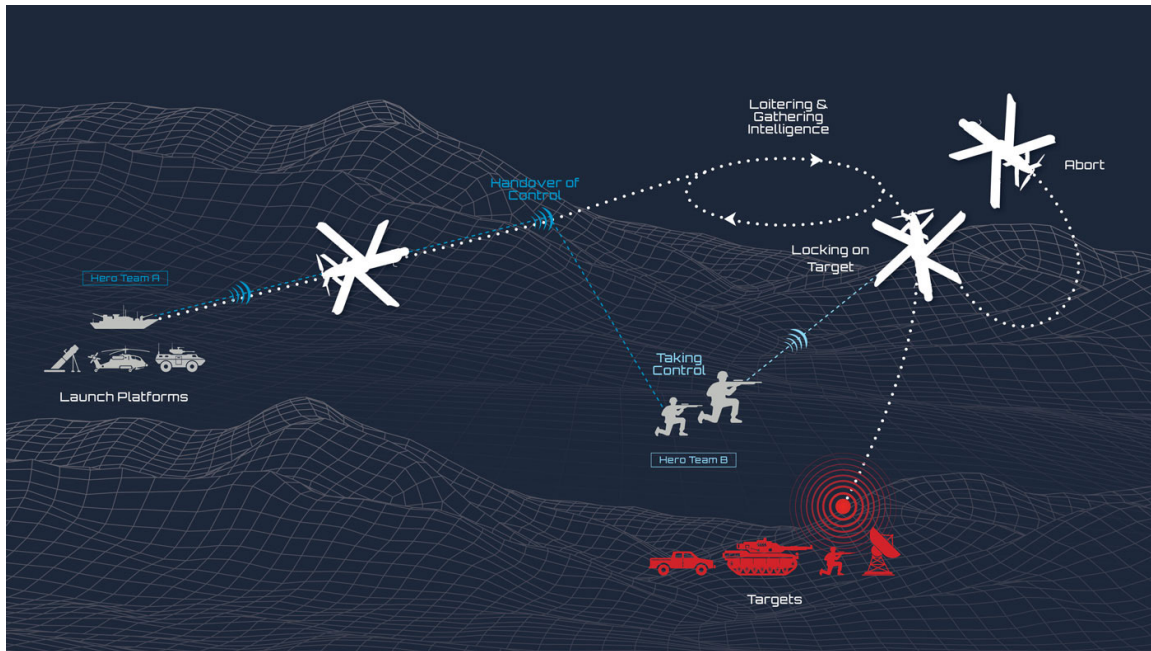


Figure 21. Loitering Munitions Operational Concept. Source: Uvision. (2023).

The necessary SA to reach targets at extended ranges is enabled through small UAS or intelligence, surveillance, and reconnaissance assets at the Company or Platoon level. This is achievable if the communication protocols are standardized, and flight/payload control capabilities are provided to each dismounted operator employing the system.

As the dismounted operator would likely be consumed with other warfighting tasks, the utilization of AI/ML capabilities to assist with targeting decisions would be essential for this concept to be practical for use in a combat environment. Leveraging AI models that personnel could receive over the tactical network from the larger Linchpin architecture to be processed and employed at the edge would give an extreme targeting advantage to friendly forces gauging adversary elements at extended ranges.

B. ENHANCING SITUATION AWARENESS OF THE DISMOUNTED UNIT

Situational awareness (SA) results from soldiers' direct perception of the environmental surroundings using visual, aural, olfactory, etc., sensors. In situations of limited visibility, the dimensions of enhanced perception provided by individual equipment (e.g., NVDs or 3D HUD technologies) are critical in allowing a dismounted warfighter to

“see” the situation beyond what could be obtained through simply using their eyes (Figure 22). The merging of natural perception, enhanced perception, and additional information portrayed to the collective Small Unit results in shared SA. Improved SA remains critical while conducting multi-domain operations.



Figure 22. Fully Ruggedized and Militarized Version of Integrated Visual Augmentation System. Source: Freedberg (2022).

SA capabilities enhance dismounted warfighter mobility, lethality, and protection necessary to maintain freedom of movement and action to defeat enemy forces. Future dismounted infantry forces require a wholesale transition from analog to interconnected and fused digital systems. Digital systems provide unparalleled capability at the Small Unit level, leveraging on-body processing enabled by AI/ML, AR/VR (Figure 23), and real-world information portrayal. Edge computing linked to the tactical network represents leap-ahead capabilities and would enable the ability to fight and target anywhere, anytime through extended ranges.



Figure 23. Soldiers Test the Ruggedized Version of the Integrated Visual Augmentation System Goggles. Source: Freedberg (2022).

While much of this capability could be provided to dismounted war fighting elements today, a future conflict would likely see a very contested EM environment. Simply put, the systems may be susceptible to degraded performance based on enemy electronic warfare attempts to degrade or disrupt system functionality.

A future dismounted war fighting system for SA that leverages AI/ML would not only need to sense or detect when it may be susceptible to electronic attack, but also be hardened to resist those attacks without substantial impact to system performance. Multiple capabilities exist today for dismounted elements to sense and detect electronic attack; however, the size and power requirements of these capabilities are not advantageous to dismounted war fighters carrying complete combat loads upon their human torso (Figure 24).



Figure 24. The Latest Version of the Communication Emitter Sensing and Attack System II. Source: Haystead (2022).

While there likely will not be a technological advance that would allow for hardening against electronic attack for a dismounted system, the potential for a future system to identify, attack, and transfer to an alternative location within the EM spectrum for communication would appear to be more feasible. Hardening communications equipment against electronic attack for a dismounted element would likely incur significant weight increases to system components, as well as greatly reduce the connectivity strength among the various radio components that are attempting to transmit in areas of the EM spectrum that could be easily targeted. Integrating EA sensing capabilities, coupled with AI/ML capabilities at the edge that could identify uncontested and viable areas of the EM spectrum for system communication would likely be the most achievable strategy for a shared communications in a contested EM environment.

Technological advances in the areas of antenna miniaturization and battery efficiency would likely have to occur for an AI/ML EA sensing capability to be integrated within the system for every dismounted warfighter. Once the EA is detected, the system

could (utilizing AI/ML) identify an alternative and viable area within the EM spectrum for successful communication and transmittal of friendly force data.

C. FUTURE HUMAN MACHINE TEAMING OF DECISION AID

Through the development and implementation of longer-range strike capabilities and reliable SA through assured communication paths, a future AI/ML enabled dismounted warfighting system would greatly assist in achieving overmatch against a future adversary. The potential benefits of loitering munitions that are delegated for control once launched from an alternate location would greatly enhance the lethality of a dismounted maneuver element. Additionally, this concept for integrating this capability into a future system would help increase the survivability of a dismounted element by potentially keeping their location concealed. At times, doctrine and maneuver constraints call for dismounted elements to halt and wait for close air support assets to drop ordnance on an enemy target before resuming maneuver operations. This capability enhancement would allow that element on the ground to essentially have close air support type capabilities organic to their formation and on-demand for engaging enemy targets to support follow-on maneuver operations.

The likelihood that a future conflict would have an uncongested EM environment is very low. Dismounted warfighters are not vehicle platforms or aircraft that are capable of reconfiguration or redesign to support the materials and components necessary to harden all communication components from the effects of electronic attack. A more viable solution to the electronic attack dilemma is to identify the element is under electronic attack and then have the system identify more viable and available communications paths for the various system components transmitting data.

Integrating these longer-range strikes and reliable SA concepts into a future system are not only achievable but would greatly enhance the survivability, mobility, and lethality of dismounted maneuver force equipped with an AI/ML enabled system.

VI. SUMMARY

This section provides a high-level summary of the findings and observations Project Linchpin discovered through research, analysis, and critical thinking. It will also discuss the ethical and societal issues that personnel must address prior to the development of this AI/ML wargaming tool, as well as the potential for future analysis of this capability.

A. STUDY FINDINGS AND OBSERVATIONS

Overall, the AI/ML wargaming aid empowers soldiers with advanced computational capabilities, data-driven insights, and tactical support, leading to improved real-time decision-making, enhanced operational efficiency, and increased mission success rates.

Designing an AI/ML wargaming aid that utilizes a sensor suite for war strategy would require a combination of various sensors and ML algorithms on secure networks that both gather and process data effectively. Personnel would have to maximize computation and processing power in the smallest possible units to ensure they are both lightweight and robust to serve their purpose on the battlefield. It is also important to note that developing and deploying AI/ML technologies must hold a high standard for the use of force, protection of civilians, and the conduct of warfare. Additionally, personnel should put in place safeguards to prevent the misuse or accidental harm caused by these systems.

The intent of this capability is to not replace soldiers, but instead assist them and provide a competitive advantage. Human judgement and oversight remain essential in all military operations. To ensure this AI/ML wargaming capability could be used on the battlefield and to optimize total system performance, personnel would require rigorous validation testing at the system level to ensure the wargaming tool not only meets threshold requirements but is also reliable. Operational testing is also necessary to ensure the sensor suite can perform with accuracy and reliability in war-like scenarios, as well as training and strategic wargaming.

B. ADDRESSING ETHICAL AND SOCIETAL ISSUES

As addressed in Chapter III. SYSTEM ANALYSIS, with these advanced AI/ML capabilities being incorporated in the Linchpin wargaming capability, there are ethical and societal issues personnel must identify, manage, and in some cases solve in order to use the technology safely and effectively, while avoiding the associated downsides of the use of AI.

Ethical and social issues are areas that personnel should consider regarding AI. Consider if the warfighter was using this Wargaming capability and the automated targeting system began to engage targets that were not the U.S. Army's enemy and caused a major situation with a foreign ally. Who is responsible? The defense contractor/developer of the AI algorithm, the engineer who incorporated the AI/ML algorithm into the system, or the warfighter using the system? The reality is that the issue of who was at fault would be minimal to the situation that the U.S. may have now created with a foreign ally, but it still needs to be addressed.

As previously discussed, the five AI principles the DIB provided to the DOD to incorporate into AI development needs to be a priority in the development process. Ensuring the AI/ML system is: 1. responsible, 2. equitable, 3. traceable, 4. reliable, and 5. Governable (Defense Innovation Board 2019, 8), is essential as AI/ML tools begin to develop and potentially become sentient. The DIB provided a framework, but defining requirements for a system to operate within these five principles would be challenging. When it comes to ethical and societal issues, there are multiple conflicting ideologies in our society. Being able to agree and provide a standard for the Linchpin wargaming tool, as well as other AI/ML capabilities, would require multiple stakeholders to come together and make an informed decision.

There are 12 recommended activities to assist in the communication and application of these proposed principles:

1. Formalize these principles via official DOD channels.
2. Establish a DOD-wide AI Steering Committee.
3. Cultivate and grow the field of AI engineering.
4. Enhance DOD training and workforce programs.
5. Invest in research on novel security aspects of AI.

6. Invest in research to bolster reproducibility.
7. Define reliability benchmarks.
8. Strengthen AI test and evaluation techniques.
9. Develop a risk management methodology.
10. Ensure proper implementation of AI ethics principles.
11. Expand research into understanding how to implement AI ethics principles.
12. Convene an annual conference on AI safety, security, and robustness. (Defense Innovation Board 2019, 8–10)

Although the DOD has already started to implement some of these recommendations, there is still more room for growth, research, and innovation as it relates to determining the appropriate ethical and societal principles that must be incorporated into AI/ML capabilities for not only this wargaming capability, but for the future of systems within the DOD.

C. POTENTIAL FOR FUTURE ANALYSIS

As technology continues to advance, the U.S. must modernize its systems to maintain overmatch in the ground domain to protect national security interest. In this context, tracking individual status, utilizing holographic and HUD visual technologies, and implementing targeted UAS strikes at extended ranges are integral components of future military systems for dismounted warfighters.

The ability to accurately track the status of warfighters on the battlefield is paramount for effective command and control of dismounted maneuver elements. A future military system for dismounts would need to incorporate advanced biometric sensors, wearable devices, and AI algorithms to monitor vital signs, location, and overall health of each warfighter. These systems would provide real-time data to commanders, enabling swift decision-making, resource allocation, and medical assistance.

To ensure optimal performance of a future dismounted system, the requirements for tracking individual status would include ruggedizing and miniaturizing sensor technologies, increasing levels of encryption on communications, and continually improving AI algorithms. Personnel would need to construct and reinforce current commercial-grade sensor technologies for use in military environments. Ruggedization of sensors capable of monitoring vital signs, to include but not limited to blood pressure, heart

rate, respiration rate, body temperature, stress levels, etc., would need to occur. These sensors must withstand harsh military operating environments with few opportunities for preventative maintenance and provide accurate, reliable data.

Personnel would need to reinforce the networks architectures and information transport protocols to assure secure communication and enable transmittal of real-time data from warfighters to various operations centers throughout the formation. They must develop and employ advanced encryption and authentication techniques (at both the edge system and within the data holdings) to prevent data breaches and cyber-attack vulnerabilities.

Personnel must develop continual advancements in AI algorithms to the data set and provide actionable insights on individual warfighter statuses. These algorithms would identify anomalies, forecast potential health risks, and enable commanders and support elements to make informed decisions and allocate resources accordingly.

The advancements in commercial head mounted visual display technologies have the potential to revolutionize dismounted military operations by providing warfighters with immersive real-time information, enhancing SA, and enabling effective decision-making. The requirements for integrating HUD technologies into future dismounted system/s would include advancements in optics and display technologies, improved sensor data fusion, and continual enhancements to the system's user experience for the warfighter.

Development of lighter weight, higher resolution, and operationally durable holographic displays that could overlay AR information into the visual space of the warfighter would be essential for this concept of a dismounted system to be practical. These display concepts should be capable of withstanding extreme conditions of the military operating environment and must have very minimal latency. Additionally, personnel should optimize designs with every effort to reduce the weight of stored battery or power source that would be mounted to the head or neck area.

The continual enhanced integration of various data sources, including real-time satellite imagery, UAV feeds, and ground-based sensors, would be necessary to provide warfighters with comprehensive SA in a future contest conflict on the ground. This requires

continual investment into robust data processing capabilities at various levels within the fighting formation with reliable connectivity.

Personnel would need to continually refine and optimize the user experience to translate large amounts of data into a viable decision-making aid for dismounted system operators on the ground. Intuitive and user-friendly interfaces that allow warfighters to interact with the holographic displays using voice commands, gestures, or eye-tracking technology would enhance effectiveness and allows system operators to focus on primary warfighting tasks. Personnel should continually optimize the system to minimize cognitive load and allow for quick decision-making in quickly evolving combat situations.

The utilization of loitering munitions or kinetic UAV technology for targeted strikes has become increasingly prevalent in current conflicts. A future military system must exhibit a high degree of precision, reliability, and adherence to force escalation policies. Investments in advanced target recognition and further improvements to encrypted communications networks would need to continually occur in the coming years.

Continual refinement and development of sophisticated ML algorithms and computer vision technologies would be required to enable accurate identification and classification of targets. This requires resourcing and the constant improvement of extensive training datasets, and ongoing refinement to minimize false positives and negatives of potential targets to ensure successful kinetic strikes in the enemy.

As with any military system involving data transmission, personnel must prioritize increasingly secure communication protocols to prevent unauthorized access or manipulation of UAV assets. They must implement encryption techniques to ensure the integrity and confidentiality of data transmission while also balancing the power requirements and lower bandwidth communication constraints that are resident within any dismounted system that is employed for dismounted combat operations.

A future dismounted decision aid systems incorporating individual status tracking, advanced HUD display technologies, and long-range strike capabilities require a multidisciplinary approach, combining advancements in sensor technology, AI algorithms, optics, and improved communication systems. While these technologies offer immense

potential for enhancing military capabilities, technological advancements and investment across many areas would need to occur for the system to be viable for the dismounted warfighter. By addressing the outlined requirements stated previously in this section, a future dismounted decision aid system would facilitate optimal decision-making, enhance SA, minimize casualties and collateral damage, and make for a for more capable and lethal dismounted fighting force in our nation's future conflicts.

AI/ML pipelines are utilized by SMEs to develop robust models for the evaluation of systems. These pipelines also allow for full scale training and deployment of AI/ML capabilities in which higher level computing performance is a factor for critical mission success. According to Bono and Patel (2023), advancements in AI capabilities will be achieved in the organized and structured transfer of information via ML operations such as intelligence sensors; Project Linchpin has brought this kind of pipeline to the Army. "Adopting industry best practices for AI and machine learning pipelines creates dual-use opportunities and encourages an ecosystem of partners for the Army and the Department of Defense that can ensure that the United States maintains an advantage over adversaries in AI" (Bono and Patel 2023). The jury is still out as to whether the current expenditure in AI/ML operations will be fruitful, additionally the future investments in the ever-evolving technology has the potential to be significant. The question is do the costs outweigh the benefits?

The truth is that the history of the dismounted soldier in war is one of increasing clarity and security. Technological advances in communication lift the fog of war and similar advances in medicine and protection increase the chance the soldier makes it home. The future holds more of the same. An AI-enabled soldier would be confident knowing roads would be cleared by autonomous vehicles and reconnaissance would be faster and more accurate thanks to aided target recognition. But maybe most important, as the characteristics of war change to welcome AI/ML on the battlefield, when that soldier is wounded in action, sensors would instantly alert generative AI to automatically employ life-saving targeted treatments. Humans and machines working together through AI/ML capabilities would empower soldiers to have a competitive advantage and combat overmatch over our adversaries.

The AI/ML wargaming tool discussed in this report is only the beginning of what this technology could achieve and provide to the dismounted soldier. With the continued development in the AI/ML field, it is inevitable that its role in military operations will continue to evolve as well. “It is an enabling capability, akin to electricity, the internal combustion engine, or computers, and as such, it is the decisions of human beings that will determine whether AI will advance or undermine our efforts to make the world safer and more prosperous” (Defense Innovation Board 2019, 5). Society must be cognizant that its role in the evolution of AI/ML would influence the future of how countries fight wars, and ultimately the way humankind lives their day-to-day lives.

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APPENDIX. THE HEALTH INSURANCE PORTABILITY AND ACCOUNTABILITY CONUNDRUM

HIPAA has wide-ranging implications for healthcare institutions and providers. The HIPAA Act was passed into federal law in 1996 with the original intent of increasing the number of Americans covered by health insurance and to make healthcare delivery more efficient. What came from the implementation of the act was a logistical nightmare for providers who were tasked with ensuring patient's private health information would be protected and not disclosed without the patient's express permission in an environment where digital data storage and sharing is under constant surveillance and attack.

For the purposes of the active-duty military members, PHI can be shared under specific circumstances in accordance with the Military Command Exception (U.S. Army 2022). The exception includes a variety of instances where a healthcare provider can share pertinent health information about military members to Command authorities who need the information to make decisions. For example, Command may ask the healthcare provider if members are fit for specific active-duty requirements prior to deployment. Conversely, healthcare providers are permitted to share healthcare information with the command group if there is concern that a member's health may interfere with personal safety, the safety of others, or compromise the mission.

The Military Command Exception is widely used throughout the military service branches and could be implemented into the physiologic monitoring system requirements for the purposes of this project. Within the rules of the exception, a specific clause regarding Special Personnel is perhaps best suited to this project. The clause delineates the urgency that real-time reporting in combat scenarios would require.

The service member is in the Personnel Reliability Program or is in a position that has been pre-identified by Service regulation or the command as having mission responsibilities of such potential sensitivity or urgency that normal notification standards would significantly risk mission accomplishment. (U.S. Army 2022)

While the Military Command Exception is useful in a variety of situations, it is vitally important to ensure that the data shared in a real-time combat scenario is fully

protected against outside intrusion. Providing secure data transfer protects the mission, the team, and the individual service member. Future success depends on expanding the security of information as technology expands.

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