Beyond DOTMLPF-P:
A New HMI Paradigm By 2040

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Beyond DOTMLPF-P:
A New Human-Machine Integration Paradigm by 2040

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About This Document

The members of Team Future Storm produced this collective strategic research project as a prerequisite to completing the Master of Strategic Studies program at the United States Army War College (USAWC). This report's research, analysis, and production were conducted from October 2023 through May 2024 as part of the Army Futures Seminar for the Academic Year 2024.

Figure 1: Team Future Storm's logo

Requirements

This report answers a strategic question posed by GEN James E. Rainey, Commanding General, United States Army Futures Command, based on open-source information and interviews with subject-matter experts. (See Annex A)

How will human-machine integration (HMI) between 2030 and 2040 likely evolve the character of warfighting and necessitate changes across DOTMLPF-P to gain or maintain a competitive advantage in future military conflicts?

- What functions will likely remain human/CDR-centric, aided by machines?
- What processes, educational initiatives, and tools will likely develop a military workforce that can ask the right questions and frame decisions to fight and win in a data-centric environment?

The team's results were presented in various formats: primarily an abbreviated report, a complete digital PDF, and a soft-bound book. They employed several methodologies to identify key findings and points of convergence, such as interviews with subject-matter experts, analysis of scholarly publications, open-source reporting, network analysis, and the nominal group technique.

Words of Estimative Probability

The research team members used Kesselman's List of Estimative Words for determining their Words of Estimative Probability (see Figure 2 and Annex D) for determining how likely HMI will evolve the character of warfighting and necessitate changes across DOTMLPF-P to gain or maintain a competitive advantage in future military conflicts between 2030 and 2040.

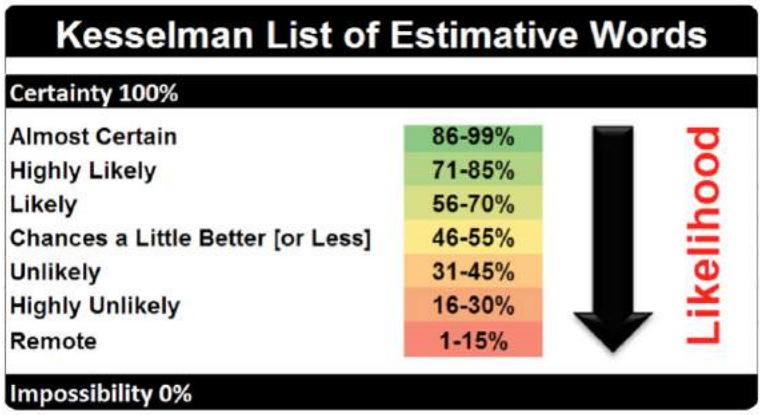

Figure 2: Team Future Storm used Kesselman's list of estimate words to show probability. Source: Verbal Probability Expressions

Source Reliability

Source reliability is noted at the end of each citation as low (L), moderate (M), or high (H). The citation is hyperlinked to the source. Source reliability is determined using the Trust Scale and Website Evaluation Worksheet (see Annex F). Sourced figures and photos embedded in this report are hyperlinked to their source.

Analytic Confidence

The analytic confidence for our overall findings is *moderate*. Team Future Storm evaluated analytic confidence using the Peterson analytic confidence factors coupled with Friedman Corollaries (see Annex E). Sources were reliable and tended to corroborate one another. The team validated responses from various AI tools including ChatGPT, Perplexity, and Elicit, among others, which amplified our further research. All information and sources were accessed through an unclassified, open academic network. Furthermore, given the lengthy time frame of the findings, this report is sensitive to change due to new information.

Key Findings

How will human-machine integration (HMI) between 2030 and 2040 likely evolve the character of warfighting and necessitate changes across DOTMLPF-P to gain or maintain a competitive advantage in future military conflicts?

- What functions will likely remain human/CDR centric, aided by machines?
- What processes, educational initiatives, and tools will likely develop a military workforce that can ask the right questions and frame decisions to fight and win in a data-centric environment?

Between 2030 and 2040, HMI is highly likely (71-85%) to fundamentally reshape the character of warfare globally, affecting all elements of force design (DOTMLPF-P) and every military warfighting function. Despite this widespread impact, the transformation is unlikely to be evenly distributed (see Figure 1). In fact, it is likely that the convergence of key technological, societal, industrial, and governance trends over the next 15 years will focus this transformation in five distinct areas:

- HMI-Enhanced Command and Maneuver
- Ethical AI-Enhanced Decision-Making
- Future-Proofing Military Capabilities
- Future Support Infrastructure
- Sunsetting the DOTMLPF-P Paradigm

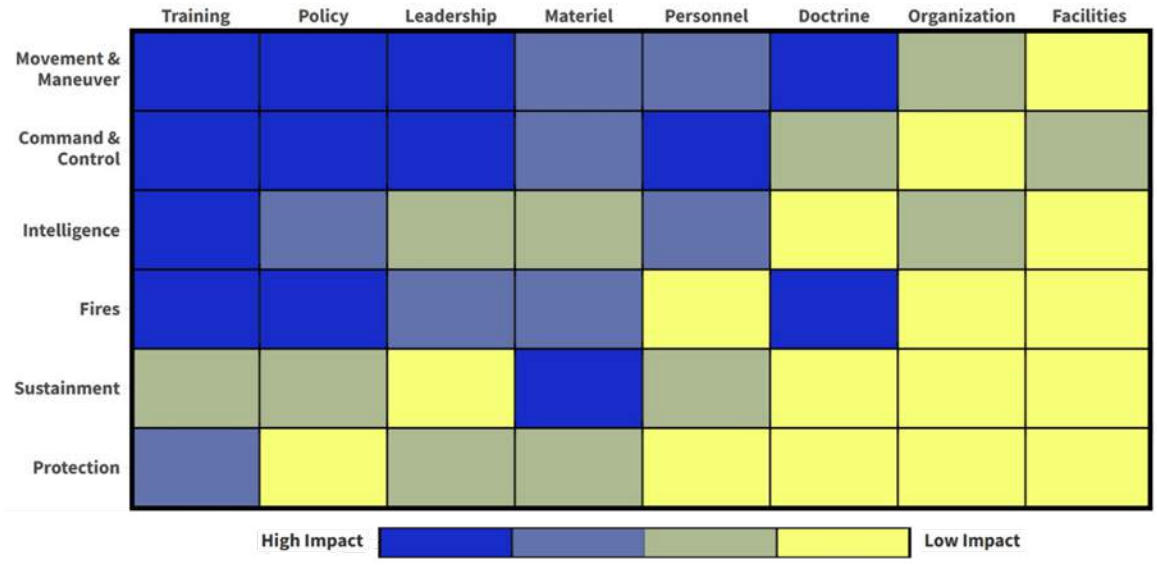

Figure 1: This chart shows the intersection of the DOTMLPF-P elements with Warfighting Functions and the forecasted impact of HMI systems and processes on each from high to low. Source: Team Future Storm

First Key Area: HMI-Enhanced Command and Maneuver

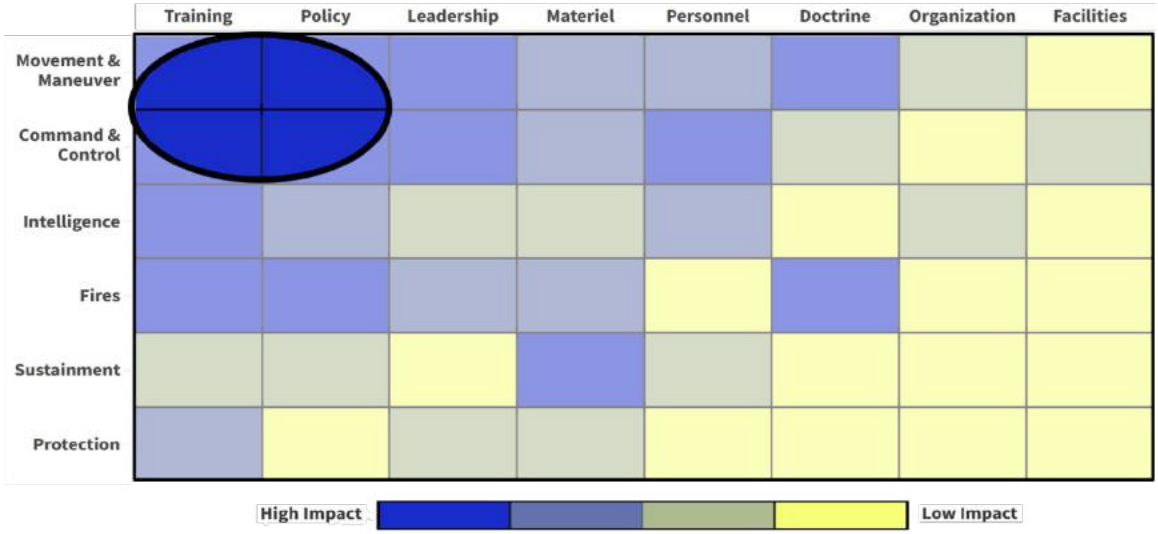

Figure 2: The first key area captures the high impact between Training/Policy with M2/C2. Source: Team Future Storm

By 2040, HMI systems will likely drive advances in combat capabilities in Command and Control (C2) and Movement and Maneuver (M2) primarily through training and policy force design elements (see Figure 2). Beyond well-documented innovations such as autonomous systems, the convergence of one doctrinal innovation, two novel HMI-affiliated technologies, and an emerging pedagogical process will likely accelerate these advances: tactical playbooks, lightweight and ubiquitous AR/VR technology, Brain-Computer Interfaces (BCI), and microlearning. Additionally, HMI ethical policies, while often late or incomplete, will likely serve to highlight the significance of the human component in these advancements. Militaries that master this convergence will highly likely gain the ability to continuously learn and adapt in real-time on the battlefield and rapidly distribute new knowledge to the rest of the force.

- Tactical playbooks. A dramatic extension of the Mission Command philosophy, a "playbook" mentality is likely to serve a human-machine integrated force best. Dr. Jaclyn Hoke, Associate Director for Unmanned and Advanced Programs with Collins Aerospace, "Like a quarterback who calls a play, when humans set the directive, the systems should understand and execute based on that guidance. Pursuing this 'playbook autonomy' is essential for effectively integrating autonomous systems into our comprehensive defense strategy."

- Lightweight and ubiquitous AR/VR. As AR and VR devices become sleeker and more advanced, militaries optimized with HMI will likely conduct high-fidelity training instantly and anywhere, including on the battlefield. These technologies

have proven valuable across various fields. For instance, the New York Police Department uses immersive simulations for emotional detachment training, reinforcing fairness and helping officers make unemotional decisions.

- BCIs. Noninvasive BCIs will likely be an advanced way to interpret brain signals to communicate with humans and machines. A noninvasive BCI can send and receive thought-activated messages, utilizing an electronic "middleman" device for stealth communication. Expected to ship in 2024, the Galea Beta device from OpenBCI (see Figure 3) integrates physiological sensors that monitor brain, heart, skin, muscle, and eye activities to bridge mixed reality and neurotechnology.

Figure 3: OpenBCI's Galea creates a seamless bridge between mixed reality and neurotechnology, "paving the way for human-computer interactions that feel more like a natural extension of the user's own body." Source: Galea.co

- Advanced Microlearning. By 2040, it is almost certain that Soldiers will use microlearning for training and operational preparation. Microlearning involves concise, targeted learning segments designed for quick skill acquisition, ideal for dynamic environments like military training. Advanced microlearning incorporates adaptive AI technologies, augmented and virtual reality to simulate real-world scenarios, and mobile technology for access in any location. It also features gamification to boost engagement and data analytics to tailor and optimize learning experiences. In a Western Mail article from March 2024, Dylan Jones-Evans, who teaches entrepreneurship at the University of the West of England, pointed out that almost half of the companies, or 47%, are projected to implement microlearning tactics by the end of 2024.

- HMI Ethics Policy. Integrating human ethical decision-making with AI's computational power combines precise machine data with human judgment and values at speed. Organizations will likely need to adapt their ethical approaches to this new structure, and governments will almost certainly need to define related policies. Carnegie Mellon University's Software Engineering Institute combined deontological ethical frameworks with machine right/wrong decisions improving the effectiveness of HMI systems in C2 decision-making scenarios and increasing trust, accountability, and usability.

Second Key Area: Ethical AI-Enhanced Decision-Making

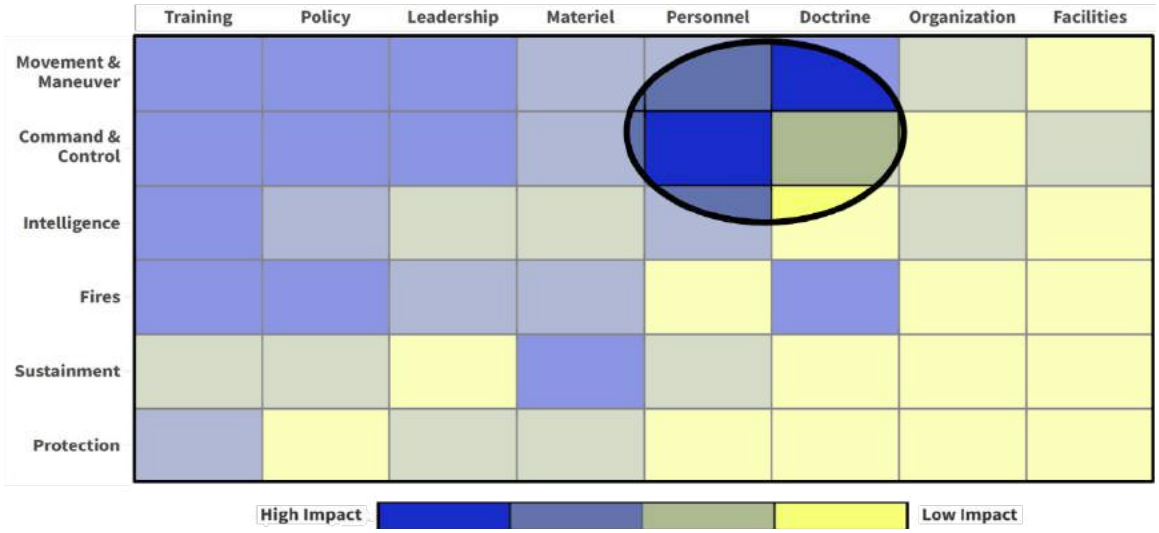

Figure 4: The second key area highlights the intersection between Personnel/Doctrine and M2/C2. Source: Team Future Storm

By 2040, it is highly likely that HMI will enhance AI ethical decision-making in C2 and M2, primarily affecting personnel and doctrinal elements (see Figure 4). Grounded in the human dimension, this finding lists three innovative techniques and protocols likely to boost this efficiency: AI-optimized decision-making at speed, "artificial wisdom," and AI-Informed Crisis Management. Combined with human's preexisting anthropomorphic bias, these advancements are likely to impact traditional military decision-making processes in high-stakes environments, enabling quicker and more effective responses.

- AI Optimized Decision Making. Due primarily to the rapid advances in large language and large action models, advanced computer systems will highly likely be capable of analyzing unstructured and qualitative data in real-time to enhance C2 decision-making processes. Additionally, due primarily to a generational shift and the targeted education and training these systems enable, military leaders will also likely develop the skills necessary to interact with machines efficiently and

interpret their outputs. A 2023 Deloitte study emphasized this integration, revealing that combining human ethical decision-making with AI-optimized machine computing power enables decisions at near-machine speed (see Figure 5).

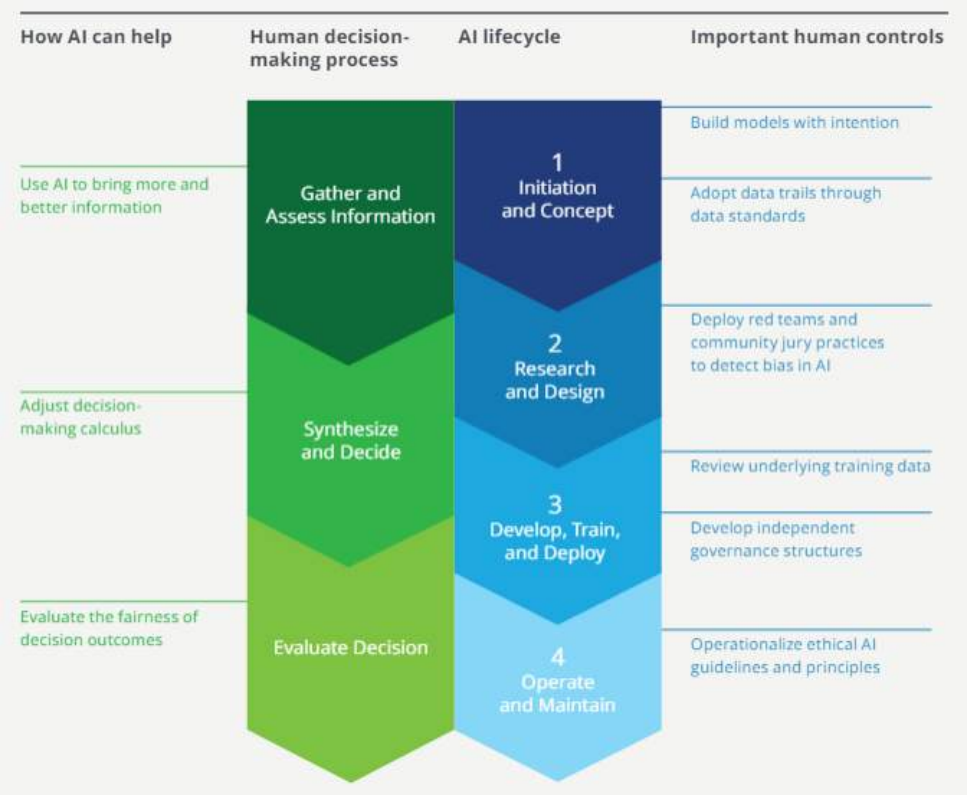

Figure 5: AI can help create fairer, more inclusive services when combined effectively with human oversight. Source: How teaming Artificial Intelligence (AI) with humans can help debias decision-making

- Artificial Wisdom (AW). Advancements in cognitive AI systems that are not merely tools of computation and analysis but are fully imbued with the capacity for ethical decision-making, empathetic interactions, and adaptive learning are unlikely by 2040. Elements of these systems and early prototypes, however, are virtually certain to find their way into ethical AI-enhanced decision-making systems as militaries increasingly recognize the need to make leaders not just smarter but wiser. Hume AI released a beta version of an Empathic Voice Interface (EVI) in March 2024; this emotionally intelligent AI, trained on millions of human conversations, can detect when users finish speaking, predict their preferences, and tailor vocal responses to improve satisfaction over time.

- AI-Informed Crisis Management. The use of artificial intelligence in managing crises is currently underexploited but is likely to become a standard protocol in resolving future emergencies. DiPLO, a non-profit established by Malta and Switzerland with support from Finland's Ministry of Foreign Affairs, is

researching AI's ability to simulate human-like conversations and strategic reasoning, which is transforming negotiations and crisis management, suggesting a future where AI's integration in diplomacy and international cooperation becomes even more profound.

- Anthropomorphism. Anthropomorphic bias, or the tendency for humans to ascribe human characteristics to non-human objects, will likely create significant new challenges as machines gain autonomy and the ability to converse. Leaders must understand that strong bonds between Soldiers and machines, are virtually certain to develop and will require sophisticated strategies and protocols for effective bias management. Dr. James Johnson, Senior Lecturer at the University of Aberdeen and advisor on AI and nuclear policy to the US, UK, and EU, notes that design choices affect user perceptions of AI interactions. AI can be programmed—or might independently learn—to suppress or exhibit human-like traits, potentially for deceptive activities like false flag operations or disinformation campaigns.

Third Key Area: Future-Proofing Military Capabilities

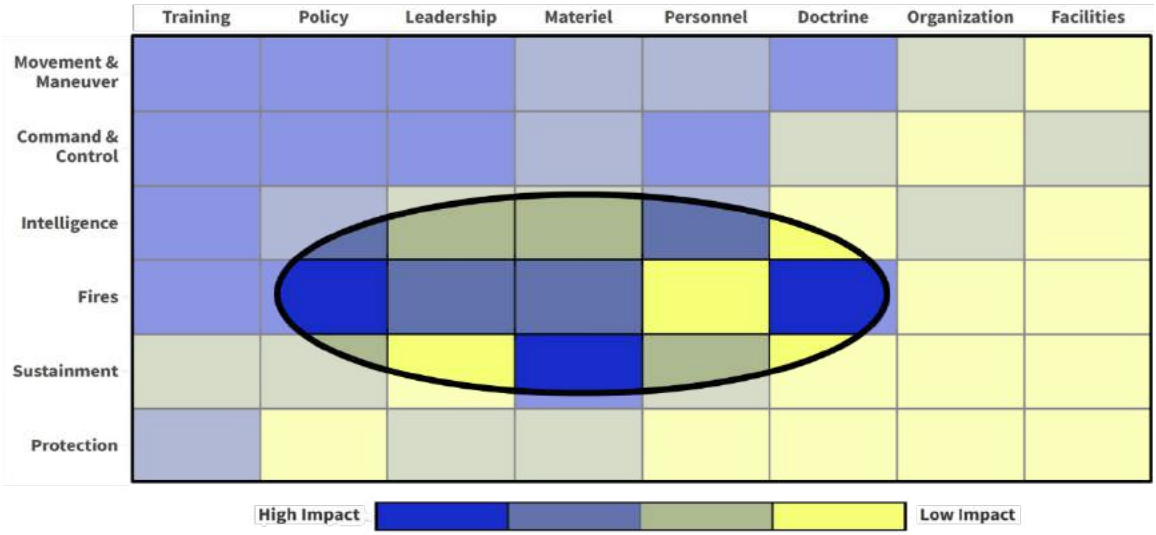

Figure 6: The third key area encompasses Intelligence, Fires, and Sustainment. Source: Team Future Storm

By 2040, advanced technology is likely to influence elements of force design such as Intelligence, Fires, and Sustainment albeit at strikingly different levels across these functions (see Figure 6). These variations are driven, in turn, by the tech industries, which largely drive innovation, and are unlikely to focus on these war-fighting functions, opting instead to pursue research into commercial products where the potential market is larger. Four emerging technologies, however, when combined, are likely to permit a

technological leap-ahead, mitigating some of the effects of the commercial focus of most tech industries. They include neuromorphic technology, which simulates human brain processes; advanced neural networks that can, among other things, expedite supply chain operations; enhancements in AI and blockchain; and the advent of meaningful quantum computing. In addition, these technologies will likely necessitate a shift towards more cognitive roles over physical ones in military personnel by 2040.

- Neuromorphic Technology. Neuromorphic technology processes sensory data such as images and sounds in human-like ways, which will likely enable more natural responses from systems used by Soldiers. This technology will likely drive smaller form factors for HMI systems by reducing the power needed for processing. A good example of the potential of neuromorphic computing is the NeuRAAM chip. Developed in 2022 by a global team of bioengineers from UC San Diego, the chip embodies neuromorphic technology that processes AI applications directly within its memory. This design greatly lowers energy use compared to traditional AI platforms, making NeuRRAM ideal for edge devices like smartwatches, AR/VR headsets, smart sensors, and space rovers. Devices with NeuRRAM-like chips can perform advanced cognitive tasks independently, without needing central servers or cloud connections.

- Advanced Neural Networks (ANN). Understanding relationships between factors like procurement, manufacturing, warehousing and transportation, ANNs will likely offer insights for inventory management and facilitate tasks in supply chain management such as evaluating and selecting suppliers based on specific criteria. Cherkasy State Technological University in January 2022 highlighted the critical role of speed in the supply chain and, through a study, demonstrated significant improvements in prediction accuracy through advanced neural networks.

- AI and Blockchain. HMI advances using AI and blockchain are highly likely to enable the seamless transfer of resilient and secure data between humans and machines is likely. The MIT Center for Transportation & Logistics highlights that by 2040, HMI will enable smoother transitions from automated systems to human-guided interventions in complex scenarios. This integration will likely increase operational flexibility, strengthen security protocols, streamline supply chain management, and enhance trust and reliability in logistics operations.

- Quantum Computing. Near the end of the 2030s, quantum computing will likely begin to transform military operations by introducing new capabilities and methods to influence data analytics, sensors, and cryptography. Google and IBM anticipate surpassing one million qubits by 2029 and 2030, respectively, marking significant quantum computational achievements.

- Military Personnel Technical Skills. Advanced HMI and autonomous equipment are almost certain to fundamentally transform the role of Soldiers and the broader culture within military institutions by 2040. This transformation will necessitate a significant shift from physicality to technological proficiency, blurring the lines between combat roles and technical specialties. In 2021 the Journal of Science and Medicine in Sport published findings supporting the warfighter transition almost certainly due to emerging technology on military human performance out to 2040 as shown in Figure 7.

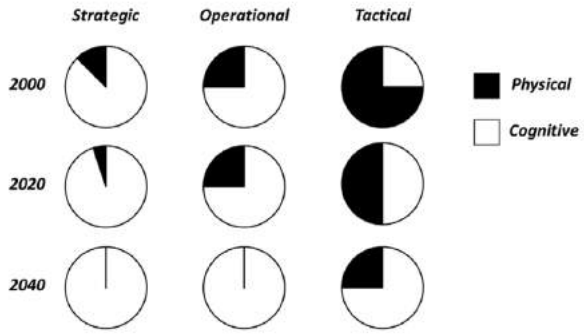

Figure 7: Transition of demand for the military warfighter from physical to cognitive at each level of war. Source: [The implications of emerging technology on military human performance research priorities]

Fourth Key Area: Future Support Infrastructure

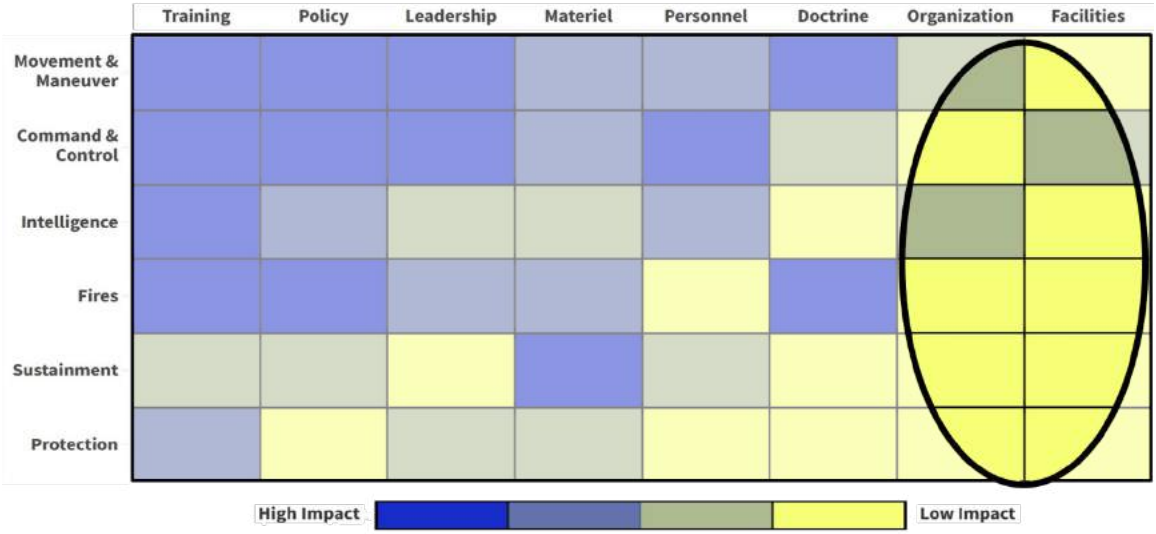

Figure 8: The fourth key area highlights the area with the lowest impact between DOTMLPF-P and the WfFs. Source: Team Future Storm

By 2040, the integration of HMI into military and industrial applications is set to redefine operational landscapes. As demonstrated in so-called "collaboration centers," the synergy between humans and machines will likely enhance performance, requiring purpose-built environments that foster effective partnerships. Similarly, the shift towards more autonomous systems will likely necessitate advanced power solutions, such as mobile microgrids and high-capacity batteries, to support increasingly energy-intensive

operations. Moreover, the evolution of 3D printing technology will likely impact supply chains, enabling rapid onsite production and repair, thus maintaining continuous operational readiness. However, these technological advancements present substantial challenges in modernizing physical facilities, which will likely evolve concurrently to support the sophisticated infrastructure required. This will likely necessitate a proactive approach to overcoming regulatory and logistical barriers to ensure that these innovations are effectively integrated and leveraged across various domains.

- Collaboration Centers. Efficient collaboration between humans and machines will likely require dedicated space to operate and integrate. Launched in 2020, a RAND Australia report continued the work started with the Royal Australian Navy's RAS-AI Strategy 2040, highlighted that the success and characteristics of HMI are significantly dependent on the willingness of individuals to incorporate robots into diverse workforce and military environments (see Figure 9).

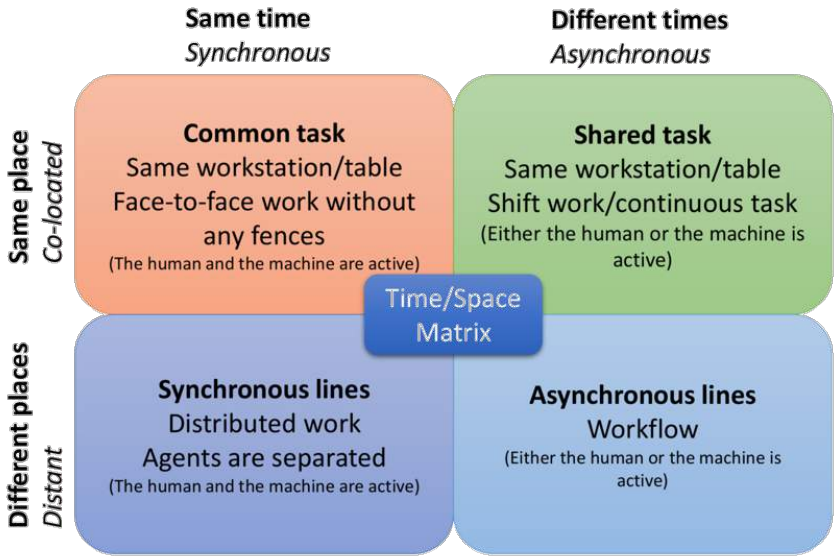

Figure 9: Johansen time-space matrix for robot-supported cooperative work. Source: [Engineering Human–Machine Teams for Trusted Collaboration]

- Power Generation. As nations deploy more unmanned equipment and aim to reduce reliance on fossil fuels, demand for electrical power generation resources is likely to grow. Microgrids, capable of operating independently in "island" mode, require significant infrastructure. Leading companies like Siemens, SEL, and Schneider Electric are pioneering the development of mobile microgrids to meet these demands.

- 3D Printing. HMI systems will highly likely need facilities and an organization capable of producing and repairing battlefield wearable equipment. As 3D printing becomes smaller and easier to operate over the next decade, this will unlock field printing of parts, quickly getting Soldiers and equipment back to full

mission capability. Industry leaders like Greg Brown from Velo3D and Jason Vagnozzi from Braskem have noted the growing importance of productivity and process control in 3D printing, which is crucial for producing complex, integrated assemblies at a lower cost.

- Facilities Modernization Challenges. Constructing or altering facilities presents numerous challenges, and even changes in unrelated areas can likely impact existing facilities. When changes occur on a large scale, these challenges can intensify, potentially surpassing the pace of facility investments. A 2021 Rand research report titled "Review of US Army Non-Materiel Capability-Development Processes" also found shortfalls with the facilities domain falling behind when the remaining force design elements of DOTMLPF-P implement changes.

Fifth Key Area: Sunsetting the DOTMLPF-P Paradigm

Figure 10: Network analysis revealed that DOTMLPF-P presents areas of interest in a stove-piped systemic manner. Source: Team Future Storm

While DOTMLPF-P is unlikely to disappear entirely, its utility is likely to fade by 2040 as HMI becomes more prevalent across the force. HMI technology combined with elevated data competency requirements will likely necessitate assessing evolving warfighting characteristics from non-traditional perspectives. Network analysis

paradigms reveal complex adaptive systems and the most influential parts of the system, the connections inside the system, and the potential outliers of the system simultaneously. Network analysis clearly shows (see Figure 10) a dynamic intersection among items inside the system, whereas DOTMLPF-P presents areas of interest in a stove-piped systemic manner.

Utilizing this network to analyze the impact of HMI by 2040, two new areas emerged that differed significantly from our earlier DOTMLPF-P findings:

- Philosophy of HMI. By 2040, the intersection of HMI and ethical decision-making will likely undergo significant transformation, requiring hard philosophical choices for military leaders. For more information, see findings underneath: "What functions will likely remain human/CDR centric, aided by machines?"
- Training and Recruiting for an HMI Workforce. Between 2030 and 2040, the development of tools, processes, and educational initiatives essential for a workforce to thrive in a data-centric environment is highly likely to increase significantly. These tools, processes, and educational initiatives, however, are highly likely to focus more on improving civilian and commercial needs than military ones, absent significant engagement. For more information, see the findings below: "What processes, educational initiatives, and tools will likely develop a military workforce that can ask the right questions and frame decisions to fight and win in a data-centric environment?"

What functions will likely remain human/CDR centric, aided by machines?

While philosophers and theologians will continue to argue about it, it is likely that there are three main frameworks (see Figure 11) for understanding the philosophy of ethical decision-making: rules-based thinking, care-based thinking, and ends-based thinking utilitarian. According to philosopher and ethicist Dr. Rushworth Kidder, these three frameworks "provide different lenses through which to see our dilemmas, different screens to use in assessing them."

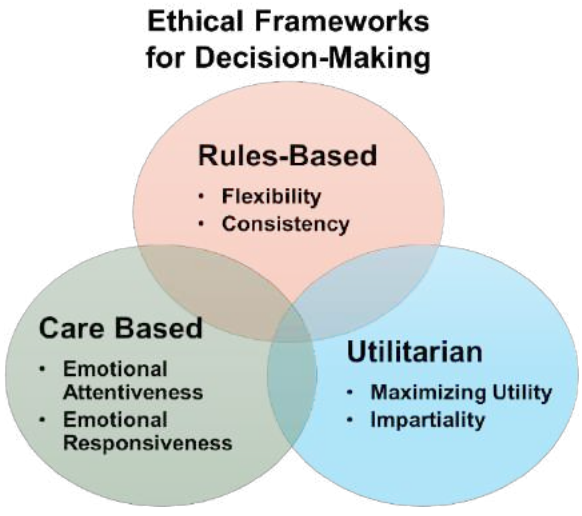

Figure 11: Rules-based, care-based, and utilitarian are the three main ethical frameworks for decision-making. Source: Team Future Storm

Each framework provides criteria to determine whether decisions should be made by humans alone, primarily by humans, entirely by machines, primarily by machines, or through a combination of human and machine efforts. Over time, the integration of these decisions is likely to increase as humans grow more trusting and experienced in working with artificial intelligence and machines. Concurrently, machines will likely develop a deeper understanding through advanced interactions and improved cognitive behaviors as technology progresses.

To graphically show this transformation, the team used multi-criteria decision analysis and nominal group technique to evaluate the six ethical criteria against the unclassified, open source research conducted over the last five months. There is currently more reliance on human decision-making in the care-based thinking aspects of emotional attentiveness and emotional responsiveness (see Figure 12). Likewise, humans can better maximize utility than machines. And lastly, humans are heavily favored in the flexibility criterion, which likely leads to better rules-based decision-making during dynamic situations.

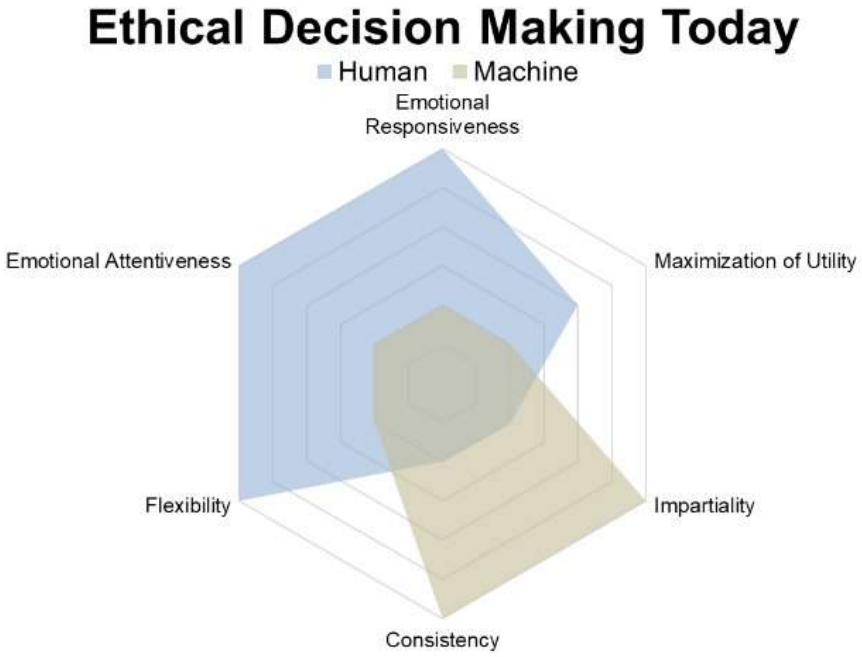

Figure 12: It is likely that machines gain ethical flexibility by learning over time. Source: Team Future Storm

By 2040, machines will likely gain flexibility by learning over time, which will likely improve AI's ability to maximize utility (see Figure 13). Furthermore, machines will also likely increase, albeit only slightly, in the emotional attentiveness area due to increased trusted interaction with humans and progress in artificial wisdom. It is also likely that because of these engagements, humans will become more consistent due to access to data and their ability to understand and process before, during, and after the decision-making process.

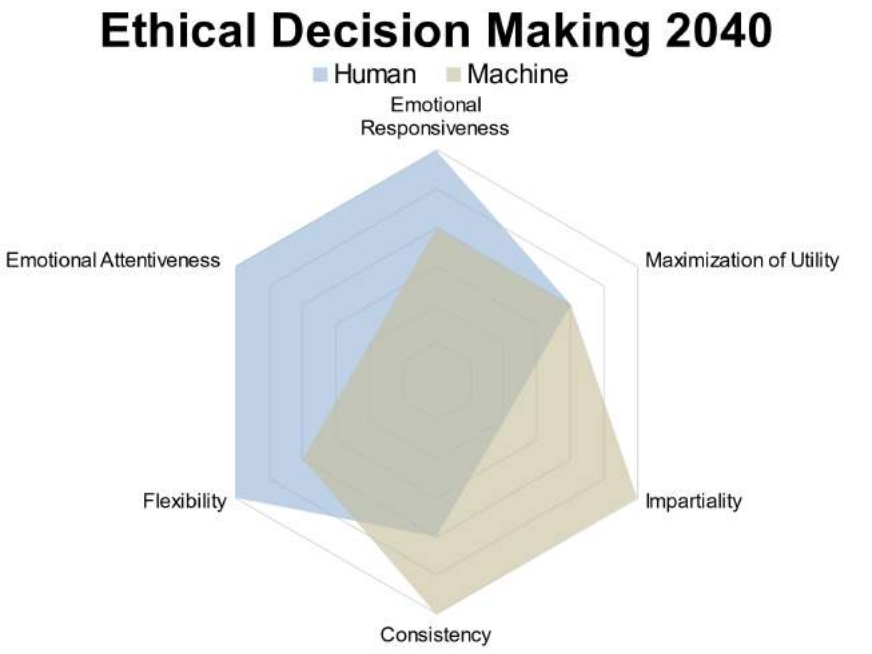

Figure 13: Humans are favored in the flexibility criterion in ethical decision-making today. Source: Team Future Storm

Note: For a complete list of human capabilities and where current large language models rank relative to humans see Annex H.

What processes, educational initiatives, and tools will likely develop a military workforce that can ask the right questions and frame decisions to fight and win in a data-centric environment?

The processes, educational initiatives, and tools that will likely develop a military workforce are proliferating at a rapid pace and are likely to continue to do so for the foreseeable future. For example, the website TheresAnAIForThat.com currently lists over 12,000 AI applications in its directory, up from a little over a thousand a year ago.

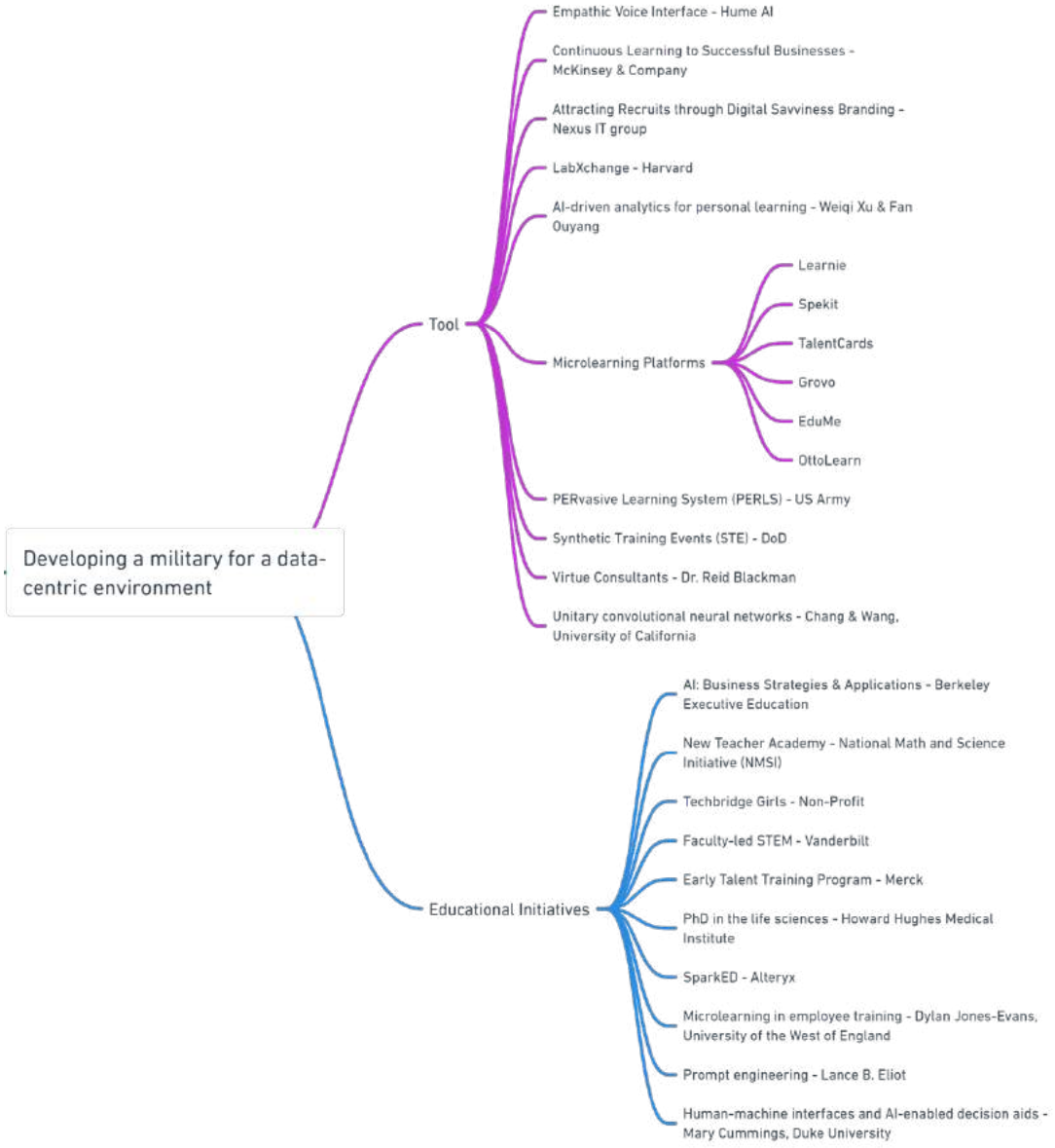

Figure 14: Mind map showing tools and initiatives that are expected to transform HMI operations by 2040. Note: The full mind map can be found in Annex B. Source: Team Future Storm

However, most of the educational initiatives and tools will likely be optimized for the lucrative business and civilian educational markets and will likely require at least some modification for use by military forces. Processes will also likely evolve to ensure a data-centric workforce knows how to interact with the tools to find maximum efficiency in operations. In addition, their impact is likely to be ephemeral as new, better products come along.

Figure 15: Mind map showing 21 processes that are expected to transform HMI operations by 2040. Note: Full mind map can be found in Annex B. Source: Team Future Storm

That said, the team identified 21 processes, 10 educational initiatives, and 16 tools that are militarily relevant and currently impacting how the workforce is developed, as shown in Figures 14 and 15. The consolidated list of all processes, initiatives, and tools is included in Annex B.

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HMI–Enhanced Command and Maneuver

Augmented Reality, Virtual Reality, And Haptic Technology Are Highly Likely Critical Components Of Future Superiority On The Battlefield By 2040

Executive Summary

Augmented Reality (AR) and Virtual Reality (VR) technology are highly likely (71-85%) to be critical components of future US military technological superiority by 2040 due to their ability to provide advanced awareness on the battlefield. From combat vehicle crew glasses to medical personnel getting remote instructions from doctors, AR and VR advances will make Soldiers training more realistic and them more lethal and adaptive on the future battlefield. While this technology is not right for everyone (some people get motion sickness), this technology will continue to advance despite the high costs and sometimes lackluster results from ambitious projects.

Discussion

Honeywell has developed a system that they say can be applied to armored vehicles, with the capability to allow ground forces to "see through" the vehicle without being exposed outside the vehicle. [M] Overlays of maps or turn-by-turn directions through AR are being tested today and are highly likely to be expanded in the next decade. [H] For the future vertical lift systems, Army pilots will have the capability to fly more than twice as fast as the current platforms allow; this means pilots will have to process information faster as they maneuver the aircraft. AI-enhanced AR helmets will allow the information to be presented to the pilot in an intuitive and understandable manner. [L]

Figure 1: Honeywell 360-degree view headset currently being tested by the US Army. Source: Honeywell shows off augmented-reality headset for tank crews

The military will make vast strides over the next decade in training simulations and AR/VR technology through Synthetic Training Events (STE). Improvements in the software and the AR/VR technology interaction will continue to make training scenarios more realistic. [H]

Advances in medical care on the battlefield during the Global War on Terror increased survivability for Soldiers on the battlefield. [H] Augmented Reality capabilities in training and on the future battlefield are likely to take this to another level. [H] Using AR, medical professionals can overlay anatomic landmarks and provide step-by-step instructions. [M]

This same technology will be expanded to include medical personnel on the battlefield and connect them with additional medical teams to help guide the patient's care. [H]

In FY24, the DOD asked for over $20 million in funding to increase gaming technology, a key component of STE, as it ramps up the use of these technologies in other areas. [M] These systems will allow Soldiers to train in realistic environments virtually that reflect the actual conditions they will see on the ground. [M] They also allow for the programs to be modified and changed as technology and techniques change on the future battlefield. [M]

One significant drawback to current AR/VR technology is the potential for motion sickness from using the devices. To address this, Apple has developed a new chip to handle the task of real-time processing for sensors. [H] The National Institute of Health conducted a study and found ways to reduce motion sickness in real time that individuals can apply as they are using the devices. This was found to be very effective. [H]

Technology companies developing AR and VR systems have met with numerous setbacks and delays. Google has invested millions and has launched and canceled several forms of glasses that did not make an impact in the market. [H] This is like what the US Army experienced in the late 1990s and early 2000s with the Land Warrior System; the Army spent over half a billion dollars only to cancel the program after setbacks, delays, and equipment that didn't work as desired. [M] This matters because, despite these setbacks, both Google and the Army have revived those programs as the technology continues to advance. [H]

Analytical Confidence

The analytic confidence for this estimate is *high*. Sources were generally reliable and tended to corroborate one another. All information in this estimate came from unclassified sources. This estimate was completed under time constraints, the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame (out to 2035) of the estimate and the speed at which this technology is advancing, this report is sensitive to change due to new information.

Author: LTC Tyler J. Waterhouse

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Brain-Computer Interface Technology Highly Likely To Enhance A Soldier's Efficiency With Cognitive And Physical Enhancements By 2040

Executive Summary

The potential of noninvasive brain-computer interface (BCI) technology by 2040 is highly likely (71-85%) to revolutionize military operations by enhancing cognitive capabilities, aiding in physical rehabilitation, improving communication and training, and enabling direct control of technology. However, there are concerns that the low accuracy in interpreting noninvasive brain signals will likely (56-70%) inhibit BCI from being reliable. Machine learning and higher computer processing will likely increase the ability to translate signals from the brain accurately.

Discussion

Brain-computer interface (BCI) technology, which enables direct communication between the brain and external devices, bypassing the normal neuromuscular pathways, has a wide range of applications, from healthcare to entertainment. [H] In the field of BCI, both invasive and non-invasive methods have been explored. Invasive BCIs, while offering high performance, are associated with high risk and cost, making them less accessible to healthy users. [H] Non-invasive BCIs, such as those using EEG, have been used for diagnosis and rehabilitation of brain diseases, including epilepsy and brain tumors. [H] This paper explores the anticipated advancements in non-invasive BCI technologies by 2035.

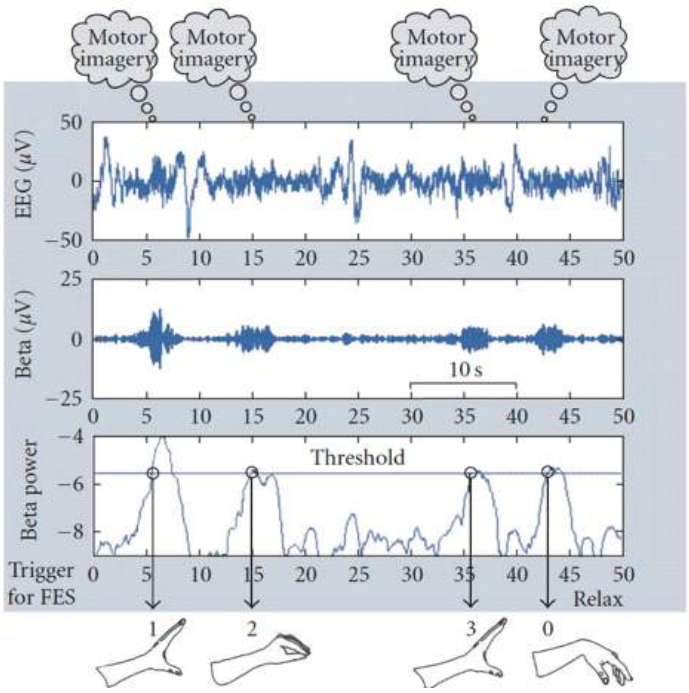

Figure 1: Example EEG signals to control a prosthetic hand. Source: EEG-Based Asynchronous BCI Controls Functional Electrical Stimulation in a Tetraplegic Patient

Physical capabilities can be assisted with non-invasive BCIs, especially in the realm of rehabilitation and the control of prosthetic devices. [H] By decoding neural signals obtained through techniques like electroencephalography (EEG), non-invasive BCIs can translate the user's intent into control commands for external devices without physical movement (see Figure 1). [H] This

technology is particularly promising for individuals with motor impairments or paralysis, enabling them to control prosthetic limbs, wheelchairs, or other assistive devices through thought. For instance, a study demonstrated how individuals could control a hand orthosis using EEG-based BCIs, showcasing the potential for these systems to restore some degree of independence and enhance the quality of life for people with severe physical disabilities. [H] The continuous improvement in signal processing and machine learning algorithms further enhances the efficacy and accuracy of these interfaces, making them more responsive and intuitive for users. [H] This advancement in non-invasive BCIs paves the way for broader applications to aid in human-robotic control. [H] The BCI can transfer functions activated by hand gestures or keystrokes to brain-controlled functions. [H] This frees up the hands for other controls, such as controlling the appendages of a robot.

Non-invasive BCIs have shown significant promise in assisting and enhancing cognitive capabilities by facilitating direct communication between the brain and external devices without surgical intervention. [H] These technologies primarily utilize EEG to capture brain signals, which can be interpreted to understand the user's intentions or cognitive states. One of the key applications of non-invasive BCIs in enhancing cognitive capabilities is neurofeedback training, where individuals can learn to modulate their brain activity to improve attention, concentration, and mental relaxation. [H] This research has demonstrated that EEG-based neurofeedback can improve artistic performance, music quality, and creative thinking by enhancing the flow state and reducing performance anxiety levels among performers. This exemplifies the potential of non-invasive BCIs in therapeutic settings and in optimizing cognitive functions in healthy individuals, opening new avenues for improving decision-making under pressure—a common challenge in military operations.

Non-invasive Brain-Computer Interfaces (BCIs) have the potential to significantly enhance military command and control systems by providing a direct communication channel between the human brain and computer systems. [H] BCIs can be used to control a complex robot swarm or be paired with computer vision for faster interaction, elevating the cognitive load on operators and potentially improving reaction times in critical situations. [HH] By enabling commanders to directly interface with digital maps, surveillance feeds, and other data sources with augmented or virtual reality, adding BCIs is almost certain to streamline the flow of information, leading to more informed and timely decisions on the battlefield. [H]

Figure 2: Commercial BCI-EEG available on Amazon. Source: MindWave Mobile 2

Several non-invasive BCI systems have been developed and are available for various applications, ranging from medical rehabilitation to gaming and consumer electronics. Companies like Emotiv, NeuroSky, and OpenBCI have commercialized EEG-based BCI headsets designed for consumer use, enabling gaming, mental health, and cognitive training applications (see Figure 2). [HHH] These headsets allow users to control computer applications or games using their brainwaves, demonstrating the potential of BCIs in everyday technology interactions. Furthermore, advanced research prototypes, such as the OpenBCI platform, offer customizable EEG systems for hobbyists, researchers, and developers, promoting innovation and broader applications of BCI technology. [H]

One of the significant challenges likely facing non-invasive BCIs is their accuracy and reliability; a study showed accuracy rates for an invasive BCI to control a robotic arm to grab a softball ranged from 20.8% to 62.2%. [H] Reliability with noninvasive BCIs is more difficult due to the variability in signal quality and the susceptibility to environmental noise and artifacts such as muscle movements or electrical interference. [H] Advances in human-machine learning, computer processing, and BCI training are highly likely to improve the reliability and usability of non-invasive BCIs in real-world settings. [H] Recent advances with Google's Nueralink show great promise in accuracy and receiving government approval. [HH]

Figure 3: Google's first Neuralink patient describes his experience with an invasive BCI. Source: First Neuralink Patient Leaves Audience Speechless

Analytic Confidence

The analytic confidence for this estimate is *high*. Sources were generally reliable and corroborated one another. ChatGPT 4, Elicit, Perplexity, and other generative AI sites were used, and ideas from the results were utilized in further research. Elicit and Perplexity suggested sources that were validated and then used as references. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information, especially any hurdles or discoveries that may affect development.

Author: LTC Allan S. Jackman

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Microlearning Is Almost Certainly How The Military Trains For A Human Machine Integrated Battlefield by 2040

Executive Summary

Micro-learning, a just-in-time learning strategy, is almost certainly (86-99%) how the military trains for a human-machine integrated battlefield by 2040 based on the availability of multiple platforms suitable for micro-learning, increased investments in this area, and the successful application of micro-learning in other industries. These factors create a conducive environment for integrating micro-learning into military training. Despite these positive indicators, keeping content constantly relevant represents a significant barrier to use.

Discussion

In a Western Mail article from March 2024, Dylan Jones-Evans, who teaches entrepreneurship at the University of the West of England, Microlearning integrates training into employees' daily workflow, allowing them to learn in small, digestible pieces and immediately apply new knowledge to address current challenges. [H] This approach enriches learning and significantly boosts retention and practical skill application. [H] It's anticipated that by 2024, 47% of all companies will adopt microlearning strategies, demonstrating a strong commitment to the evolving needs of today's dynamic work environment. [H] According to a recent Forbes Article, online

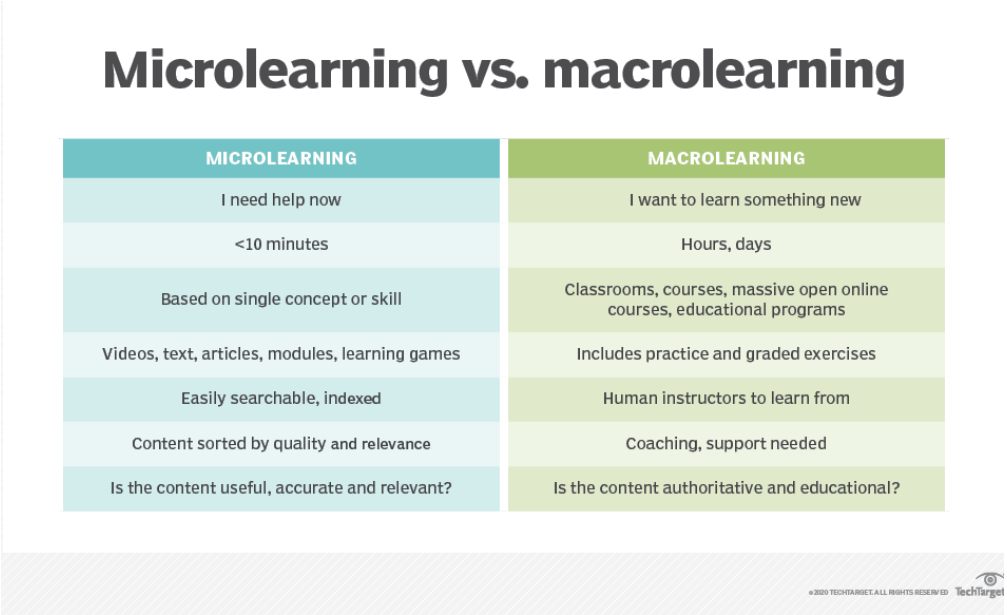

Figure 1: Microlearning vs. Macrolearning. Source: Definition: microlearning (microtraining)

education technology platforms like Udacity, Coursera, Udemy, and EdX fuel the increasing popularity of lifelong learning. [H] These platforms cater to the growing need for continual skill renewal and enhancement in response to the rapid pace of technological

change. [H] They facilitate a microlearning model, which allows learners to periodically update their skills in a more manageable and focused way. [H]

The study "Microlearning and Online Simulation-Based Virtual Consultation Training Module for the Undergraduate Medical Curriculum" showcases impactful results in medical education. [H] It reveals that using microlearning and simulation-based training significantly enhances students' skills in virtual consultations. [H] Notably, 95.7% of students found the module beneficial, and 95.9% reported a boost in self-efficacy for conducting virtual consultations. [H] This innovative educational approach effectively prepared students for contemporary medical practices, reflecting the efficacy of integrating modern learning methods into medical curricula. [H] Based on another study on teacher professional development, microlearning is an effective tool that can cater to teachers' needs for continuous, on-demand professional development. [H]

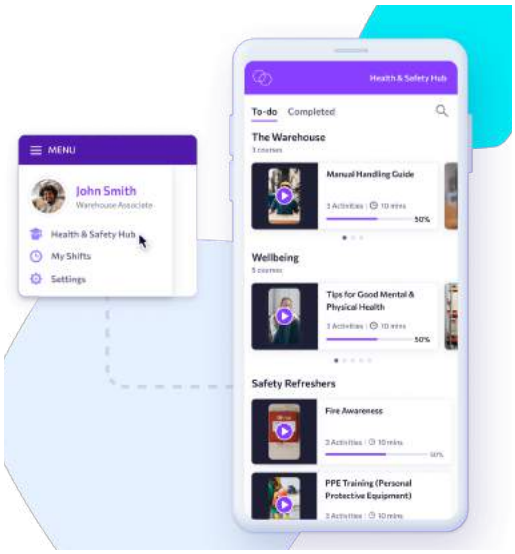

Figure 2: eduMe Example. Source: eduMe

In 2024, Pazcare showcases top microlearning platforms, each serving distinct training needs. [M] Learnie stands out as a cloud-based platform, focusing on private learning for businesses, featuring user-generated video courses. [M] TalentCards offers a mobile-friendly flashcard format, ideal for frontline workers, with quick, engaging training like compliance and safety. [M] Spekit serves small to mid-size firms with in-app learning and a suite of tools including microlearning and content analytics. [M] Grovo provides a vast library of over 2500 lessons, customizable for various topics, suited for medium to large businesses. [M] EduMe is designed for deskless workforces, offering easy-to-use, mobile-based training. [M] Finally, OttoLearn introduces gamified microlearning, improving employee productivity and knowledge retention across business sizes. [M]

The PERvasive Learning System (PERLS) in military education utilizes microlearning techniques to enhance self-regulated learning, self-efficacy, and behavior in an Army schoolhouse setting. [H] PERLS, designed in line with the science of learning recommendations, combines deep-level questions, immediate feedback, and bite-sized content, aligning with the U.S. Army's goal to integrate adaptive, personalized learning experiences into its training programs. [H] The study yielded that this learning method was effective for military students. [H] A recent study in the Journal of Military Learning

uncovered a use rate of 40%, highlighting the need to understand hesitancy in adopting this learning method. [H]

Despite the benefits, studies have identified keeping content relevant in a changing environment as a consistent struggle. [H] Organizations aiming to integrate microlearning applications must align employee-shared information with the app's design framework. [H] The role of a content manager becomes crucial, requiring support from higher management to maintain uniformity in content design, irrespective of the employee contributing the information. [H] To facilitate this, content managers should prepare a variety of microlearning material examples, like infographics, podcasts, and videos, along with design guidelines, to assist employees in creating content that adheres to microlearning principles. [H] The format of microlearning content should be tailored to the learner's environment. For instance, sales personnel on the road may prefer podcasts, while those on noisy sales floors might benefit from non-audio, mobile-first content. [H] Conversely, a manager seeking information on specific tasks might find quick-reference guides, infographics, or short videos more useful. [H] Thus, the learner's work setting significantly determines the most effective microlearning format. [H] Crowdsourcing material for microlearning introduces a variety of viewpoints and innovative ideas, thus improving the quality and applicability of educational resources by leveraging the shared wisdom of a broad audience. [H] Utilizing external content in the realm of legal and compliance education can maintain information both pertinent and recurring, which in turn bridges learning disparities and boosts the overall efficacy of the training. [H]

Analytical Confidence

The analytic confidence for this estimate is *high*. Sources were reliable and tended to corroborate one another. ChatGPT was used, and ideas from the results were utilized in further research. ChatGPT, Google Scholar, and ProQuest suggested sources that were validated and then used as references. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information.

Author: Lt Col Joseph G. Dolce

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Balancing Innovation With Moral Responsibility Highly Likely To Be Critical To The United States Military By 2040

Executive Summary

Leaders and individual Soldiers are highly likely (71-85%) to have to navigate the decision-making process using the technology they have available, and in the future, that is highly likely to be human-machine integrated teams. Using ethical frameworks and the advanced information power of machines, leaders will be required to make ethical decisions at increased speed. Organizations will need to adapt their ethical approach to fit within the new structure. Governments will need to translate these activities into definable policies. Despite increased automation in systems, it is highly likely to require dedicated training for the humans using the systems.

Discussion

There are many new ethical challenges facing the world with the advent of new emerging technologies. Deep Fake AI, biased algorithms, brain-computer interfaces, lack of transparency in data usage, and prompt engineering are just a few of the issues identified today as having ethical concerns, and they are highly likely to continue to 2040. [H] Each of these presents (among other things) a potential for an ethical dilemma. Dr. Reid Blackman, author and founder of Virtue Consultants, an ethical risk mitigation firm, stated that companies need to do two things: first, identify what ethical issues they are trying to avoid, and second, ask: how do we systematically and comprehensively ensure those things don't happen? [H]

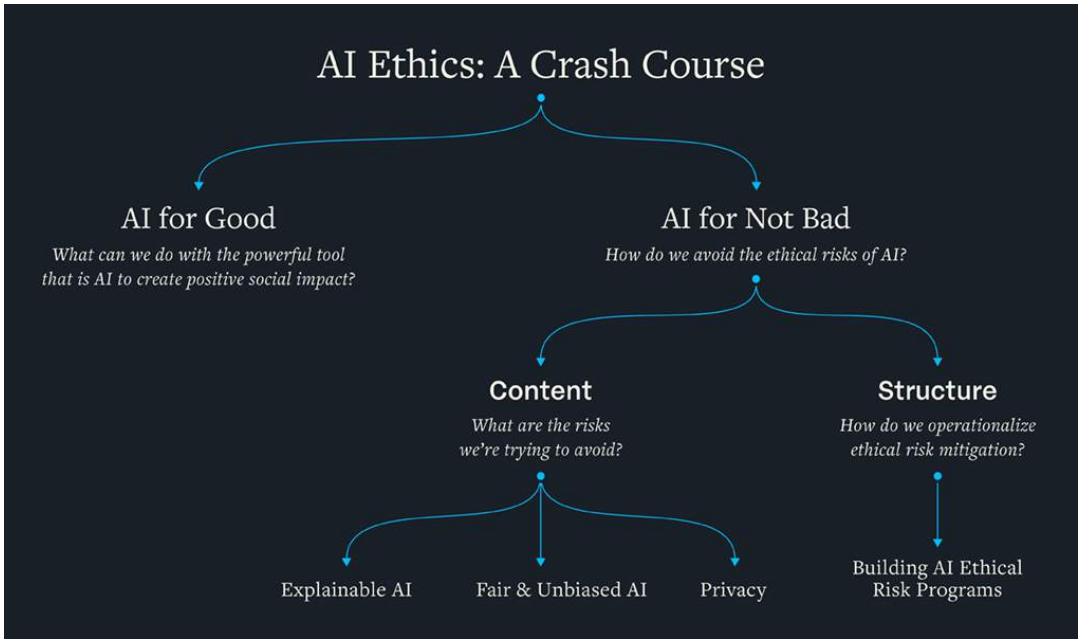

Figure 1: AI Ethics flow chart from Dr. Reid Blackman. Source: Crash Course on AI Ethics

Ethical frameworks are a way to frame potential ethical problems and try to determine what action leads to moral acceptability (see Figure 1). [H] The US military, for example, is typically very deontological in its framework, the idea that one needs to do their duty in a way that strives to make every decision a moral one and ensure the actions that result from that decision are in keeping with the high moral and ethical standards that it maintains for itself. [H] While this framework works for most human-based ethical decisions, AI systems are good at making rules based decisions. [H] The combination of these two frameworks can give the future Soldier the ability to make ethical decisions at speed. [H]

An example of a new technology on the horizon that has potential military capabilities, but extreme ethical concerns is brain-computer interface (BCI) systems. (See Brain-Computer Interface) These systems aim to enable direct communication between the brain and external devices. An ethical concern is the extent to which a person will be held accountable for the actions of the device. [H] A critical concern for a Soldier who might be using this technology to control an entire swarm of drones on the battlefield. [H]

Figure 2: Soldier with a BCI testing device. Source: Neurotechnology overview

A 2020 Rand Study listed the future warfighter with BCI as potentially having the capability to "make decisions more rapidly due to advances in AI, enhanced connectivity, and autonomous weaponry." [H] The speed of decision-making will be increased dramatically because of the advanced computing power of AI. [H] By integrating human ethical decision-making with the computing power of AI, it puts the precision of the machine data with human judgment and morals at speed. [H]

There are already concerns about biases in prompt engineering of large language model AI machines. (See Training In Prompt Engineering) Prompts that are purposefully used to create a bias in the system are just as dangerous as a machine that was originally programmed with bias. [M]

Figure 3: Example of recommendation to increase ethics in technology. Source: Beyond good intentions

The US Government has already begun outlining policy on the use of AI within the government. The Biden White House released an Executive Order on the safe and trustworthy use of AI, [H] that they claim is the strongest action of any government at this time. [H] The US Department of Defense updated its policy on autonomous weapons systems. (See Battlefield Use Policies) These foundational documents will drive US policy both inside the US and in its discussions with international bodies.

The increase in automated systems over the next decade is primed to go up dramatically. One World Economic Forum study estimated that by the mid-2030s, 30% of jobs and 44% of workers with low levels of education would be at risk of automation. [H] Increased automation does not negate the need for ethical conduct, it will require users that can control or complement those technical solutions with their own morals and ethics. [H]

Research by Dr. Chase Theil at the University of Wyoming found that there are specific areas of ethical decision-making that can be trained. (See Effective Ethical Decision-Making Report) Training in these areas is highly likely to be critical for leaders and Soldiers using HMI technology. The same 2020 Rand Study cited earlier also stated that "Beyond cognitive enhancement, BCI could also be used to reduce pain or to regulate such other emotions as fear." This type of statement exemplifies the concerns that many have about HMI and the impact it will have on the human side of the integrated partnership. [H] Studies like these are causing hesitation on the part of policymakers as they grapple with this emerging and rapidly evolving technology. [H] Training can help mitigate

some of those concerns and get the US in a position to lead the policy discussion with its international partners. [H]

Analytical Confidence

The analytic confidence for this estimate is *high*. Sources were generally reliable and tended to corroborate one another. AI was used for idea generation and sourcing. All information in this estimate came from unclassified sources. This estimate was completed under normal time constraints; the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame (out to 2040) of the estimate and the speed at which this technology is advancing, this report is sensitive to change due to new information.

Author: LTC Tyler J. Waterhouse

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Military Recruits Will Likely Possess Essential STEM Skills For Human Machine Integration By 2040

Executive Summary

By 2040, it is likely (56-70%) that military recruits will possess essential STEM skills for human machine integration, due to enhanced focus and investment in STEM education and results proving the use of AI and video learning. Despite persistent disparities in technology access, particularly affecting minority and low-income communities, which will likely be solved by increased mobile connectivity.

Discussion

According to the 2022 CoSTEM Progress Report the U.S. education system's shift towards enhancing STEM skills reflects the evolving demands of the military, particularly in areas like human-machine integration. [H] This report anticipates that a significant percentage of military recruits will have these advanced STEM skills by 2040, vital for modern military operations. [H] It also underscores the need for a workforce proficient in technology and digital fluency in defense and security fields. [H] The report highlights challenges like unequal technology access and educational disparities, potentially impacting the uniformity of these skills among recruits. [H]

Figure 1: Techbridge Girl's Reach. Source: techbridge girls

This commitment to developing capabilities is exemplified by substantial investments in initiatives to eliminate systemic barriers in STEM fields. [H] For instance, Techbridge Girls is receiving a $3 million investment to foster equitable extracurricular STEM learning environments, especially for black, Indigenous, and people of color, girls facing economic challenges. [H] Additionally, the National Math and Science Initiative (NMSI) is expanding its New Teacher Academy to support over 1,300 teachers, focusing on professional development for Black, Latino, and Indigenous STEM educators. [H]

Significant investments are being made in STEM education, emphasizing the importance of these fields in the current and future workforce. [H] The Amgen Foundation, for instance, has committed $43 million to support LabXchange at Harvard University, aiming to serve 50 million users by 2025. [H] Vanderbilt University is launching faculty-led STEM training across its programs with over $30 million in investments, in collaboration with Fisk University. [H] Merck and the ACRP are introducing high school and community college students to clinical research through the Early Talent Training Program, starting

with 50. [H] The Howard Hughes Medical Institute is establishing a post-baccalaureate program for 200 college graduates, aiming to enhance their readiness for a PhD in the life sciences. [H] These initiatives represent a broader trend of focusing on and allocating resources to enhance STEM education and opportunities, particularly for underrepresented groups. [H]

Figure 2: The benefits and use cases of AI in education. Source: Building smarter classrooms

In educational settings, AI has shown promising results in several key areas. [H] It has been instrumental in personalizing learning experiences, where algorithms adapt teaching materials to individual student's learning styles, often leading to improved engagement and comprehension. [H] AI-driven analytics have also enabled educators to more effectively identify and address learning gaps, contributing to enhanced academic performance. [H] Furthermore, AI tools have assisted in administrative tasks, allowing teachers more time to for student interaction and personalized teaching. [H]

The Public Policy Institute of California's report reveals that despite advancements in educational technology, significant digital access disparities persist in the U.S., especially impacting Latino, Black, and low-income families. [H] Federal funding of over $15 billion has facilitated the distribution of 2 million devices and nearly 1 million internet connections to California students in the 2020–21 school year. [H] This intervention helped increase the share of K–12 households with reliable computer access from 68% to 82% from spring to fall 2020. However, internet access only rose marginally from 71% to 75%, highlighting the challenges faced in remote and low-income urban areas. [H] While low-income and less-educated households experienced improvements in both device and internet access, Black and Latino households saw significant gains in device access but not in internet connectivity. [H] The highly likely (71-80%) expansion of mobile connectivity, as indicated in the Connectivity report, is likely to reduce these disparities.

Educational technology, as discussed in a Brookings article, provides valuable tools for improving learner engagement and understanding, particularly in areas facing digital

access disparities. [H] Self-paced video tutorials are a notable example, allowing students to focus on challenging topics and learn at their own pace, beneficial for those with limited digital access. [H] Studies like the one on the Khan Academy portal in Brazil highlighted that such technology slightly improved learners' attitudes towards math, although it didn't significantly enhance performance. [H] In contrast, a similar study in El Salvador showed a notable improvement in student performance with the use of Khan Academy, with teacher-assisted lessons leading to a 0.24 standard deviation improvement. [H] Implementing these types of technology-based learning tools can provide flexible, engaging educational alternatives and help bridge the gap in educational disparities. [H]

Analytical Confidence

The analytic confidence for this estimate is *high*. Sources were reliable and tended to corroborate one another. ChatGPT was used, and ideas from the results were utilized in further research. ChatGPT suggested sources that were validated and then used as references. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information.

Author: Lt Col Joseph G. Dolce

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Advanced Biofeedback Devices, Immersive Simulations, And Improved Intuition Drills Are Likely Core Elements Of Effective Ethical Decision-Making Training By 2040

Executive Summary

Ethical Decision-Making training is likely (56-70%) to become a crucial part of Western military training by 2040 due to advancing human-machine integration. Emerging technologies will likely enhance ethical training for military leaders and personnel, focusing on Emotional Regulation, Forecasting, Self-Reflection, and Information Integration (areas that can be trained). Advanced biofeedback devices will likely ensure engagement and effective learning, particularly in Information Integration. Immersive simulations will likely provide realistic training scenarios, aiding in Emotional Regulation, Self-Reflection, and Information Integration. Additionally, improved intuition drills, shown to reduce bias, will support Forecasting and Self-Reflection. Although these technologies have not been widely tested together in military contexts, their effectiveness in other training fields suggests they could significantly benefit ethical training.

Discussion

Enhanced ethical training for military leaders and personnel is likely to focus on Emotional Regulation using immersive simulation training. Forecasting through the use of intuition drills. Self-reflection and Information Integration training can be enhanced with advanced biofeedback devices. According to University of Wyoming Professor Dr. Chase Thiel's research, training in these four areas is essential for leaders' ethical decision-making and will be crucial for soldiers in future combat situations. [H]

Immersive Simulations have already started to become popular in many fields, including political science, law enforcement, and the medical community. Augmented reality training for medical professionals, including surgeons, has made great strides, increasing not only their speed and lowering their error rate, but it has also improved their ethical decision-making. [H] Emotional detachment training through simulations has proven useful to law enforcement in the US to preserve the principles of fairness and justice and help the officers decide to act without emotion. The addition of emotion in a critical incident is what can lead to dangerous consequences. This training protects the officer's mental health and helps remove bias from the officer's response. [H] This approach helps soldiers manage their emotions and engage in self-reflection after incidents.

Figure 1: Microsoft Hololens2, one of the AR surgical devices tested by the National Institute of Health. Source: Microsoft HoloLens 2

Improved intuition drills and training have proven effective in helping people improve their understanding of their own confirmation bias tendencies and help them make better decisions. [H] This training is essential for soldiers to build confidence in their abilities and equipment, enabling them to make ethical choices. By repeatedly exposing people to ethical scenarios, they can hone their skills and be able to recognize ethical dilemmas more quickly, increasing their time to respond appropriately. [H] The ability to repeatedly train in ethical dilemmas will improve the soldier's ability to forecast more accurately what ethical scenarios they might be facing. [H]

Advanced biofeedback devices are making a significant impact in the healthcare, gaming, and convenience industries. [H] For example, Apple applied for a patent in 2023 for "Eye Gaze Biofeedback," which they say can allow the system to determine the user's attentive state during use. [H] Being able to track the user's attention during critical ethical training scenarios will help ensure the information is received in the most effective manner. [H] The system looks at patterns in eye movement while users are performing mindful tasks. [H]

While the US Department of Defense completes yearly ethical standards training, no formal program uses these four techniques together to train Soldiers or leaders to improve their ethical decision-making.

Analytical Confidence

The analytic confidence for this estimate is *high*. Sources were generally reliable and tended to corroborate one another. AI was used for idea generation. All information in this estimate came from unclassified sources. This estimate was completed under time constraints; the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame (out to 2040) of the estimate and the speed at which this technology is advancing, this report is sensitive to change due to new information.

Author: LTC Tyler J. Waterhouse

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Ethical Concerns Around Human-Machine Integration And Lethal Autonomous Weapons Systems, Within The Changing Character Of War, Highly Likely To Remain Contentious Through 2040

Executive Summary

Human-machine integrated weapons systems and lethal autonomous weapons systems (LAWS) will be highly likely to remain a significant point of contention for the United States through 2040 due to US societal demand (and many of its allies) for moral and ethical use of weapons systems. This will be the case despite progress with outstanding concerns about artificial intelligence and the fact that some countries or actors are developing and using LAWS in an unethical manner, as the character of war is poised to change significantly with the combat application of new technology.

Discussion

As of February 1st, 2024, the United States has no policy or law prohibiting human-machine integrated weapons systems or LAWS' development or employment. [H] The Department of Defense policy (last updated in January 2023) is that LAWS or Semi-Autonomous systems be designed to "allow commanders and operators to exercise appropriate levels of human judgment over the use of force." [H] Even with commanders exercising judgment, concerns about automation bias (the human part of the integrated team deferring to the machine because they feel the information is always correct) or fears that the information will be moving too rapidly for humans to assess effectively, are not unimaginable. [H]

Figure 1: AI generated image of a lethal autonomous weapon in 2040. Created 3 March 2024 by DALL-E

Ethical concerns about human-machine integrated weapons and lethal autonomous weapons are not new, they date back to the use of land mines as an autonomous weapon. [H] Within the past year the concerns about future weapons systems with artificial intelligence have risen exponentially. [H] In December 2023, the UN General Assembly passed a resolution regarding the need to urgently address the dangers of removing human control from the use of force. [M] This resolution passed with 152 countries voting for the resolution. Of concern to the United States is those countries that abstained, China, Iran, North Korea or voted against the resolution, Belarus and Russia. [H]

Research conducted at North Carolina State University found that by infusing a human decision-making model, like agent-deed-consequence (ADC), into the machine, it can team with a human to make better decisions and close the gap in distrust. [H] This model states that moral judgments can be broken down into three components: the character of a

person (Agent), what they did (Deed), and what consequences that action had (Consequence). [H]

One significant concern is whether an Artificial Intelligence platform can make tough ethical decisions, or decisions that are both right, but one less so than another. It is easy to program machines to recognize right versus wrong, but right versus right is more complex. [H] This is a distinction that a human can make and a person whose knowledge, training, life experience, and own morals and ethics informs their decision making. The Philosopher, Rushworth Kidder, argues these types of dilemmas are rooted in our basic core values: Truth versus loyalty, individual versus community, short-term versus long-term, and justice versus mercy. [H] All can be right, depending on the person's perspective.

Another concern is that other nations (or non-state actors) may not be challenged with ethical dilemmas regarding LAWS and will seek to exploit the US's position. [M] The Russian and Ukraine war has brought drone and autonomous weapons systems to the forefront; videos of drone swarm attacks on land, sea, and air have shown the power and agility of relatively inexpensive platforms, thus changing the usually high-cost bar that put new military technology safely in the hands of a few nation-states. [H]

Ongoing debates in the international community, particularly about LAWS, are highly likely to prevent any formal policy decision for several years. Land mines, for example, have been used at volume since before World War II; it wasn't until 1980 that the UN Convention on Certain Conventional Weapons (CCW) formally published suggested protocols. The final document wasn't signed until 1997, and Russia, China, India, and the US did not sign. [H] If this is any indication about the future of LAWS, the debate will continue well into the future.

Analytical Confidence

The analytic confidence for this estimate is *high*. Sources were generally reliable and tended to corroborate one another. AI was used for idea generation. All information in this estimate came from unclassified sources. This estimate was completed under normal time constraints; the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame (out to 2040) of the estimate and the speed at which this technology is advancing, this report is sensitive to change due to new information.

Author: LTC Tyler J. Waterhouse

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Disputes In International Community About Human-Machine Integration, Lethal Autonomous Weapons Systems, And Human Trust Highly Likely To Drive The Battlefield Usage Policies Through 2040

Executive Summary

It is highly likely (71-85%) that written policy on lethal autonomous weapons systems (LAWS) will spark controversy in the United States and abroad due to trust concerns between human operators and the machines, and doubts about the machines' programmed ability to make ethical decisions independently. Internationally, leaders are struggling with how these technologies are transforming the character of warfare, and the current war in Ukraine has demonstrated the capabilities of these weapons. Non-governmental organizations (NGO) are uniting in their message and advocacy against the technology. even as numerous countries strive to enhance their technological capabilities rapidly, aiming to match or exceed the United States in future conflicts.

Discussion

The United States has been a leader in guiding the international discussion about the use of AI and LAWS in a military context, and was the first nation state to put this in an official policy [H] There are several forums where governments are discussing the future of LAWS (see Figure 1). The US Department of Defense (DoD) revised its policy on Autonomy in Weapons Systems in January of 2023, and it does not prohibit the use or development of human-machine integration (HMI) systems or LAWS as long as they are designed to give the commander appropriate levels of human judgment over the use of

Figure 1: Venues for Autonomous Weapons Systems Internationally. Source: Autonomous Weapons Systems

force. [H] The emphasis in the DoD document is on human decision-making about the use of force in the first place, not on what system is used (HMI or LAWS) to perform the force. [H]

There is currently a trust issue between the general public in the United States and letting machines make critical decisions. A 2023 Forbes survey found that 67% of adults surveyed do not want AI to make life-or-death decisions in war. [H] The data community has become sensitive to the potential for bias in the realm of machine learning due to the highly publicized issues major programs like Google's Gemini have had, the focus has now shifted to ethics and AI. [H] Paul Lushenkos's research on human-machine teaming in the United States Military found that Soldiers' trust in human-machine teaming is greatly shaped by their personal moral considerations and that trust is enhanced when the machine's use falls in line with previously established international laws of land warfare. [H] Policymakers in the United States remain sensitive to these concerns and are looking for policy options to assuage public distrust and find ways to share this burden with our allies and partners. [H]

The international community, through the United Nations, voted in December of 2023 that autonomous weapons systems use should fall under previously established international humanitarian law and international human rights law. [H] Of particular concern was spurring a new arms race and lowering the threshold for conflict and proliferation to non-state actors. [H] Other groups like Stop Killer Robots have brought NGOs from around the world together in an effort to stop the advancement of autonomous weapons systems all together. [M]

Of concern to the United States is the fact that adversaries like Russia and their close ally voted against the UN resolution, and China and Iran (among others) abstained from the vote. [H] Some of these countries have a history of stealing military technology from the US and our allies. [H] Similarly, there are some countries that have already established policies that outright bans LAWS (El Salvador 2018, Guatemala 2016, Vatican 2014). [H] The international discussions are evolving quickly, the problem for US policymakers is going to be the speed at which policy decisions are going to have to be made for the US to remain a leader on the world stage. [H] Working through the UN Convention on Certain Conventional Weapons is a slow process (debate on LAWS began in 2014) that requires consensus among the member states who advocate based on their country's position. [H]

Chinese diplomatic overtures to the UN have been focused on reaching a consensus in diplomatic channels for regulating military use of AI and LAWS to conform to the established international humanitarian laws. [H] Mr. Gregory Allen from CSIS testified to congress in 2023 that their research and analysis showed that China was indeed pursuing

AI and LAWS in a manner that would provide them with a distinct advantage on a future battlefield. [H]

Analytical Confidence

The analytic confidence for this estimate is *high*. Sources were generally reliable and tended to corroborate one another. AI was used for idea generation. All information in this estimate came from unclassified sources. This estimate was completed under normal time constraints; the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame (out to 2040) of the estimate and the speed at which this technology is advancing, this report is sensitive to change due to new information.

Author: LTC Tyler J. Waterhouse

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Training In Prompt Engineering Highly Likely A Critical Requirement For Military Leaders And Soldiers Operating In A Human-Machine Integrated Environment Between 2030 And 2040

Executive Summary

The requirement for Army leaders to be able to formulate and ask the right questions of their machine counterparts is highly likely (71-85%) to be a critical leadership skill and skill for junior Soldiers who operate in data-heavy environments due to the increasing number of systems that use artificial intelligence in their operation. Leaders and Soldiers currently don't possess the skills or have the training needed to ask the right questions and fine-tune their data set. Despite the increasing data literacy in new leaders and Soldiers, and because of the potential for bias and hallucinations within the systems, the Army must apply focus and training to ensure the next generation of Soldiers and leaders is prepared to fight and win in a data-centric environment.

Discussion

Prompt Engineering is the ability to craft the most optimal prompt to interact with the generative artificial intelligence tool. [H] Fine-tuning is an advanced technique that can maximize the ability of the tool by "training" the AI to suit the specific needs of the user. [H] The "cost," or the ability to access information rapidly, is speeding up, so the "value" of asking the right question is going up. [H]

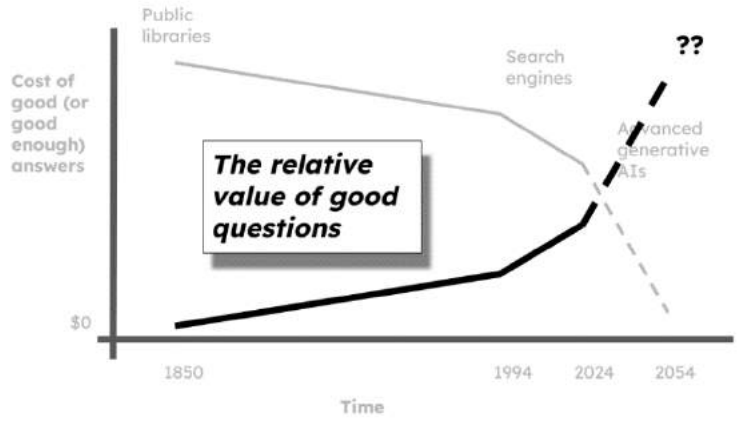

Figure 1: The Value of a Good Question. Source: The relative value of a good question

AI and machine learning expert Dr. Lance B. Eliot has stated, "The use of generative AI can altogether succeed or fail based on the prompt that you enter." [H] There are teams now working to develop programs to model themselves (the machine) and not with a human engineer at all. [H] Companies are paying large sums of money for people to engineer their large language model machines to be more in tune with their requirements and have found success. [H]

Fine-Tuning is another way of working to improve the performance of the AI. Instead of focusing on the question, this looks to make machines that are being brought online for a specific task and then retraining the model on that specific data set, making sure the weights and parameters are adjusted to maximize that specific task. [H]

A step-around prompt is a way to try to get the AI machine to either find a hole in the machine's security or even get around a bias that has already been infused into the machine. [H] One counter to this process is to have human reviewers examine the step-by-step that the machine is using to generate its response and call out any problematic steps (think of this as asking it to show its work). [H]

Data literacy rates are increasing throughout the world, and in the US, there is a concerted effort to keep this momentum going. Congress has introduced the Data Science and Literacy Act (H.R. 1050) to increase funding for all levels of education. [H]

Prompt engineering is not without its controversies, however. AI that is prompted with false or misleading information may cause the response to be a "hallucination," or be an attempt to use the prompts to insert bias into the machine. [H]

Analytical Confidence

The analytic confidence for this estimate is *high*. Sources were generally reliable and tended to corroborate one another. AI was used for idea generation and sourcing. All information in this estimate came from unclassified sources. This estimate was completed under normal time constraints; the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame (out to 2040) of the estimate and the speed at which this technology is advancing, this report is sensitive to change due to new information.

Author: LTC Tyler J. Waterhouse

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Chances That Comprehensive Yet Tiered Needs In Digital Competencies And Basic Military Principles To Increase Training And Education Requirements Up To 10% By 2035

Executive Summary

The chance the (46-55%) integration of advanced digital technologies and evolving human-machine integration (HMI) into military operations to increase training and education requirements for military personnel by 2035 due to the need for digital competencies, the complexity of HMI, and the imperative for a new set of operational skills that blend with traditional military principles. Critics are likely (56-70%) to argue that artificial intelligence (AI) and similar technologies could streamline training, possibly shortening training timelines. Regardless of the potential efficiencies from artificial intelligence, the intricate character of modern warfare and the necessity for comprehensive knowledge in data-driven decision-making (DDM) and HMI will likely extend training durations to ensure broader proficiencies.

Discussion

The evolving character of warfare will likely necessitate a transformation in military training paradigms, emphasizing the importance of digital competencies like AI and data literacy. [MM] As the complexity of future battlefields increases so does the reliance on DDM and HMI. [M] Adapting to these changes requires a curriculum review to update the specific and generic knowledge, skills, abilities, and other abilities (KSAOs). [H] For instance, trust and transparency concerns surrounding AI in military operations highlight

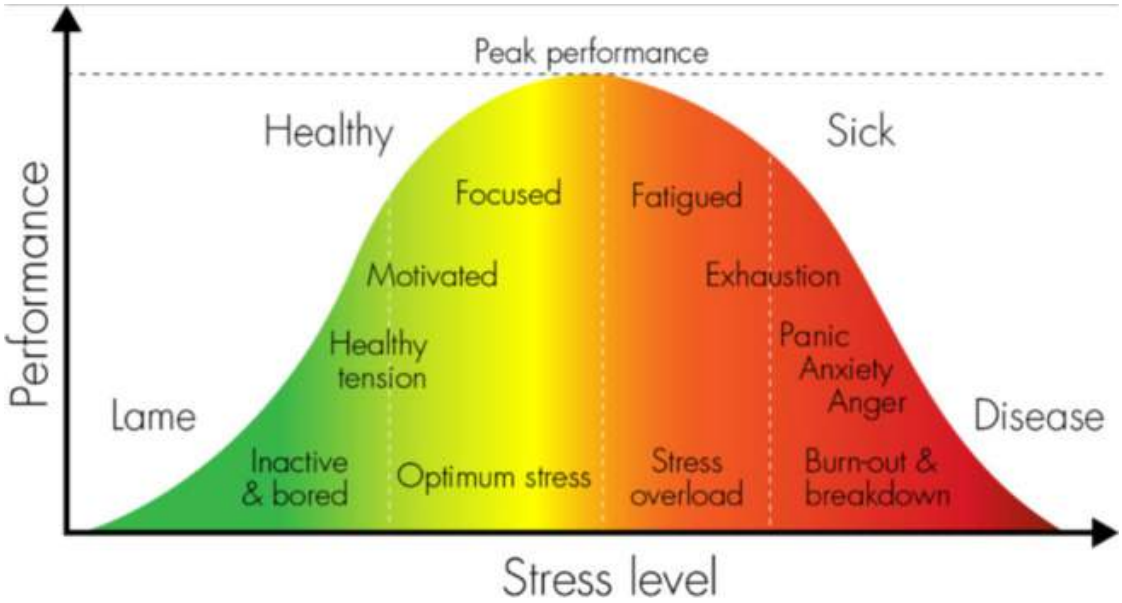

Figure 1: The Yerkes Dodson Curve shows the reality of the false belief that teaching more content students will learn and retain more. Source: Overcrowded curriculum is an impediment to change

the need for systems that support, not replace, human decision-making. [HH] The military education curriculum already integrates these topics and likely must be adapted to support DDM with respect to future AI presented options. [M] This expansion of knowledge requirements and the need for hands-on training in both traditional and HMI environments will likely require longer training periods to avoid curriculum overload or curriculum imbalance. [HH] OECD's report highlights this educational issue as the push for curriculum expansion through changes in society's needs and the trade-offs with a "mile wide – inch deep" curriculum. [H] The medical field also struggles with this issue as the Canadian Medical Education Journal reported medical students are suffering from higher rates of burnout and distress due to the sheer volume of information they are expected to learn. [H]

The rapid advancement of technologies, particularly in AI, autonomous systems, and robotics, presents both opportunities and challenges for training future leaders in HMI. As technology develops, it will likely replace tasks, but not occupations; driving the need for individuals to work both with and without machine assistance. [H] This evolution will likely require learning to work with machines using similar approaches to building good human teams. For example, Soldiers would cross-train the machine tasks and learn to think like a machine. [H] The tragic and extreme case of the 2009 AirFrance Flight 447 crash illustrates this critical importance of maintaining a delicate balance between training reliance on autonomous systems and the irreplaceable value of human oversight and decision-making capabilities. [M]

While some military leaders recommend an expertise-in-depth approach to new technologies, multiple new technologies are likely to have an unavoidable compounding effect. [M] This phenomenon is similar to the increase in time to earn technical college degrees, the increased number of people seeking master's degree post traditional undergraduate degrees, and the increased training for specialized skillsets for medical doctors. [MM] Furthermore, keeping pace with technological advancements necessitates continuous learning and adaptation, a process that is likely to extend the training period for human operators. [MMM] This is particularly true because mere high consumption or use of technology does not inherently equate to the development of digital competency. [HM] Proficiency in traditional tactics alongside the ability to leverage and adapt HMI capabilities will be crucial. Success will depend on sustaining a higher level of situational awareness and operational flexibility from human operators. [M] Just as machines will help cover human shortfalls, machine support adds a new psychological task of monitoring machine activities and evaluating solutions. [H] Training for these capabilities while avoiding burnout, is likely to be more time-consuming as it involves not only technical proficiency but also the development of trust and effective communication between humans and machines. [H]

Despite the potential for technological advancements to streamline training processes, the remains likely that the complexity and pace of change in military operations demand a more nuanced approach. [H] While initiatives to accelerate training or offload some of the burdens through the use of AI and other technologies are underway, these efforts face significant challenges. [M] The integration of AI into training programs, for instance, requires careful consideration of the ethical and practical implications of relying on automated systems for decision-making. [H] Just as software development rapidly improves to keep pace with military needs, the rapid evolution of technology also likely means that the military must continuously update training programs, thereby adding to the complexity and duration. [M] Furthermore, the British think tank strongly emphasizes the importance of human judgment which cannot be fully replicated or replaced by machines. [H] Developing the soft skills necessary for effective leadership, teamwork, and ethical decision-making in complex, high-stakes environments require time and experience. [H] Therefore, while technological advancements can support and enhance training, they are unlikely to fully address the increasing demands placed on military personnel. [H]

Analytical Confidence

The analytic confidence for this estimate is *moderate*. Sources were reliable and corroborate one another. The analyst worked alone, used a structured method, and had adequate time to research. In addition to traditional research methods, ChatGPT4 and Perplexity.ai were used but all results were reviewed, further researched, and validated against other sources. Furthermore, given additional organizational alternatives, technological advancements, adversary capabilities, and politically directed military force structure this report is sensitive to change due to new information.

Author: COL Robert F. Jordan

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Ethical AI-Enhanced Decision-Making

Future Of Artificial Wisdom: Embracing Emotional Intelligence, Ethical Decision-Making, And Multidisciplinary Approaches Unlikely By 2040

Executive Summary

In order for machine common sense and artificial wisdom (AW) to be realized, the focus will likely (56-70%) be on creating more sophisticated models of knowledge representation, improving emotional intelligence in AI, and developing ethical frameworks for AI decision-making. The future of artificial wisdom hinges on overcoming the dual challenges of integrating commonsense reasoning and emotional intelligence into AI systems. Progress in AW will require a multidisciplinary approach, drawing on insights from cognitive science, psychology, and ethics to create systems capable of ethical decision-making, empathetic interactions, and adaptive learning. Despite challenges in aligning machine common sense with military standards—requiring quick, logical reasoning and understanding of complex social dynamics—significant challenges remain, particularly in developing systems that are able to navigate the complexity of human emotions and societal norms with the nuance and flexibility that true wisdom requires.

Discussion

Machine common sense refers to the type of background knowledge or understanding that humans typically use naturally to navigate everyday situations, which includes employing reason, understanding social norms, and making judgments about the physical world. [H] Like many fields within AI, research on common-sense reasoning primarily falls into three approaches: knowledge-based, web mining, and crowdsourcing with knowledge-based using machine learning techniques that analyze vast datasets, typically text-based, with minimal overlap between the three approaches. [H] The first, knowledge-based methods, can further be categorized into three distinct groups: (a) those employing mathematical logic or other formal mathematical

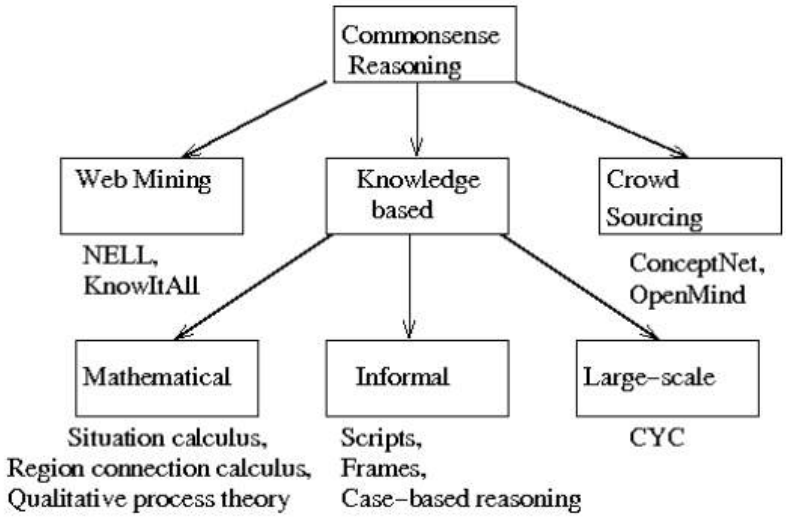

Figure 1: Visual depiction of the taxonomy of commonsense reasoning approaches. Source: Commonsense Reasoning and Commonsense Knowledge in Artificial Intelligence

frameworks; (b) informal strategies that eschew mathematical formalization, often drawing on theories from cognitive psychology; and (c) expansive (large-scale) strategies, which aim to amass substantial amounts of knowledge and may vary in their use of mathematical or informal approaches. H

A collaborative study from the Allen Institute for AI, Facebook AI, and the University of Washington Paul G. Allen School of Computer Science and Engineering utilizes a mathematical knowledge-based method to address the concept of abductive commonsense reasoning, which is explained as inference to the "most plausible explanation." H The findings established two reasoning tasks—Abductive Natural Language Generation (*a*NLG) and Abductive Natural Language Inference (*a*NLI)[1]—achieving 68.9% *a*NLI accuracy, compared to human performance at 91.4%; the *a*NLG task proves more challenging, with humans providing valid explanations 96% of the time, while the best generative models achieve only 45%. H A separate study from Stanford University, where the AI interacted with people on social media platforms, proved that agents can learn socially within complex domains like natural language question generation, discovering new concepts and societal norms simultaneously. H

Emotional intelligence (EI), popularized by Daniel Goleman's 1995 book, is the skill to identify, understand, and manage one's own and others' emotions to guide thoughts and actions. H Stanford University's top AI expert, Fei-Fei Li, found that advancing AI involves deepening its grasp of emotions through insights from both brain science and cognitive science. H Hume AI released a beta version of an Empathic Voice Interface (EVI) in March 2024; this emotionally intelligent AI, trained on millions of human conversations, can detect when users finish speaking, predict their preferences, and tailor vocal responses to improve satisfaction over time. H The MIT Media Lab explains harnessing emotional intelligence within AI systems like EVI marks a significant leap toward more natural and intuitive human-computer interactions. H This fusion of AI with emotional intelligence aims to bridge the gap between digital and human empathy, making technology not just a tool but a companion that understands and reacts to the emotional states of its users. H The integration of emotional intelligence into AI opens up new possibilities for enhancing customer service, mental health support, and personalized experiences across various industries. M As these emotionally intelligent systems become more sophisticated, they promise to transform our interaction with technology, making it more responsive and attuned to the nuances of human emotion. M

[1] *a*NLG is defined as a reasoning task that generates a hypothesis from options and *a*NLI is defined as a reasoning task generating an inference from options and hypotheses.

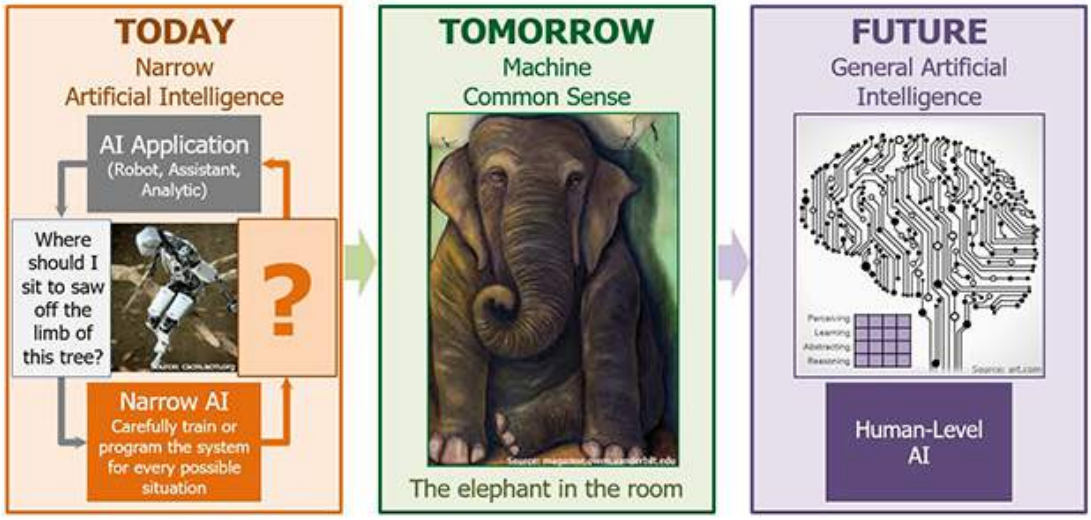

Figure 2: Graphic representation of AI/AW evolution. Source: Teaching Machines Common Sense Reasoning

The evolution of Artificial Wisdom (AW) heralds a new era in which AI systems are not merely tools of computation and analysis but are imbued with the capacity for ethical decision-making, empathetic interactions, and adaptive learning. [H] A University of California San Diego study found that achieving this ambitious vision requires a collaborative, multidisciplinary effort that leverages the insights and methodologies from cognitive science, psychology, and ethics. [H] Cognitive science offers the framework for understanding how knowledge and decision-making processes can be emulated in machines, psychology contributes by providing insights into emotional intelligence and empathy—essential for truly understanding human needs and responses. [M] Meanwhile, ethics ensures that these systems operate within a moral and societal framework, guiding their decision-making processes to be just and fair. [M] This fusion of disciplines aims to create AI systems that are not only intelligent but also wise, capable of making decisions that consider the well-being of humans and society as a whole, marking a significant leap forward in the development of technology that can genuinely benefit humanity. [H] Despite GPT's significant advancements, it faces challenges with subjective tasks due to inherent limitations like contextual understanding, interpreting implicit meanings, and data biases, thereby contributing to the dialogue on AI's role in managing complex, context-sensitive tasks and providing insights for future progress.

At the 2023 International Conference on Machine Learning and Applications Conference, a presentation led by the School of Computing from Clemson University highlighted that, despite GPT's significant advancements, it faces challenges with subjective tasks due to inherent limitations like contextual understanding, interpreting implicit meanings, and data biases, thereby contributing to the dialogue on AI's role in managing complex, context-sensitive tasks and providing insights for future progress. [H] Ben Gurion University conducted a comprehensive study that merged social sciences with data

science, leveraged simple yet theoretically robust models, included state-of-the-art language models like GPT and NLI-based Zero Shot Text Classification, alongside automatic rule discovery, to accurately classify social norm violations, deeply rooted in an understanding of human psychology and social emotions. [H] Ultimately, the study concluded that within this framework, there are challenges of detecting breaches of broad social norms because norms can vary in specificity from social groups down to individuals. It's suggested that individuals tend to follow their "personal norms"—their own beliefs about the right actions—which could significantly explain altruistic behavior in humans, but that machines are not currently capable of imitating. [H]

Analytic Confidence

The analytic confidence for this estimate is *high*. Sources were reliable and tended to corroborate one another. ChatGPT, Elicit, SciSpace, and Perplexity were used, and ideas from the results were utilized in further research. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information.

Author: COL Erin H. Frazier

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Perspective Taking, Performance Monitoring, And Conflict Resolution Likely Crucial Human Tasks For Human Machine Integration In 2030s

Executive Summary

Perspective taking, performance monitoring, and conflict resolution are likely (56-70%) to be crucial human tasks for human-machine integration (HMI) operations. This need stems from the growing complexity of interactions, the necessity for human oversight over autonomous systems, and the importance of trust and clear communication between humans and machines. Critics are likely to project that real-time artificial intelligence (AI) analytics could surpass human performance monitoring capabilities, that rapid AI advancements may lead to a preference for machine-led decision-making, and that AI could assume traditional human roles. However, human insight proves significant for external system monitoring, ensuring ethical oversight, grasping cultural nuances, and delivering the empathy and moral judgment AI can only mimic. This underscores the importance of human guidance in HMI.

Discussion

When developing the right skills to support HMI, Dr. Samantha Dubrow of the MITRE Corporation suggests regardless of whether a machine is a tool or a teammate, many of the necessary skill sets remain the same. [H] Perspective taking, concerning working with machines, includes the ability to understand and consider its capabilities, motivations,

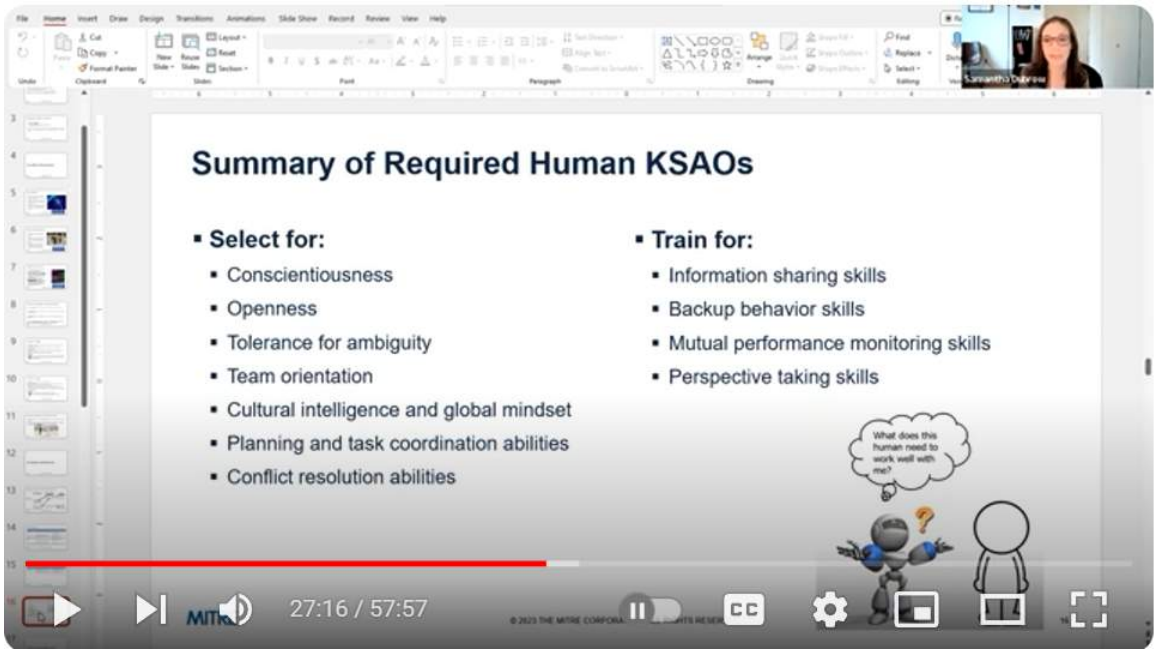

Figure 1: Video discussing Human-Machine Teaming and associated human skills. Source: OTTRS Speaker Series: Samantha Dubrow

and limitations. [M] This is fundamental for operating future human-machine (HM) formations for several reasons. Perspective taking will likely optimize HM performance by the mitigation of performance costs during ineffective group interactions. [H] Within team building, perspective taking enables humans to design and implement machine behaviors that are complementary to human team members, thereby enhancing team cohesion and constructive interaction. [H]

Next, a nuanced approach to perspective taking helps to counteract the phenomenon of human anthropomorphizing of machines; where humans incorrectly attribute human-like thought processes to machines. [M] By recognizing that machines process information and make decisions in fundamentally different ways, leaders can foster a more accurate understanding and trust in machine actions, preventing the distrust that arises from unmet anthropomorphic expectations. [H] For example, Chaz Firestone of Johns Hopkins University encourages a species-fair approach to human-machine comparisons, unique competencies, and constraints of AI systems. He argues this perspective is crucial for preventing the erosion of trust in AI by clarifying that machines operate under a different set of competencies and constraints. [H] This clarity is essential for leveraging the strengths of machines and integrating them more effectively into team dynamics. [M]

As technology advances, it will likely replace specific tasks rather than entire occupations, requiring individuals to collaborate both with and independently of their machine counterparts. [M] The future of HMI is likely to require people to continue performance monitoring to oversee the contributions and progress of both human and machine members. This skill is important because of a human's ability to adapt to new situations when compared to something outside a machine's program or trained models. [M] The MIT Sloan article highlights AI's shortcomings in tasks needing social skills, dexterity, and common sense, underscoring the necessity of human oversight for AI's successful workforce integration, particularly in roles that demand a high degree of adaptability and judgment. [M] Moreover, as machines become more autonomous and capable of making decisions independently, the significance of human performance monitoring escalates. [M] Operators must be adept at discerning when autonomous systems are functioning optimally and when recalibration or human intervention is necessary to maintain or enhance team performance. [H] Within this complex relationship between human intuition and machine precision, performance monitoring demands a subtle approach which accounts for both quantitative and qualitative measures of team performance. [H]

Conflict resolution becomes even more important considering critics' claims that improvements in real-time AI analytics and autonomous decision-making could reduce the need for humans, leading to decisions made more by machines and replacing humans

with AI. [MM] Contrary to these assertions, conflict resolution plays a pivotal role in the functionality and success of HMI. [H] While perspective taking helps to prevent humans from anthropomorphizing machines, conflict resolution skills will help recognize and resolve misunderstandings between what humans expect machines to do and what they provide. As machines become more integrated into collaborative work environments, the potential for misunderstandings or disagreements between humans and machines increases. [H] These conflicts, if not managed and resolved effectively, can lead to breakdowns in trust and coordination, ultimately hindering team performance. [H] Operators must use effective conflict resolution skills to address and mediate these conflicts, ensuring they understand and manage any limitations or errors of machines in a way that maintains team harmony and effectiveness. [M] By mediating conflicts and ensuring that human team members' concerns about machine actions are addressed effectively, people can maintain a balanced and productive team dynamic. [H] Finally, people will likely continue to navigate the complex socio-cultural landscapes in which HMI operates, ensuring that machine actions align with local customs and ethical standards without causing inadvertent conflicts. The human capacity for empathy and moral judgment is crucial in resolving conflicts and making decisions that respect the dignity and rights of all stakeholders involved. [H]

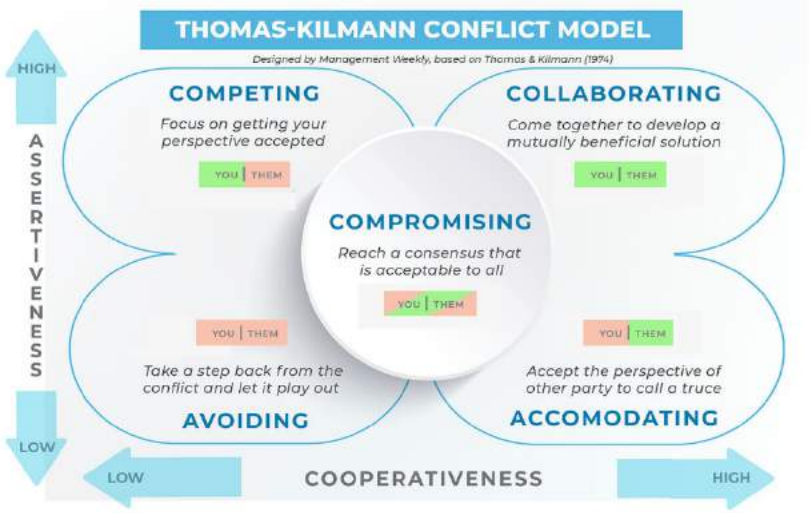

Figure 2: Thomas-Kilmann Conflict Model. Source: Thomas Kilmann Conflict Model

However, there is a belief that AI could eventually assume roles traditionally held by human operators, given its ability to learn, adapt, and make decisions rapidly. [M] While AI outperforms at data processing and analysis, humans excel at interpreting this data through a broader lens, incorporating ethical considerations, cultural sensitivities, and judgments rooted in empathy and moral reasoning. [M] Human oversight ensures that autonomous systems operate within ethical boundaries and societal norms. This oversight involves not just monitoring but also the active evaluation and recalibration of systems based on ethical considerations a machine cannot autonomously manage. [H] Finally, humans possess the unique ability to contextualize data and insights generated by AI, applying them to broader strategic objectives and ethical considerations. [M] This external

monitoring extends beyond mere performance metrics to include the assessment of how autonomous actions align with overarching goals and values. [M]

Analytical Confidence

The analytic confidence for this estimate is *moderate.* Sources were reliable and corroborated one another. The analyst worked alone, used a structured method, and had adequate time to research. In addition to traditional research methods, ChatGPT4, Google Gemini, and Perplexity.ai were used but all results were reviewed, further researched, and validated against other sources. Furthermore, given the design of HM formations or organizations, political decisions on AI regulations, potential reduction in HMI complexity, society adjustments to working with AI, and development and abilities of artificial general or artificial superintelligence this report is sensitive to change due to new information.

Author: COL Robert F. Jordan

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Artificial Intelligence Highly Unlikely To Replace Human Rationality In Military Strategy Formulation During Crises By 2040

Executive Summary

Military commanders are highly likely (71-85%) to remain the sole decision maker in strategy formulation for crisis response at the strategic level due to AI's inability to adequately replicate human rationality and intentionality by 2040. Due to the challenges of decision-making during strategic crises, there is a need for processes that respect democratic principles and stress the necessity of incorporating human judgment, especially in complex situations where cultural differences and value-laden judgments play a crucial role. Despite the challenges associated with integrating AI into crisis management procedures, significant strides will likely be made by developing mechanisms for responsible data sharing that respect privacy concerns, ensure the transparency and interpretability of AI models, and build the capacity of personnel involved in crisis management to understand the promises and limitations of AI models fully.

Discussion

AI tools play a role in diplomatic negotiations, peacebuilding, security, and resource allocation during pandemics, demonstrating their potential applicability in predicting conflict escalation points and strategic vulnerabilities. [H] Such capabilities are especially crucial in identifying threats and opportunities in the dynamic landscape of decisions

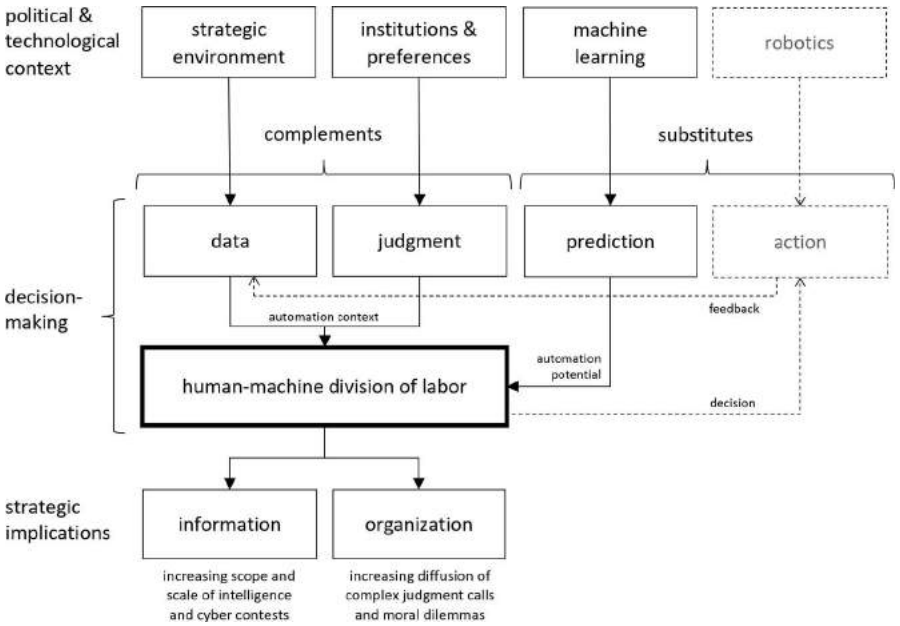

Figure 1: "The Strategic Context of Decision-Making in Military Organizations." Source: Prediction and Judgment

during crises, underscoring the technology's value in enhancing military efficiency and precision. [H]

The utility of AI in strategy formulation is tempered by its current limitations in understanding and incorporating ethical considerations and cultural nuances, which are central to military strategy. [H] Strategic decisions, particularly in the military sphere, often entail navigating complex moral dilemmas and ethical judgments where the consequences of actions can be profound, especially if the technology is not fully understood. [H] Unlike AI, human commanders possess a unique capacity for ethical reasoning, allowing them to make decisions that reflect not only strategic objectives but also ethical imperatives, underscoring the irreplaceable role of human judgment in the strategic decision-making process. [H]

AI's inability to fully comprehend human intentions and the complexity of human rationality presents significant ethical, moral, and political dilemmas through the dehumanization of AI-enabled war, the potential for cognitive and automation biases, and moral responsibility associated with military technoethnics. [H] Anticipating the actions and intentions of adversaries and allies is also a critical aspect of military strategy that requires an understanding of psychological factors, historical contexts, and the unpredictable nature of human behavior that dates back to the ancient Greeks and continues into the foreseeable future. [H] Human leaders, with their intrinsic understanding, ensure strategies are both effective and adaptable to the shifting dynamics of conflict situations, avoiding biases like the "Einstellung effect" and the "illusion of control" that could impair AI effectiveness. [H]

AI plays a crucial role in enhancing diplomacy through innovative applications like AI-assisted simultaneous translation, which aids in international meetings, and through AI-powered evidence gathering in critical areas during times of crisis. [H] These advancements underscore the necessity for a shared understanding and the translation of scientific evidence into policy guidance, aligning AI's technological innovations with legal and ethical standards demands international governance frameworks, highlighting the need for education among diplomats and officials on AI's potential impacts. [H] This is vital for mitigating risks and preventing AI from exacerbating global inequalities through technology protectionism. [H] Additionally, the application of AI in disaster management and crisis response is evolving, with international collaborations aiming to leverage technology for situational awareness and decision-making. [H] DiPLO, along with the Ministry of Foreign Affairs of Finland, is conducting continuous research on AI's growing capability to mimic human-like conversations and strategic reasoning, which is transforming negotiations and crisis management, suggesting a future where AI's integration in diplomacy and international cooperation becomes even more profound

military operations, where the strategic deployment of resources can mean the difference between success and failure. [H] As illustrated in Figure 1, the complex interweaving of strategic AI's impact on diplomacy and crisis management—coupled with predictive analytics offerers—can significantly contribute to informed and strategic. [H]

Analytic Confidence

The analytic confidence for this estimate is *high*. Sources were reliable and tended to corroborate one another. ChatGPT, SciSpace, Academia, Elicit, and Perplexity were used, and ideas from the results were utilized in further research. Elicit suggested sources that were validated and then used as references. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information.

Author: COL Erin H. Frazier

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Anthropomorphism's Impact On AI And HMI Likely To Alter Battlefield Dynamics By 2040

Executive Summary

Anthropomorphism's impact on Artificial Intelligence (AI) and technology, particularly within the realm of autonomous weapon systems and human-machine integration (HMI), is likely (56-70%) to alter warfare's dynamics by 2040. This shift is expected to stem from the interplay of human psychological tendencies, group interactions, the strategic formulation of machine designs, and the protocols for initial engagement with adversaries, advocating for a nuanced approach to design and training that maximizes anthropomorphic advantages for military efficiency. Despite concerns about Soldiers being unwilling to utilize machines for their intended purposes once they have been anthropomorphized, research tends to show gained trust from such an activity, which far outweighs any potential concerns of failure or hesitation to act in lethal situations.

Discussion

Anthropomorphism is a process that extends beyond mere physical attributes to envisioning an entity in a human-like guise, thereby endowing it with cognitive abilities traditionally seen as exclusively human. This includes emotions such as empathy, revenge, shame, and guilt, as well as the abilities for conscious thought, self-reflection, and intentionality. [H] Research in social cognition indicates that anthropomorphism is a fundamental aspect of human psychology, making it an unavoidable element in human and agent interaction (HAI). The propensity for anthropomorphism is governed by three key psychological and motivational factors: (1) the elicitation of agent knowledge (that is, how accessible and relevant human-centric knowledge is); (2) the drive for effectance (namely, the urge to interpret and comprehend the actions of other entities); and (3) the pursuit of sociality (or, the craving for social interaction and connection). [H]

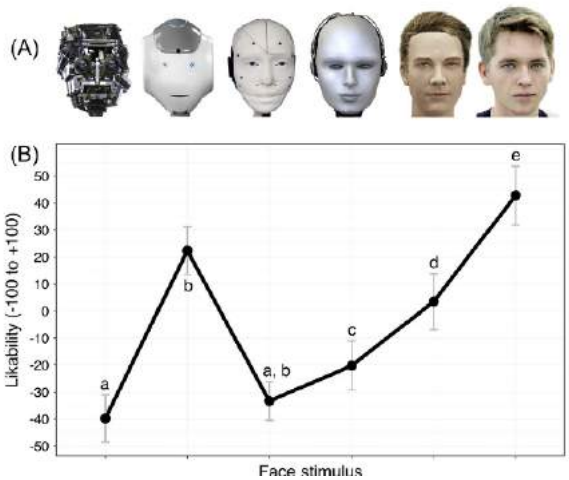

Figure 1: Graphic Depiction of Human Robot and Uncanny Valley. Source: Navigating a social world with robot partners: A quantitative cartography of the Uncanny Valley

Furthermore, the phenomenon of the "Uncanny Valley" exists when a robot creates an uneasy feeling for a human teammate when its anthropomorphic realism is off or creates an uneasiness for the user. [H] Figure 1 illustrates results from

Stanford University and the University of California of the Uncanny Valley that further informs the importance of human social psychology related to HMI.

Intellectual and emotional traits that resemble humans are intentionally integrated into AI systems by designers for reasons related to efficient control, playfulness, and cooperative interaction, which are crucial for effective human-machine interfaces. [H] In this context, the way human users perceive their interaction with the AI system appears to be influenced, to some extent, by the design decisions made. [H] Additionally, individuals tend to attribute less personal responsibility to the outcomes of tasks involving human-like human-robot interactions (HRIs), often using anthropomorphic interactions with AI agents as excuses when the technology fails. [H]

Anthropomorphizing machines, particularly autonomous ones, suggests that these machines have the ability to make decisions as humans do. This assumption should be challenged. It's not entirely accurate to ascribe such human characteristics to autonomous devices. [H] Thus, social robotics research delves into anthropomorphism's origins to improve human-robot teamwork through designs that capitalize on humans' natural perceptions of autonomous artificial agents (AAAs), enhancing the HAI experience. [H] This means that designing AAAs and training troops should proceed concurrently, targeting the creation of user-friendly interfaces to improve human-machine communication. Such an approach could markedly decrease the resources and duration needed to prepare hybrid military teams for action. [H]

New Mexico State University's Human-Robot Interaction Lab found that group affiliation influences both anthropomorphism and favorable reactions, playing a vital role in successful group dynamics as individuals generally perceive their own group (the ingroup) more favorably compared to external groups (the outgroup). [H] The more strongly participants classify robots as members of the ingroup the higher the tendency to attribute human-like qualities to them and grant them increased moral rights, potentially leading to reluctance in future HMI military engagements. [H]

P.W. Singer, renowned warfare and security author and Harvard University Ph.D. recipient, predicts that the future of warfare will be shaped by the armed forces' ability to incorporate AAAs, i.e., synthetic systems controlled by AI such as interactive robots, unmanned vehicles, and digital avatars. [H] Army Secretary Wormuth stated at AUSA in October 2023, "These integrated formations will bring robotic systems into units alongside humans, with the goal of always having robots, not soldiers, make first contact with the enemy." [H] "While we should not underestimate the risks of dysfunctional HAI, evidence that anthropomorphism leads to risky behaviors remains scarce, mostly anecdotal, and does not warrant a general ban on anthropomorphic design." [H] Moreover,

should inappropriate attachment to robots occur systematically, mitigation through proper monitoring and training could easily solve the problem. [H]

Analytic Confidence

The analytic confidence for this estimate is *high*. Sources were reliable and tended to corroborate one another. ChatGPT, Elicit, SciSpace, and Perplexity were used, and ideas from the results were utilized in further research. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information.

Author: COL Erin H. Frazier

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Convergence Of Brain-Computer Interfaces, Neuromorphic Technology, 3D Printing, And Augmented/Virtual Reality Will Likely Pave The Way For Advanced Military Decision-Making By 2040

Executive Summary

The convergence of brain-computer interfaces (BCIs), neuromorphic technology, augmented/virtual reality (AR/VR), and 3D printing is dramatically reshaping our understanding and application of natural intelligence in artificial intelligence (AI) and will likely (56-70%) enable rapid and intuitive military decision-making by 2040. BCIs are enhancing direct brain-device interactions, with neuromorphic technology boosting AI performance through brain-like processing. AR/VR integration with BCIs is set to revolutionize military domains, while 3D printing with AR/VR enables frontline manufacturing. However, these innovations will likely be challenged by ethical considerations, privacy concerns, access disparities, regulatory challenges, and broader societal impacts. This will necessitate a robust governance framework, transparent policies, and international cooperation to ensure that the development of these emergent technologies aligns with societal values and norms while fostering safe and inclusive innovation.

Discussion

The field of brain-inspired cognitive systems emphasizes the need to understand the brain and natural intelligence. [H] This is achieved through studying natural intelligence models, the formal models of the brain, and the development of brain-inspired systems such as cognitive robots and knowledge processors. Neuromorphic technology, which mimics the structure and function of the human brain, has shown promise in various applications, including AI and BCIs. (See Neuromorphic Chips Report and BCI Report) [HH] These interfaces, which enable direct communication between the brain and external devices, will likely revolutionize neurorehabilitation, virtual reality, and cognitive training. [H]

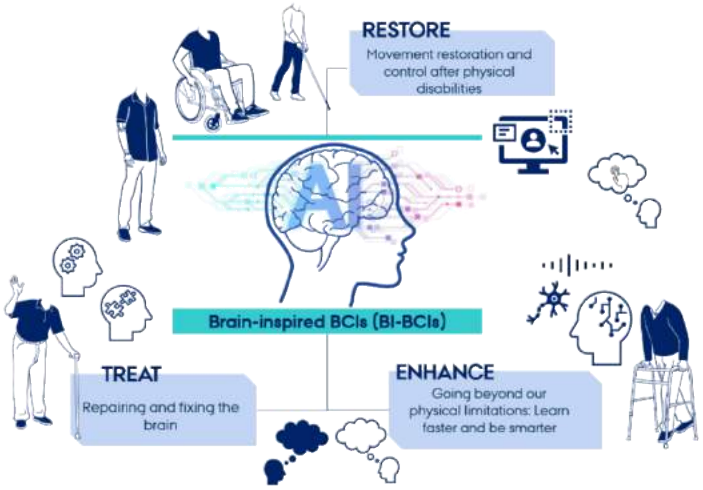

Figure 1: Brain Inspired Brain Computer Interface creates a human in the loop system. Source: In the realm of the hybrid brain

Using neuromorphic hardware in BCIs, known as Brain Inspired-BCIs (see Figure 1), is particularly promising, as it can improve system stability and efficiency. [H] However, developing and deploying these technologies raises ethical concerns, such as privacy invasion and societal disparities in access. Despite these challenges, the future of neural interfaces, including BCIs, is likely to have potential applications in neurologic disorders and robotic systems. [H]

The Intersection of BCIs with Immersive technology AR/VR (BCI-AR/VR) presents likely advancements in military operations, specifically augmenting Soldiers' situational awareness and decision-making capabilities. (See AR/VR Technology) [HH] The AI and Machine Learning Lab at Riverside Research is an organization that is pursuing making this possible by improving computer vision algorithms and leveraging cognitive science to optimize visualization methods. [H] BCI-AR/VR can significantly enhance user experience and interaction.

Figure 2: Nucleus-Hermès is a prototype BCI-AR/VR headset. Source: My review of BCI for VR/AR/XR — 2023

- Enabling active brain control of VR avatars and passively adaptive VR content [HH]
- Improving the wearability of immersive technologies (see Figure 2) [H]
- Reading the brain's EEG signals from visually stimulating stimulus (Steady-State Visually Evoked Potential (SSVEP)) [H]

The combination of EEG and SSVEPs showed a high accuracy of 93.96% when subjects were asked to control an AR robotic arm picking up objects. [H] The application of these technologies extends to training and field operations, operating a robot, and offering enhancements in performance and a reduction in cognitive load. [HHH] However, such advancements should be accompanied by systematic study and careful consideration of broader implications. [H]

Deployable 3D printing technology, combined with AR/VR, signals a transformative leap in manufacturing directly at the frontlines. (See 3D Printing) [H] The practical applications in healthcare demonstrate the viability of producing personalized medicines and biomedical equipment for on-demand. [HH] The benefits of rapid tooling and nanotechnology in manufacturing are heralding a shift towards more agile and innovative production methods. [HH] Furthermore, using industrial robotic arms in 3D printing systems suggests a path toward greater design freedom and cost efficiency. [HH] These studies

underscore the transformative potential of deployable 3D printing and AR/VR technologies in frontline manufacturing.

The rapid advancement of emerging technologies such as neuromorphic chips, AR/VR, and 3D printing likely presents a range of ethical, legal, and safety concerns. These include privacy and security issues with neuromorphic chips, comprehensive regulation in 3D printing and bioprinting, and the ethical implications of AR/VR. [HHHH] The convergence of nanotechnology with other domains also raises concerns about unknown material behavior and societal implications. [H] A robust governance framework, transparent policies, and international cooperation are essential to address these challenges. (See International HMI Concerns) [H] The development of these technologies should align with societal values and norms, and a dynamic regulatory environment is needed to mitigate risks while encouraging innovation. [H]

Analytic Confidence

The analytic confidence for this estimate is *high*. Sources were generally reliable and corroborated one another. ChatGPT 4, Elicit, Perplexity, and other generative AI sites were used, and ideas from the results were utilized in further research. Elicit and Perplexity suggested sources that were validated and then used as references. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information, especially any hurdles or discoveries that may affect development.

Author: LTC Allan S. Jackman

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Military Commanders Highly Likely To Use AI To Inform Morale And Welfare Concerns, But Will Almost Certainly Remain Enduring Human Function

Executive Summary

Military commanders are highly likely (71-85%) to utilize AI for insights into morale and welfare issues, thanks to AI's ability to predict potential concerns before they escalate further. However, the actual response to these AI-identified concerns will almost certainly (86-99%) continue to be a fundamentally human task, as AI lacks the emotional intelligence and personal touch needed for effective resolution. Despite the human touch's irreplaceable importance in addressing morale and welfare concerns, foregoing the use of AI to assist in these efforts could result in missed opportunities for early knowledge and intervention, optimized resource use, and personalized support that could significantly benefit organizational health and Soldier well-being.

Discussion

In addressing morale and welfare concerns within military contexts, AI integration presents a nuanced landscape of opportunities and challenges. AI's capability to process vast datasets enables military leaders to predict and identify potential morale issues before they escalate, offering a significant advantage in proactive intervention. [H] This capability, studied at Claremont Graduate University's Division of Behavioral and Organizational Sciences, aligns with trends in organizational psychology, emphasizing the importance of early intervention in morale-related concerns to sustain high performance and continued well-being. [H]

Figure 1: Core components of Emotional Intelligence. Source: JK Consultants

The essence of addressing morale and welfare issues lies not just in identifying these issues but in understanding and navigating the human emotions and contexts that underpin these concerns. [M] This distinction underscores the irreplaceable value of human insight and compassion in effectively managing and responding to welfare and morale issues through emotional intelligence, highlighting a fundamental interplay between technology and humanity.

However, the transition from analysis to action underscores the limitations of AI. Addressing morale and welfare concerns demands empathy, intuition, and the nuanced understanding of human emotions—qualities that AI, in its current form, cannot replicate. [H] The importance of emotional intelligence in leadership, emphasizing the capacity to read and respond to the emotional needs and well-being of individuals—a critical aspect of managing morale and welfare are the soft skills that leaders must maintain throughout technology transitions was validated by a University of Malaga literature review of over 104 peer-reviewed articles on emotional intelligence, leadership and teams. [H] Furthermore, the customization of welfare initiatives to meet the diverse needs of individuals within a command requires an understanding of cultural, situational, and personal contexts that AI cannot fully grasp. [M]

Emotional intelligence (EI) plays a pivotal role in addressing morale and welfare concerns within military organizations, a context where the stakes are high and the environment can be exceptionally stressful. [H] The ability of leaders to recognize, understand, and manage their own emotions, as well as to empathize with their subordinates, is fundamental to successful leadership. [H] A Clemson University study showed that by ensuring efficient interactions between team members, including AI

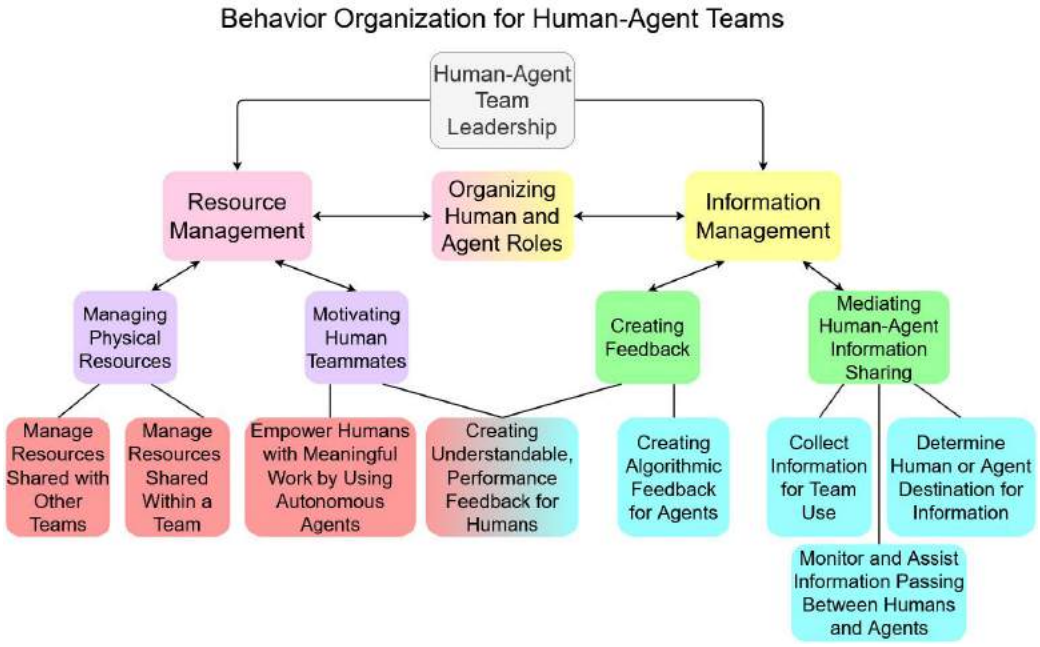

Figure 2:Clemson University Behavior Organization Recommendation for Human-Agent Teams. Source: Fostering Human-Agent Team Leadership by Leveraging Human Teaming Principles

agents, emotional awareness among leaders can significantly contribute to better communication, conflict resolution, trust, and cohesion within hybrid teams. [H] Figure 2 is a representation of the findings of the Clemson University study that visually depicts the multiple ways to cross-communicate between humans and how the interaction

can be applied across multiple domains. [H] In the military, where hierarchical structures dominate, and the pressure to perform is constant, EI helps leaders to create a supportive atmosphere that acknowledges the psychological and emotional needs of personnel. [H] Berkeley's Executive Education program highlights the importance of combining human-centered leadership with emotional intelligence to enhance organizational culture as it integrates AI. [L] Incorporating Emotional Intelligence training into military leadership programs for operational success and organizational resilience, ensures Soldiers feel valued, understood, and motivated. [H]

Leadership and educational programs must evolve to include modules on ethical AI use, data privacy considerations, and the development of soft skills essential for welfare management. [H] On the personnel front, recruitment, and retention policies likely need to adapt to attract talent proficient in both AI technologies and human-centric welfare practices. [M] A 2018 study in India presents a comprehensive analysis of various machine learning algorithms that highlight insights for HR departments to proactively implement strategies aimed at improving job performance and reducing turnover. [H]

Analytic Confidence

The analytic confidence for this estimate is *high*. Sources were reliable and tended to corroborate one another. ChatGPT, SciSpace, Academia, Elicit, and Perplexity were used, and ideas from the results were utilized in further research. Elicit suggested sources that were validated and then used as references. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information.

Author: COL Erin H. Frazier

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Future-Proofing Military Capabilities

Between 2035-2040, Artificial Neural Networks Are Likely To Speed Up Military Decision-Making By Improving Data Analysis And Predictions

Executive Summary

Artificial neural networks (ANN), specifically convolutional neural networks (CNN), are likely (56-70%) to improve strategic planning and logistics decision-making speeds by no less than 30% between 2035 and 2040 due to the increasing efficiency, accuracy, and overall effectiveness the technology provides to artificial intelligence (AI). Despite the significant potential of CNNs to transform strategic military operations by enhancing decision-making speed and accuracy, integration challenges related to legacy systems, individual skill sets, and the need for substantial datasets required may initially hinder their widespread adoption in defense mechanisms.

Discussion

ANNs will revolutionize the way military logistics and strategic planning are conducted by analyzing vast datasets to optimize supply chain dynamics, predict future logistical needs, and identify the most efficient routes and methods for transportation and supply distribution. [H] As visualized in Figure 1, for understanding relationships between factors like sales data, lead times, seasonality, promotions, and other variables, ANNs offer insights for inventory management and facilitate tasks in supply chain management such as evaluating and selecting suppliers based on specific criteria. [H]

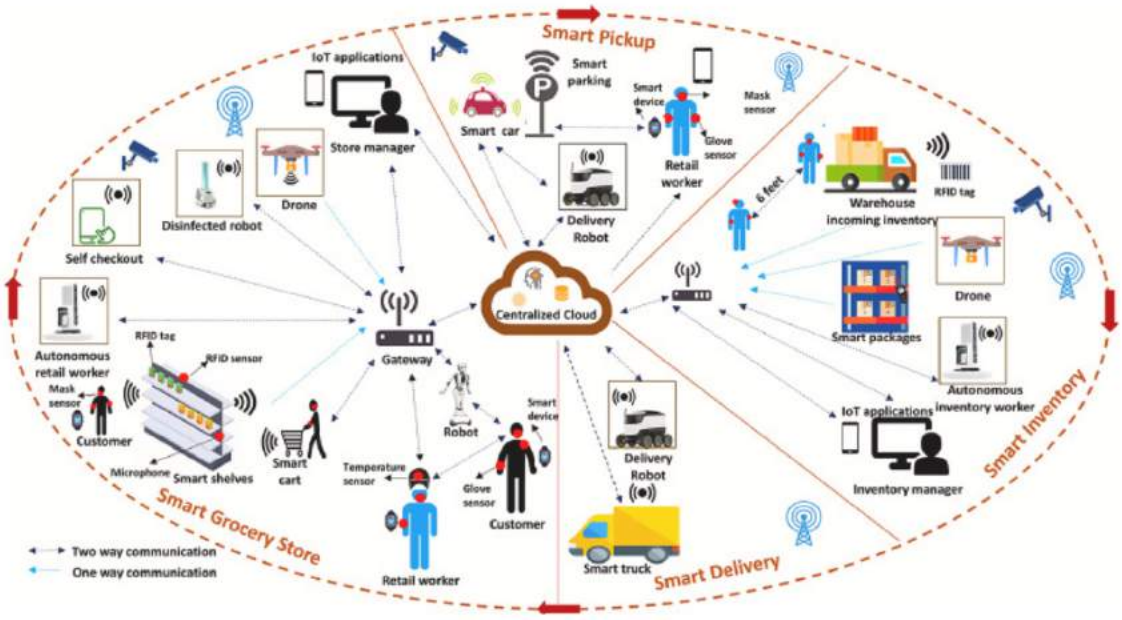

Figure 1: "Smart and Connected Supply Chain Management." Source: [Artificial neural networks in supply chain management]

CNNs have significantly improved performances in various learning tasks, gaining attention due to their kernel methods and weight-sharing mechanisms, particularly in computer vision. [H] University of California researchers Chang and Wang proposed a unitary CNN that can deliver inference speeds 32% faster while using 50% less hard disk space and maintaining competitive prediction accuracy. [H] A study from Cherkasy State Technological University highlights the critical role of speed in the supply chain, particularly evident in Ukraine, and demonstrates significant improvements in prediction accuracy through neural networks. [H] In order to affect speed effectively, the data requires a level of accuracy and trust, leading to the need for large datasets, specially labeled ones, which are costly and time-consuming to build; as a result, semi-supervised and unsupervised learning methods deserve more focus. [H]

Understanding the algorithms reasoning for reaching a specific destination or decision is imperative to increasing trust in the methodology. [H] Since 2018, Joint service leaders from the Interservice/Industry Training, Simulation and Education Conference proposed a novel approach to enhance strategic thinking by combining a deterministic PMESII-PT (political, military, economic, social, infrastructure, information, physical environment, and time) simulation tool with a proof-of-concept AI Recommender System (RS) and established social science principles to improve decision-making processes. [M] The compilation of low decision-maker trust in AI and expected supply chain disruptions requires building trust in the AI's capacity to offer viable solutions, which will likely require time and proven reliability, as commanders observe the system's recommendations aligning with unfolding situations. [MM]

Despite increased speed in decision-making based on improved artificial neural networks, Deputy Principal Information Operations Advisor for the Undersecretary of Policy Army Maj. Gen. Matthew Easley noted that while Soldiers might receive AI-enabled recommendations in the future, weapon systems will always have a human managing them, whereas “other systems where it’s not as critical … [the] machine can make the decision.” However, humans will be the ones training the AI to the point where it can be trusted for Army missions, he added. “You don’t question your mapping algorithm telling you where to move through the city—you know that that algorithm has better information than you do,” he said. But “how do we get the veracity behind the data that we can trust what went into the model, then how the model was trained, and how we’re using it? And I think that’s all … human endeavor.” [M]

Analytic Confidence

The analytic confidence for this estimate is *moderate*. Sources were reliable and tended to corroborate one another. Bard, ChatGPT, and Perplexity were used, and ideas from the results were utilized in further research. Perplexity suggested sources that were validated

and then used as references. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information.

Author: COL Erin H. Frazier

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Neuromorphic Technologies Will Likely Increase The Speed And Reduce Power Needs For Military Decision-Making By 2040

Executive Summary

Neuromorphic Technologies will likely (56-70%) increase the speed and reduce power needs for military decision-making by 2040. This leap forward is underpinned by escalating investments in research, development, and testing of neuromorphic chips, which emulate the functionality of biological brains despite today's lack of production capabilities. These chips are adept at processing sensory data like images and sound, and uniquely responding to changes in data in humanlike ways.

Discussion

Neuromorphic chips, inspired by the human brain, are designed to intuitively process sensory information like images and sound, adapting to new data without specific programming. [H] This emerging field in computing science promises significant advancements in AI, creating machines with human-like understanding and interaction capabilities. [H] By emulating biological neural networks, neuromorphic computing explores new data processing methods, including integrating storage and computation and utilizing voltage spikes to mimic biological action potentials. [H]

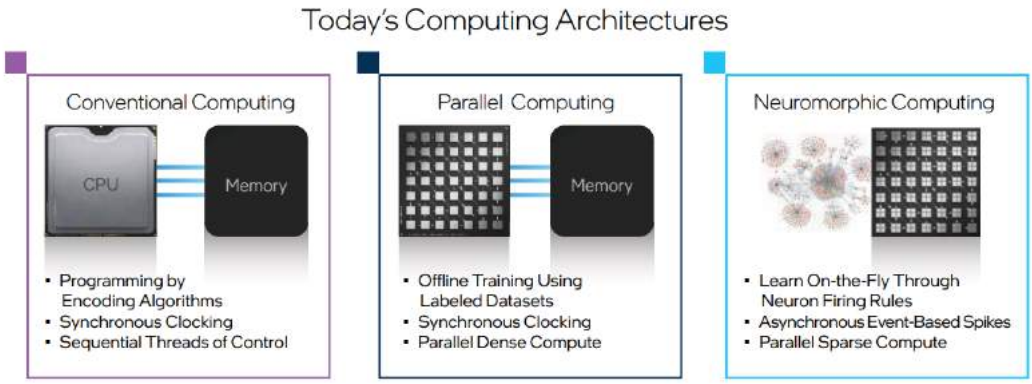

Figure 1: Computing Architectures. Source: Taking Neuromorphic Computing to the Next Level with Loihi 2 Technology

The current landscape of neuromorphic computing indeed shows significant advancements, particularly with the development of innovative chips like NeuRRAM and Loihi. [HH] Developed in 2022 by a global research team, NeuRRAM is an innovative chip that processes AI applications directly within its memory, significantly reducing energy consumption compared to standard AI computing platforms. [H] This efficiency distinguishes NeuRRAM and enhances its suitability for a wide array of edge devices from smartwatches and AR/VR headsets to smart sensors and space exploration rovers. [H] These devices, powered by the NeuRRAM chip, can perform advanced cognitive functions independently, without needing a connection to central servers or the cloud. [H]

At the Intel Innovation lab, a demonstration showcased the capabilities of the Loihi 2 chip. [H] This event involved utilizing a recurrent neural network running on Loihi 2 chips for an unconventional approach to satellite scheduling. [H] The task included coordinating satellite constellations to position cameras strategically over specific points of interest. [H] Mike Davies, the head of Intel's neuromorphic computing lab, commented in December 2023 that while "Loihi 2 remains in the research phase and with next generation silicon (in, say, the next five years) this could be tailored for more specific commercial uses. [H] This could involve modifications like altering interfaces or resizing the chip to suit high-volume applications better, broadening its potential impact and application in the commercial sector." [H]

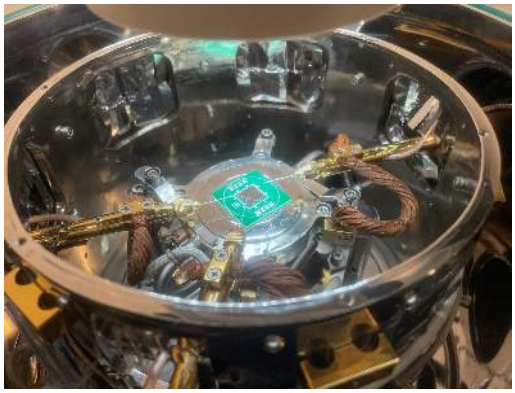

Figure 2: Ferroelectric Neuromorphic Computing Chip. Source: Protons To Power Next-Gen Memory Devices and Neuromorphic Computing Chips

Despite the lack of production and the years it will take based on Intel's forecast, in 2023, King Abdullah University of Science and Technology led researchers to discover a proton-mediated method that induces multiple phase transitions in ferroelectric materials. [M] This significant finding paves the way for creating high-efficiency, low-energy memory devices and neuromorphic chips. [M] Regarding market growth, the neuromorphic chip sector is anticipated to see rapid expansion, with projections suggesting an increase from a market size of 0.16 billion in 2024 to 5.83 billion by 2029, driven by a yearly growth rate of 104.70%. [H] Factors such as governmental initiatives and investment activities are key contributors to this growth, especially in specific regions. [H]

Analytical Confidence

The analytic confidence for this estimate is *high*. Sources were reliable and tended to corroborate one another. ChatGPT was used, and ideas from the results were utilized in further research. ChatGPT suggested sources that were validated and then used as references. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information.

Author: Lt Col Joseph G. Dolce

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Highly Likely That AI And Blockchain Will Create Advantages For Logistics On The Human Machine Integrated Battlefield In 2035

Executive Summary

Artificial Intelligence (AI) and blockchain technologies will highly likely (71-85%) create an advantage in military logistics by the year 2035. This evolution mirrors the significant changes already observed in the commercial sector's logistics and supply chain management. The integration of Human-Machine Integration (HMI) capabilities further amplifies these benefits by improving the synergy between human operators and automated systems. Deploying AI and blockchain will enhance HMI, increasing efficiency, reinforcing security, and elevating strategic decision-making capabilities for logistics. It is highly likely that challenges such as computational demands, data reliability, and the need for ethical AI practices will be overcome through technological advancements and increased investment in response to escalating needs.

Discussion

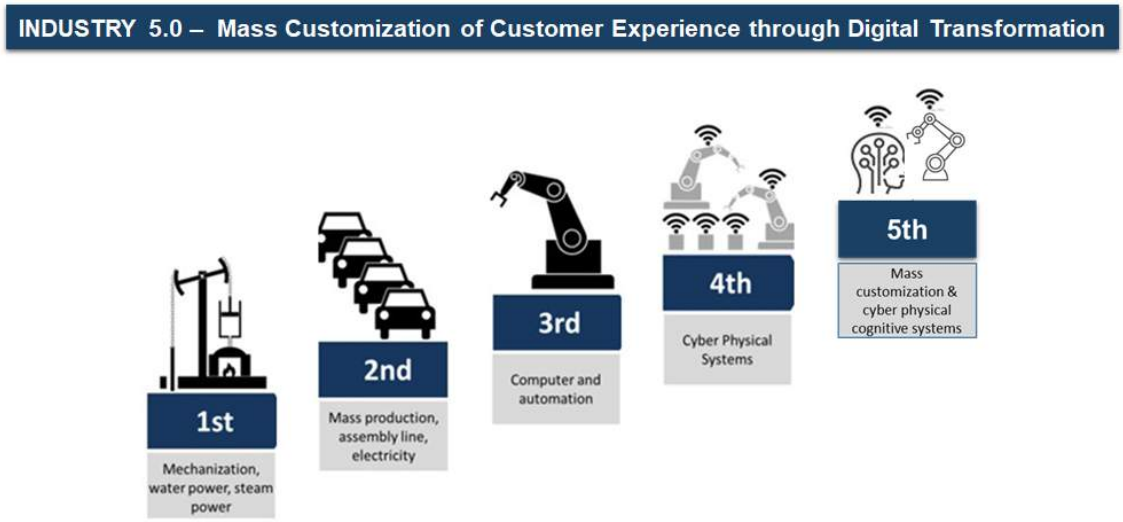

Figure 1: Industry 5.0 – Next Generation Customer Experience. Source: [Industry 5.0 – Next Generation Customer Experience Redefined?]

Human-machine integration (HMI) capabilities are set to play a pivotal role in enhancing the synergy between AI and blockchain technologies in logistics by 2040. Matthias Heutger emphasizes that the fusion of human insights with machine precision will redefine logistics operations, particularly in decision-making processes and real-time problem-solving. [H] According to Doron Azran, HMI systems will increase the efficiency of warehouse operations by integrating advanced robotics that work alongside human operators, thus optimizing the handling and sorting processes. [H] The MIT Center for Transportation & Logistics outlines that HMI will facilitate smoother transitions in warehouse operations from automated systems to human-guided interventions, especially

in complex scenarios where human judgment is crucial. [H] This integration promises enhanced operational flexibility and aims to bolster security protocols and streamline supply chain management, thereby reducing downtime and increasing trust and reliability in logistic operations. [HHH]

Figure 2: Top Strategic Supply Chain Technology Trends for 2023. Source: Gartner Reveals the Top Supply Chain Technology Trends for 2023

AI is revolutionizing logistics with predictive analytics, significantly improving inventory management and demand forecasting. [H] Automation in warehouses and transportation, facilitated by AI, significantly improves logistics performance, increasing speed and accuracy in operations. [H] Simon Jacobson, VP Analyst in Gartner's Supply Chain Practice, stated in 2023, "Supply chain leaders must have an understanding of the strategic, disruptive, and unavoidable technologies that will impact their planning processes over the next five years." [H]

AI-driven real-time insights lead to more dynamic routing and scheduling, enhancing delivery efficiency and customer satisfaction. [H] However, implementing AI in logistics involves addressing computational demands and ensuring ethical AI practices. [M] (See Cybersecurity) The growth of AI in logistics also opens new avenues for more responsive and adaptive supply chain networks, leading to overall enhanced efficiency and reduced operational costs. [H]

The AI logistics market is on a remarkable growth trajectory, with its valuation expected to expand from USD 260.3 million in 2022 to an astounding USD 4,346.4 million by 2030. This expansion reflects a Compound Annual Growth Rate (CAGR) of 36.32%. [H] This growth is driven by AI's potential to enhance logistics productivity by more than 40% by 2035, optimizing crucial processes like route optimization, demand forecasting, and predictive maintenance. [HM] Approximately 28% of businesses are preparing to integrate AI into their logistics processes, a move that early adopters have found significantly reduces costs and improves efficiency. [HM] North America dominates this market due to heavy investment in AI technologies, while Asia-Pacific is projecting to demonstrate rapid expansion, with a CAGR of 46.37%. [H] Innovations in AI, such as

machine learning, natural language processing, and predictive analytics, are pivotal in streamlining logistics operations, thus boosting supply chain efficiency and customer satisfaction. [H]

Blockchain technology significantly enhances supply chain transparency and security, offering a decentralized and tamper-proof ledger. [H] It allows for secure and traceable transactions and product tracking, reducing fraud and errors, thus increasing trust among supply chain stakeholders. [H] However, challenges in integrating blockchain include ensuring data reliability and scalability in diverse logistic environments. [H] Blockchain's immutable nature offers reliable data for audit trails, facilitating compliance and quality assurance, which is crucial for the supply chain's integrity. (See Cybersecurity) The adoption of blockchain technology in logistics also paves the way for more secure and efficient international trade, minimizing the risks of counterfeiting and ensuring the authenticity of products across global supply chains. (See Connectivity)

Overcoming AI and blockchain technology challenges in logistics requires focusing on computational demands, data reliability, and transparent and ethical AI practices. (See Cybersecurity) [H] Developing scalable blockchain solutions capable of handling complex logistic operations is critical. (See Cybersecurity) [H] Emerging trends in AI, such as machine learning and natural language processing, are also being leveraged to enhance logistical planning and predictive maintenance, further revolutionizing supply chain management. (See Collaboration & Power Generation) In blockchain, advancements in consensus mechanisms and increased interoperability are expected to address current limitations and facilitate wider adoption in logistics. (See Quantum Computing)

Analytical Confidence

The analytic confidence for this estimate is *high*. Sources were reliable and tended to corroborate one another. ChatGPT was used, and ideas from the results were utilized in further research. ChatGPT suggested sources that were validated and then used as references. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information.

Author: Lt Col Joseph G. Dolce

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Advancing The Frontlines Of Computation By 2040: Quantum Computing's Likely Leap Toward Military Cryptographic Superiority

Executive Summary

The rapid technological advances, national security implications, and private investment potential will likely (56-70%) drive corporations and nations to aggressively pursue research and development in quantum computing capability by 2040. Despite these advancements and strategic commitments, the industry faces the risk of a "quantum winter" – a slowdown period akin to what was seen in AI development – stemming from high expectations and long timelines for commercialization. To counteract this, the UK invests in diverse quantum testbeds to promote collaboration and overcome key technical challenges essential for evolving scalable quantum processors and the broader quantum technology landscape.

Discussion

A tripartite force comprised of technological advancements, national security interests, and private investment is creating a conducive environment for the development of quantum computing. [H] The interplay between these factors fosters a dynamic and competitive landscape to likely allow quantum computing to become practical by 2040, heralding a true "quantum advantage" in four opportunities. [H]

- Simulation: Simulating complex natural processes has potential in drug discovery, battery design, fluid dynamics, and finance.
- Optimization: Quantum algorithms can optimize solutions in fields like logistics and risk management.
- Machine learning: Data patterns can accelerate AI for autonomous vehicles and prevent fraud and money laundering.
- Cryptography: Breaking traditional encryption and enabling stronger encryption standards, as we detailed in a recent report.

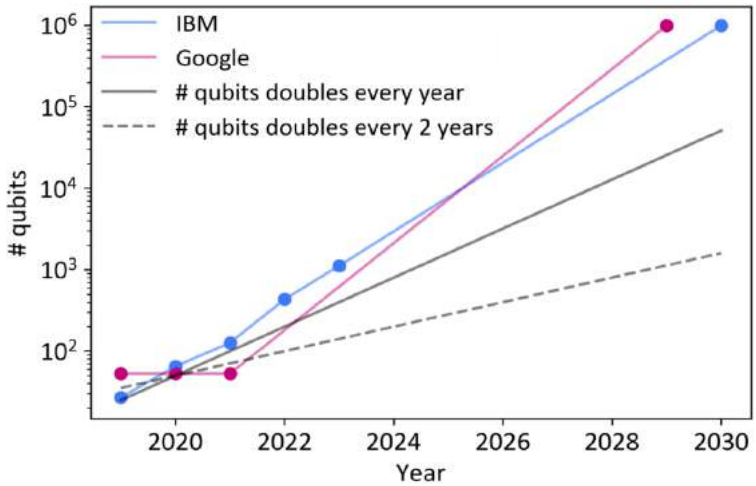

Figure 1: Google and IBM project to surpass 1 million qubits by 2029 and 2030, respectively. Source: Quantum.Amsterdam

Technological breakthroughs in quantum mechanics and engineering are at the forefront of driving quantum computing forward. Innovations in the number of quantum bits (qubits) and accuracy are quickly becoming a reality. [H] According to a recent Google and

a Swedish Armed Forces study, cryptography requires a minimum of 20 million qubits to break codes. [H] Figure 1 shows Google currently has around 1,000 qubits and estimates 1 million qubits by 2029, and IBM projects a million by 2030. Both corporations expect to double the number of qubits every seven to nine months, faster than Moore's law, which doubles the number of transistors every two years. [H] Maximizing the number of qubits allows quantum error correction to improve performance so that the error rate is low enough for accurate computation. [H] A range of studies have explored innovative methods to improve the accuracy of quantum computers by reducing errors in qubits.

- Using Resource-Efficient Quantum Error Suppression Technique (REQUEST) for active qubit resets to achieve error reduction with fewer qubits [H]
- Using molecular nanomagnet qubits with embedded quantum error correction [H]
- Demonstrating the usefulness of quantum error detection in improving the accuracy of chemical calculations [H]
- Correcting multiqubit measurement errors by focusing on efficient correction and classical bit-flip correction [HH]
- Introducing a scalable method for mitigating measurement errors on quantum computers [H]
- Compensating quantum error mitigation to dominate errors in fault-tolerant quantum computing without increasing the number of qubits [M]

In 2018, the US Executive Branch recognized the significance of quantum computing in the National Strategic Overview for Quantum Information Science (QIS). [H] This document identified initiatives such as developing quantum-smart talent, encouraging industry engagement, and understanding the implications quantum computing can have on national security. These three initiatives fall into one of the three joint research centers – industry, academia, and government (see Figure 2) and "can accelerate pre-competitive QIS research and development." The partnership allows research centers to leverage the strengths and capabilities of other centers. The US government

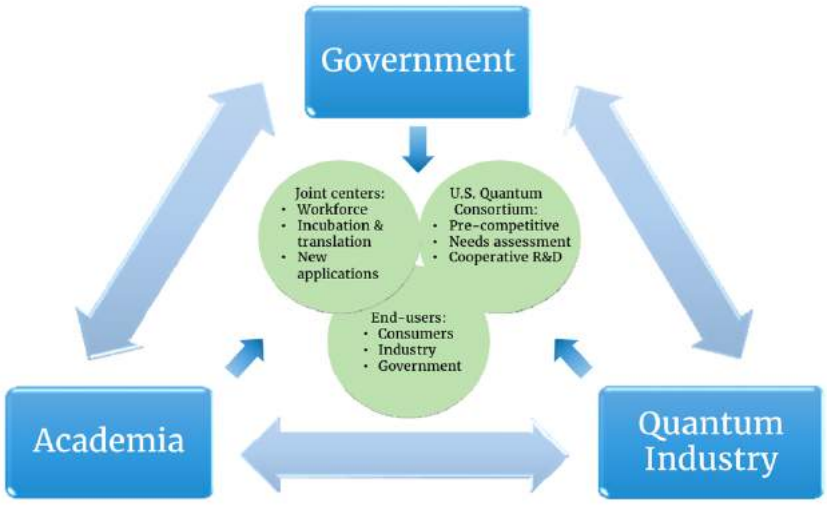

Figure 2: Joint research centers will accelerate advancing quantum science. Source: National Strategic Overview For Quantum Information Science

continues to emphasize the importance of quantum computing by passing H.R. 7535 – Quantum Computing Cybersecurity Preparedness Act and issuing a presidential memorandum to promote quantum computing and mitigate risks to cryptographic systems. [HH] The US has the largest quantum computing market (see Figure 3) despite trailing the European Union, India, and China in talent (see Figure 4). [HH]

Figure 3: US funding leading other nations. Source: Quantum Technology Investment Update 2022 Review

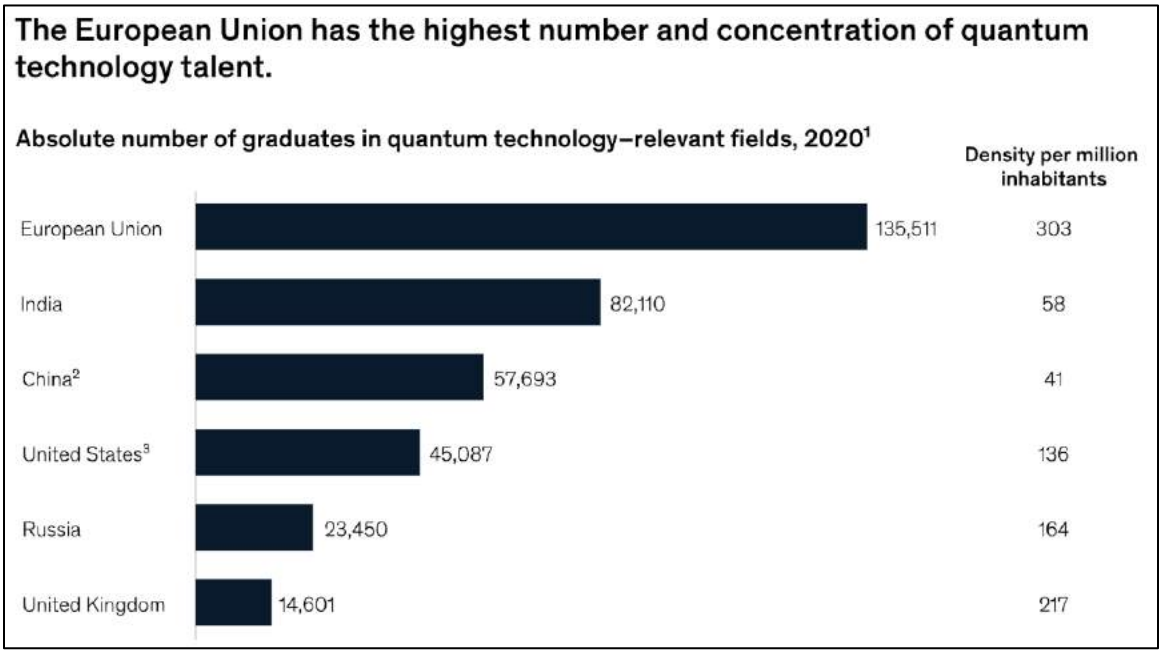

Figure 4: The United States has the fourth highest number and concentration of quantum technology talent, behind the European Union, India, and China. Source: Quantum technology sees record investments, progress on talent gap

Private investments in quantum computing can significantly advance its development by 2040. [H] The influx of capital into quantum computing startups and research initiatives drives innovation in hardware, software, and use-case development for quantum technologies. Figure 5 shows that 2023 experienced a substantial investment decline, but analysts state that 2021 and 2022 were abnormal years due to large investments in special-purpose acquisition companies. [H]

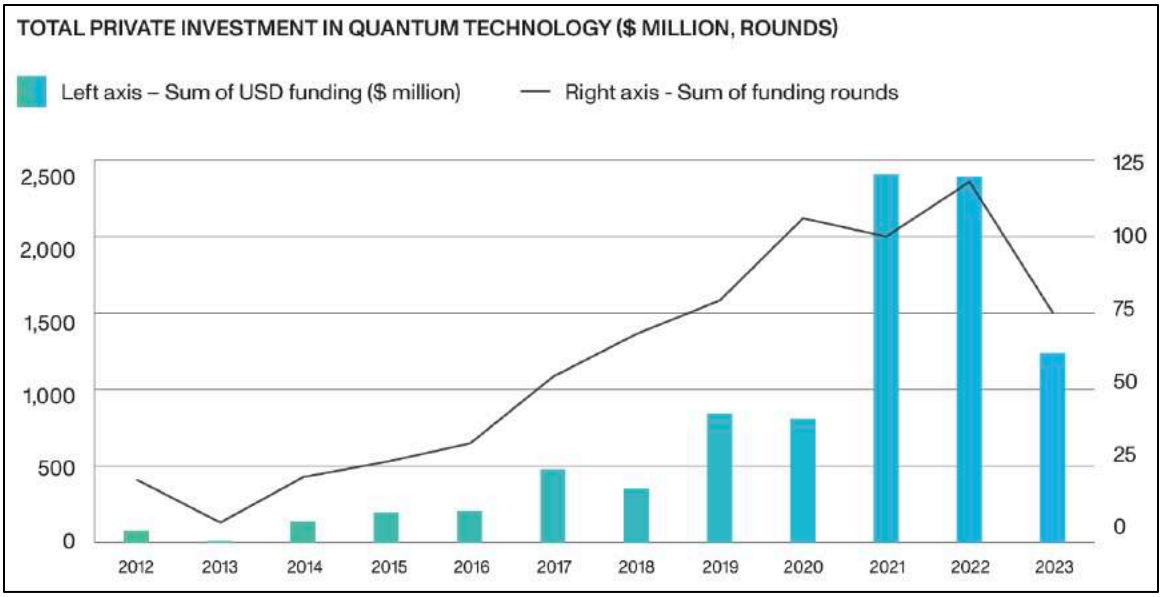

Figure 5: 2021 and 2022 had abnormally high investments in special purpose acquisition companies, creating false growth. Source: State of Quantum 2024 Report

The quantum computing industry faces risks similar to those encountered during the development of AI, with the chance (46-55%) for a "quantum winter" fueled by slow progress toward meeting high expectations and the long timelines for commercialization. [H] The current economic environment, characterized by high inflation and interest rates, adds pressure on startups and could lead to a realignment of investments towards lower-risk assets, exacerbating the challenges for quantum computing companies. [H] Overcoming the quantum winter involves addressing quantum computing's inherent challenges, like maintaining qubit coherence and entanglement, and innovating despite energy constraints. [H] Initiatives like the UK's National Quantum Computing Centre's investment in diverse quantum testbeds aim to foster collaboration and innovation, essential for advancing scalable quantum processors. [H]

Analytic Confidence

The analytic confidence for this estimate is *high*. Sources were generally reliable and corroborated one another. ChatGPT 4, Elicit, Perplexity, and other generative AI sites were used, and ideas from the results were utilized in further research. Elicit and Perplexity suggested sources that were validated and then used as references. There was

adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information, especially any hurdles or discoveries that may affect development.

Author: LTC Allan S. Jackman

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Advancement In Natural Language Processing Likely To Add Near Complete Explainable And Emotional Intelligence Military Artificial Intelligence Applications By 2035

Executive Summary

Advancement in Natural Language Processing (NLP) is likely (56-70%) to add near complete explainable and emotional intelligence (EI) military artificial intelligence AI applications by 2035 due to its potential for nuanced language understanding, military participation in Experience Sampling Method (ESM) development, improved trust through explainable artificial intelligence (XAI) NLP, and increased EI capabilities. Critics of this assessment might identify the potential bias in NLP responses and military members' lack of trust in military AI applications; however, this will likely be mitigated through improvements in AI's ability to describe its logic process to develop its solution.

Discussion

Advancements in NLP are likely to continue to improve and expand AI capabilities. While NLP has simplified human interaction concerning LLM usage, NLP has both untapped potential [H] and issues. [MH] Computers struggle to understand human language(s) to include all the word variations, nuances, tone, context, and continuous language evolutions. However, engineers are taking advantage of improved computer capabilities, larger data sets, and deep learning to shift from traditional data-driven approaches. [H] To overcome this, American researchers are using the ESM to overcome language complexity by having the AI ask questions of a user throughout a period of time. This allows the AI to gather details, improve situational language data, and create a more personalized and context-aware NLP model. [H] Military participation in ESM development is almost certainly (86-99%) required to improve the NLP capabilities of operating within specific military organizations, levels, or environments which will help develop trust in the capability in daily operations. [H] Outside of ESM, the military could use a system where it continuously updates NLP models with new data and user feedback to help improve performance over

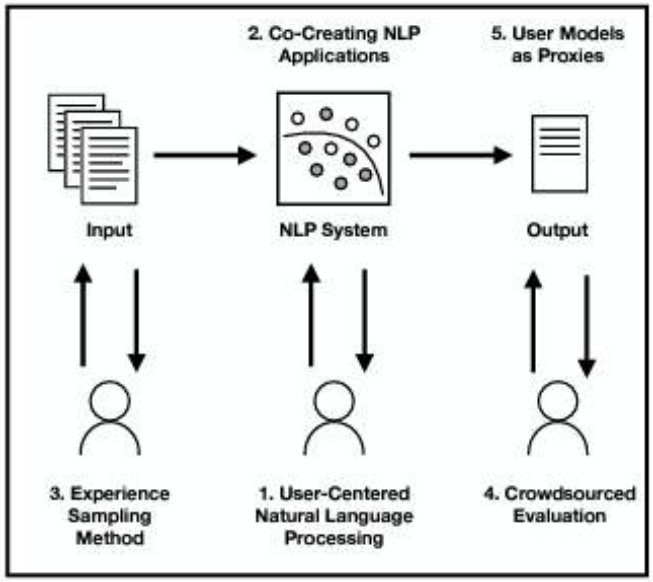

Figure 1: The model situates the five methodological proposals in the context of an NLP system. Source: Methods for the Design and Evaluation of HCI+NLP Systems

time. This would likely involve machine learning algorithms that study interactions and are fine-tuned to better serve the specific needs of military operations. [M] Additionally with more accurate NLP systems interacting with military HCI applications, operators will be able to use this AI capability without having a complete understanding of how it works or extensive formal training. [M]

The Defense Advanced Research Projects Agency (DARPA) highlighted a critical limitation in AI systems: their current inability to explain their decisions and actions to human users. [H] This lack of trust in the opaque nature of how AI actually works was

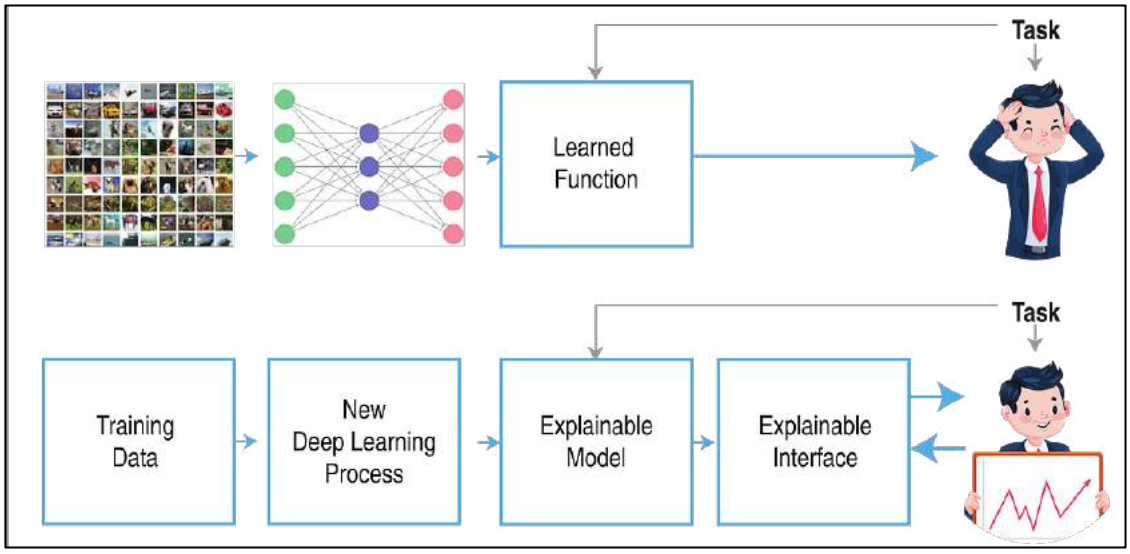

Figure 2: XAI Concept. Source: Explainable Artificial Intelligence (XAI)

prevalent in 2018 [H] and was still common in 2023. [H] XAI is likely to provide users transparency into its methodologies for the decision-making process, insight for developers to improve AI models' accuracy and correct biases, and reassurance of reliability through the understanding of the operational logic. [HM] XAI's role in demystifying AI decision-making processes is crucial for building trust, as it enables users to understand and calibrate their trust in AI systems, specifically deep learning and machine learning processes. [M] This understanding is vital for integrating AI into sensitive areas like military operations, where trust is paramount for strategic decision-making and operational tasks. XAI not only fosters transparency but also aids in optimizing personalization, mitigating and correcting bias, and ensuring fairness and accountability. [MM] Current challenges are the inherent complexity of AI and developing machine learning models. This complexity arises from the mathematical models and algorithms that underpin AI systems, which are not straightforward to explain in simple terms. [M] Achieving XAI will require a trade-off with performance. Machine learning algorithms are likely to optimize performance over the ability to explain outputs. Adding

explainability will likely mean expending additional resources or simplifying models, which might reduce their accuracy or efficiency. [M]

NLP Development chances are a little better than even (46-55%) to significantly enable EI detection by 2035. By incorporating EI into NLP systems, AI can provide a more empathetic and nuanced understanding of human emotions and intentions, facilitating interactions. The military could likely expand realistic training and simulation scenarios with immersive experiences. By accounting for not only physical responses, but also emotional and psychological factors, defense personnel would be better prepared for the complexities of real-world operations. [H] Another critical area where EI is likely to transform HCI is in support systems for mental health, such as depression and stress management. The ability of NLP systems to notify leadership or health providers or provide personalized communication and emotional support will likely help address mental stressors commonly faced by military personnel. [H] While written language is complex, accurate EI detection is even more so and not an exact science. It will require addressing a mired of ethical issues, larger data sets that account for culture balances all of which increase the required computing power. [H] Furthermore, researchers must still address challenges such as the accuracy of emotion detection and the potential for over-reliance on AI. [M] Ethical considerations, particularly regarding privacy, data security, and the mitigation of bias, are also paramount to ensure the equitable and responsible use of emotionally intelligent AI in military contexts. [M]

Analytical Confidence

The analytic confidence for this estimate is *moderate*. Sources were reliable and strongly corroborated one another. The analyst worked alone, used a structured method, and had adequate time to research. In addition to traditional research methods, ChatGPT4, Elicit, Perplexity, and Google Gemini were used but all results were reviewed, further researched, and validated against sources. Furthermore, given the size of data sets needed to develop NLPs, large computer power, and the need for military participation to develop effective military NLPs; the possibility for ethical or legal restrictions on said data; and the length of time, this report is sensitive to change due to new information.

Author: COL Robert F. Jordan

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Near Real-Time Connectivity With Limited Setup Time For Human Machine Integration In The Field Will Be Highly Likely By 2040

Executive Summary

Near real-time connectivity with limited setup time for human machine integration will be highly likely (71%-85%) by 2040 due to the growth of innovations in Mobile Virtual Network Operators (MVNO), the availability of SIM devices to connect small-form-factor devices, and the introduction of 6G communications by 2030. Despite issues with security and spectrum, industry and military will continue to evolve these technologies within the next decade due to the use of mobile devices and the need for bandwidth.

Discussion

To have a ubiquitous network, today's silos between radio networks, devices, and applications must be broken and work together effectively. [H] Sensors in users' devices, cell towers, and elsewhere will be linked to AI, which works out how, why, and where people or Internet of Things (IoT) objects need connectivity and how best to deliver it. [H]

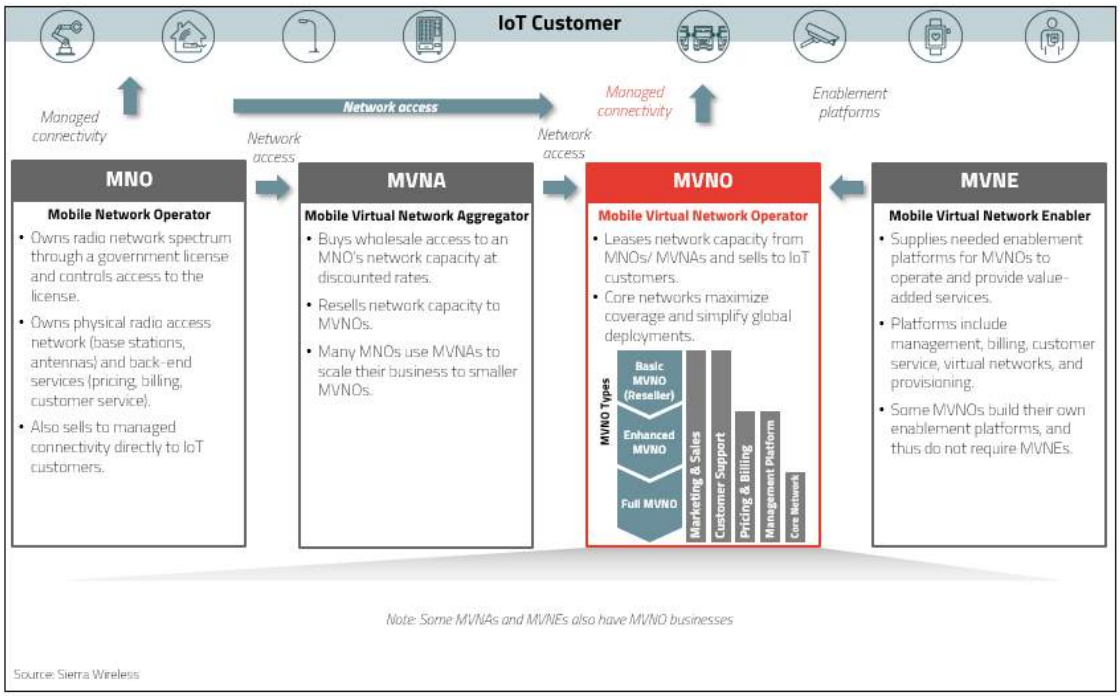

Figure 1: What is the benefit of MVNOs? Source: What is an MVNO (Mobile Virtual Network Operator)?

Examples of this technology are being provided by Google, Mint Mobile, and Access Wireless in the United States today. [H] The Mobile Virtual Network Operator (MVNO) market globally is witnessing substantial growth, expanding from a market size of $84.36 billion in 2023 to an estimated $149.13 billion by 2030, progressing at a rate of 8.5%. [H]

The widespread adoption of 5G services across the globe is opening new avenues for MVNOs, enabling them to provide consumers and businesses with high-speed, low-latency mobile connectivity. [M] Furthermore, MVNOs focusing on specific sectors, including healthcare, retail, and automotive, increasingly offer customized mobile services. [M] This sector-specific focus is propelling the application of 5G technology in various industries, enhancing IoT connectivity, and developing enterprise solutions. [M] Moreover, intense competition drives investments in network development, achieving greater coverage, enhanced reliability, improved stability, increased throughput, and smoother transitions between 5G and Wi-Fi networks. [H]

This expansion of connectivity networks brings an expanded attack surface due to the widespread deployment and increased connectivity of devices, coupled with a higher volume of data transmission. [H] This expansion presents significant security challenges within a more intricate ecosystem encompassing IoT devices, autonomous vehicles, and critical infrastructure. [H] Additionally, the inherent dynamic properties of 5G, including network slicing and virtualization, introduce novel vulnerabilities and potential exploitation points. [H] Ensuring robust segmentation and isolation between network slices and virtualized network functions is vital to safeguard against unauthorized access and data breaches, thereby maintaining the integrity and security of these advanced networks. [H] This leads to network-slicing software and hardware and better SIM capabilities. [H] Network slicing improves flexibility for an autonomous vehicle to be controlled on a mobile network slice with latencies under 5 milliseconds, and stringent packet delivery guarantees the minimum throughput required to ensure responsive control. [H]

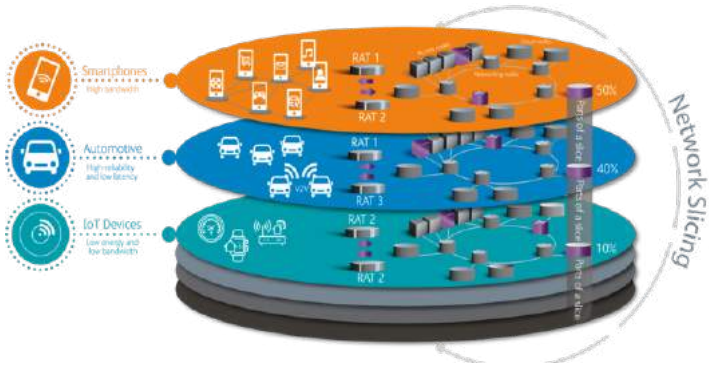

Figure 2: Network Slicing. Source: What is the Importance of Network Slicing?

SIM, originating in 1991, is a Java-based card tailored for manual device insertion and removal. [M] This traditional format lacks functionalities for most IoT applications. [M] eSIM technology emerges as a solution, addressing the shortcomings and limitations inherent in traditional SIMs. [M] An eSIM refers to either an embedded SIM card (the physical hardware aspect) or digital network access credentials (the software component) that can be downloaded to a device. [M] Despite a 3% drop in the total shipments of cellular-connected devices in 2022, devices capable of supporting eSIM witnessed a significant 11% growth year-over-year, reaching 424 million units. [H] eSIM technology has paved the

way for a shift towards more compact and integrated solutions, leading to the development of the integrated SIM (iSIM).

iSIM represents an advancement where the SIM functionality is incorporated directly into a secure section within the application processor and cellular radio, a technology already used today. [M] Unlike soft SIMs that rely on software, iSIMs are grounded in hardware-based security, utilizing dedicated physical circuits. [M] In the future, iSIM is expected to become the predominant SIM technology post-2028. [H] Forecasts suggest a remarkable rise in iSIM-capable device shipments, potentially reaching a cumulative total of 4 billion units by 2030. [H]

By 2030, the first 6G networks will likely (51%-70%) be deployed to the civilian sector, and some of the envisioned use cases will become a reality. As 6G technology develops, it is poised to support increasingly sophisticated use cases. [H] Its initial adoption is expected to be through fixed connections to residential and personal devices. [H] Innovations like contact lens displays and advanced audio/haptic interfaces are anticipated. [H] However, the envisioned 2030 rollout of 6G is contingent upon developing Terahertz (THz) communication technologies. [H] THz frequencies, essential for achieving higher data rates and capacity, present challenges including signal attenuation and limited range that need addressing. [H] Currently, 13 research laboratories are focused on THz communication systems. [H] They have achieved breakthroughs like wireless transmissions at 100 Gbit/s over 100 meters, setting a precedent for the capabilities expected in 6G THz mobile communications. [H]

Analytical Confidence

The analytic confidence for this estimate is *high*. Sources were reliable and tended to corroborate one another. Perplexity and ChatGPT were used, and ideas from the results were utilized in further research. Perplexity suggested sources that were validated and then used as references. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information.

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Advanced Cybersecurity Tools Will Highly Likely Increase The Resiliency Of Data For Faster Decision Making By 2040

Executive Summary

Advanced cybersecurity tools will highly likely (71-85%) increase the resiliency of data for faster decision-making based on the use of blockchain cybersecurity technology and the evolution of self-healing networks. This is despite the need to develop tailored cybersecurity frameworks to safeguard data and applications in these evolving technological landscapes.

Discussion

Blockchain is a technology that enables the secure sharing of information. Data is stored in a database. [H] Deloitte has stated that emerging disruptors in blockchain are creating innovative business models that are reshaping traditional commerce. [H] Transactions are recorded in an account book called a ledger. [H] A blockchain, recognized as one of today's top technological trends, functions as a distributed database or ledger. In this setup, the authority to update the blockchain is shared among various nodes or participants within a public or private computer network, a concept known as distributed ledger technology (DLT). [H] In practical applications, prominent companies like Kroger are harnessing blockchain for industry-specific purposes such as enhancing food traceability to address vital issues like food safety. [H] Similarly, Plastic Bank is utilizing blockchain technology to create a banking platform for plastic recycling, demonstrating the technology's impact on environmental sustainability. [H] Looking ahead to 2030, it is anticipated that blockchain will play a crucial role in most global trade, particularly in improving supply chain management. [H]

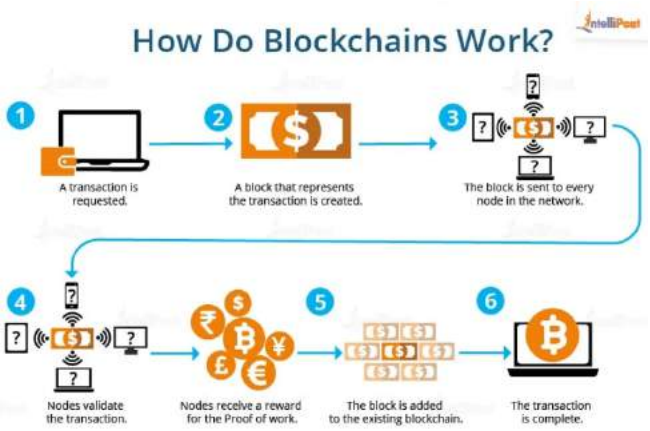

Figure 1: How Do Blockchains Work. Source: How Do Blockchains Work

The Constellation Network specializes in blockchain technology and big data processing, positioning itself as a significant player in the tech industry, and is working on a new protocol called HGTP. [H] HTTPS offers a layer of security over HTTP by encrypting data to safeguard against eavesdropping and tampering. [H] However, HGTP stands apart by focusing on the protecting of complex data types within a blockchain context. [L] HGTP, on the other hand, is designed to focus on securing complex data types in a blockchain

environment, offering a different kind of security tailored to decentralized systems. [L] The collaborative efforts between Constellation Network and Kinnami Software Corporation in developing an end-to-end secure data management solution through a combined, distributed zero-trust approach. [H]

Self-healing networks are at the forefront of network management innovation, focusing on the automated detection and resolution of network issues. [M] Key objectives of these networks include the prompt detection and automatic fixing of failures in network hardware and software, the proactive recognition of potential network problems, and the fine-tuning of network resources for improved data flow efficiency. [M] These networks greatly enhance the reliability of essential business applications by minimizing the time taken to respond to and fix network errors, employing AI and ML to optimize network functionality, thereby lowering overall ownership costs. [M] Their design removes the need for repeated manual interventions and generates vital data for business and infrastructure strategy. [M]

AI-powered IT operations platforms (AIOps) effectively lead to comprehensive self-healing network operations, offering automated data collection, in-depth cause analysis, and suggestions for problem resolution. [M] IT personnel can act based on these AI-derived recommendations, gradually building trust in AI's decision-making capabilities. [M] An element of self-healing networks is their ability to autonomously implement configuration changes to avert faults and streamline data transportation, although it takes time for network teams to trust this autonomous intelligence for essential network adjustments fully. [M]

While integrating these technologies, applying structured cybersecurity frameworks to systematically manage security risks, mitigate vulnerabilities, and enhance overall digital defense is crucial. [H] Staying abreast with the latest cybersecurity frameworks becomes essential as digital technology integration within operations intensifies. [H] Frameworks like MITRE ATT&CK, HIPAA, the National Institute of Standards and Technology (NIST) Cybersecurity Framework, ISO 27001, and Center for Internet Security (CIS) Controls are widely employed. [H] NIST is updating its popular Cybersecurity Framework to mirror the evolving cybersecurity environment and extend its applicability to diverse sectors. [H] This revision includes a new "govern" function, highlighting cybersecurity as a significant enterprise risk and a key consideration for top management. [H] The framework offers a high-level, adaptable method for managing cybersecurity risks, tailored to specific organizational demands. [H] In a rapidly digitizing world, the merging of operational technology (OT) and information technology (IT) systems calls for specialized strategies for cyber-physical systems (CPS), focusing on industry-specific cybersecurity strategies and solutions. [H]

Analytical Confidence

The analytic confidence for this estimate is *high*. Sources were reliable and tended to corroborate one another. ChatGPT was used, and ideas from the results were utilized in further research. ChatGPT suggested sources that were validated and then used as references. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information.

Author: Lt Col Joseph G. Dolce

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By 2040, Military Personnel Almost Certain To Require Much Less Physical, More Technical Skills As Human Machine Integration Advances

Executive Summary

Advanced human-machine integration (HMI) and autonomous equipment are almost certain (86-99%) to fundamentally transform the role of Soldiers and the broader culture within military institutions by 2040. This transformation will necessitate a significant shift from physicality to technological proficiency, blurring the lines between combat roles and technical specialties. The transformation is likely (56-70%) to reduce public military support as autonomous equipment removes the threat of human sacrifice. To counter this, the military must showcase the benefits of autonomous equipment beyond the battlefield.

Discussion

The character of warfare is constantly in flux, driven largely by technological advancements. This transformation extends beyond simply enhancing capabilities; it requires integrating advanced autonomous equipment with the individual Soldier's role and the broader culture of military institutions. It is almost certain that the core competencies, ethical landscape, and very identity of what it means to be a Soldier in the 21st century will be redefined.

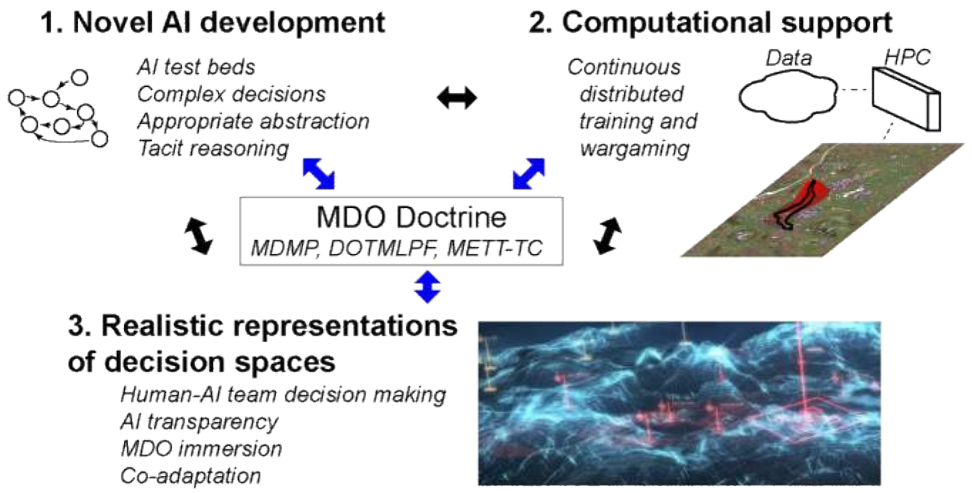

Figure 1: The three research areas (AI, high-powered computers, and battlefield visualization) of development needed for human-machine interfaces and AI-enabled decision aids. Source: The Future of Collaborative Human-Artificial Intelligence Decision-Making for Mission Planning

One significant change arising from enhanced HMI lies in the evolution of Soldier skill sets. Physical prowess and tactical knowledge are traditional Soldier skills that will likely transform towards mastering the art of operating with sophisticated technological systems

(see Figure 1). Integrating computational tools, particularly artificial intelligence (AI), is transforming the military landscape, necessitating a shift in Soldier skill sets. [H] Human-in-the-loop simulation capabilities are crucial for predicting and optimizing Soldier-systems integration. [H] The use of AI in military decision-making will highly likely:

- Significantly enhance operational quality and performance, particularly in situational awareness, logistic and operational planning, and modeling and simulation [H]
- Improve with AI decision-support tools [H]
- Be a key development for future warfighter-machine interfaces [H]

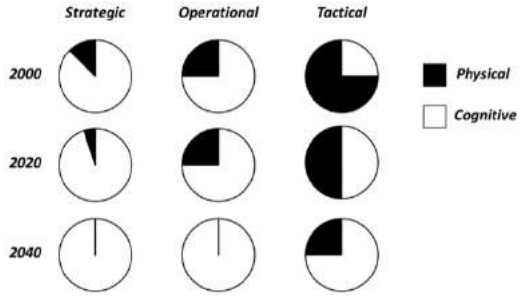

Figure 2: Transition of demand for the military warfighter from physical to cognitive at each level of war. Source: The implications of emerging technology on military human performance research priorities

These studies underscore the need for Soldiers to master cognitive skills such as data analysis, rapid problem-solving, and effective communication with AI entities, as they increasingly work with sophisticated technological systems (see Figure 2). [H]

The evolving battlefield, characterized by autonomous and semi-autonomous systems, presents opportunities and challenges. AI, particularly in the form of autonomous weapon systems and vehicles, has the potential to enhance situational awareness and decision-making support. [H] However, integrating AI at the operational level of war requires careful consideration and human oversight. [H] One solution is to understand the process architecture and identify the system of systems. An example of this can be seen using an unmanned aerial vehicle (UAV) swarm for battlefield mapping, which can enhance Soldiers' situational awareness and coordination with human and non-human teammates. [H] The application of AI in military operations, including UAV swarm technology (see Figure 3), will likely play a significant role in future battlefields. [H] This battlefield will require traditional Soldiers' skills, described as physical prowess and tactical knowledge, to be replaced with technological savvy, to operate in a sophisticated technological system.

Human-machine integration and autonomous equipment threaten to reshape military culture as the boundaries between warfighters[1] and technical specialists blur. HH This blurring will occur as Soldiers' skill sets become more technologically driven to operate autonomous equipment, with less reliance on Soldier physicality. With almost certainty, friction between warfighters and autonomous operators will occur. An example of this happened in 2013 as traditional military culture resisted the idea of a combat medal for drone pilots who are not physically located near the conflict. H The military will need to reshape the current culture so that autonomous operators receive recognition for their actions that are equivalent to warfighter recognition. H

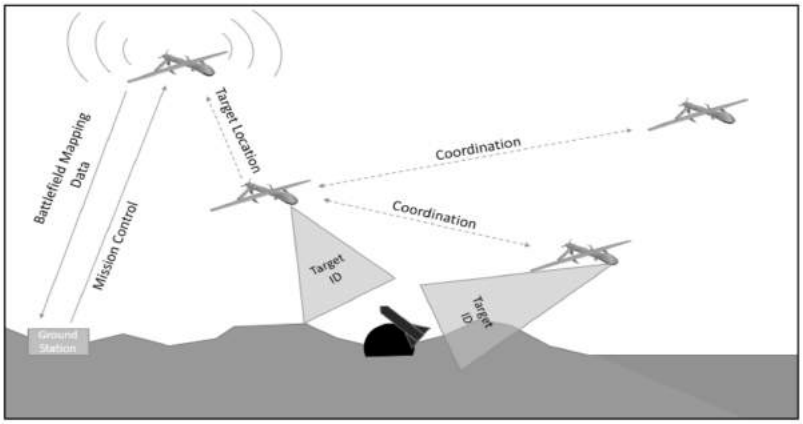

Figure 3: A drone swarm's system of systems can enable target identification through the coordination of each node in a cooperative system. Source: Battlefield Mapping by an Unmanned Aerial Vehicle Swarm

An increased inability to retain talent and lowered public perception of Soldier sacrifice in honor, duty, and country will likely arise as Soldiers become more removed from physical combat. HH Talent drain is likely to occur if autonomous operators do not feel wanted or are not acknowledged for their virtual actions. H In contrast, warfighters will believe that their actions to risk their lives are no longer viewed as the ultimate sacrifice. H[2] Public perception of the military will likely fade as Soldiers are removed from conflict and physical risk. H Once public support degrades, the military will likely face questions about its budget, which can impact its ability to innovate, recruit and retain, and provide a comparable military pay system with benefits. To counter this, the military will likely constantly reform its methods to encourage retention and highlight how military technology can be used beyond the battlefield. HH3

[1] For this paper, the term Warfighter describes the traditional Soldier in physical combat.
[2] This can occur if a combat badge is awarded to an autonomous vehicle operator equivalent to a combat badge awarded to a warfighter engaged in physical combat. The autonomous operator was never in any real physical danger, yet the warfighter is risking the ultimate sacrifice – his life. A severe friction point can create a culture chasm between the two types of Soldiers.
[3] Military GPS technology is now a necessity for the public.

Analytic Confidence

The analytic confidence for this estimate is *high*. Sources were generally reliable and corroborated one another. ChatGPT 4, Elicit, Perplexity, and other generative AI sites were used, and ideas from the results were utilized in further research. Elicit and Perplexity suggested sources that were validated and then used as references. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information, especially any hurdles or discoveries that may affect development.

Author: LTC Allan S. Jackman

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Artificial Intelligence Competitive Advantage Likely Maintained By United States In 2040 But China Aggressively Committing Resources Towards AI Dominance

Executive Summary

The United States is likely (56-70%) to maintain the competitive advantage in AI in 2040 over peer competitors based on an innovation ecosystem, talent pool, regulatory and ethical frameworks, and international cooperation. China, as a near-peer competitor, is aggressively implementing its New Generation Artificial Intelligence Development Plan from 2017, with full initiatives to be realized by 2030. Despite China's ability to rapidly implement and integrate AI technology, the U.S. wins the advantage by fostering open innovation and global collaboration, investing in next-generation research, strengthening and expanding domestic semiconductor manufacturing, and enhancing public-private partnerships.

Discussion

The US-China race to set global AI norms examines the international influence over AI's evolution from a broad societal lens, arguing that the core of this rivalry is a struggle over values, unity, influence, and global legitimacy in the emerging world order. [H] China's initiatives were set in three phases: first to enter the ranks of "innovative countries by 2020 second AI technology and applications achieve a world-leading level by 2025, and

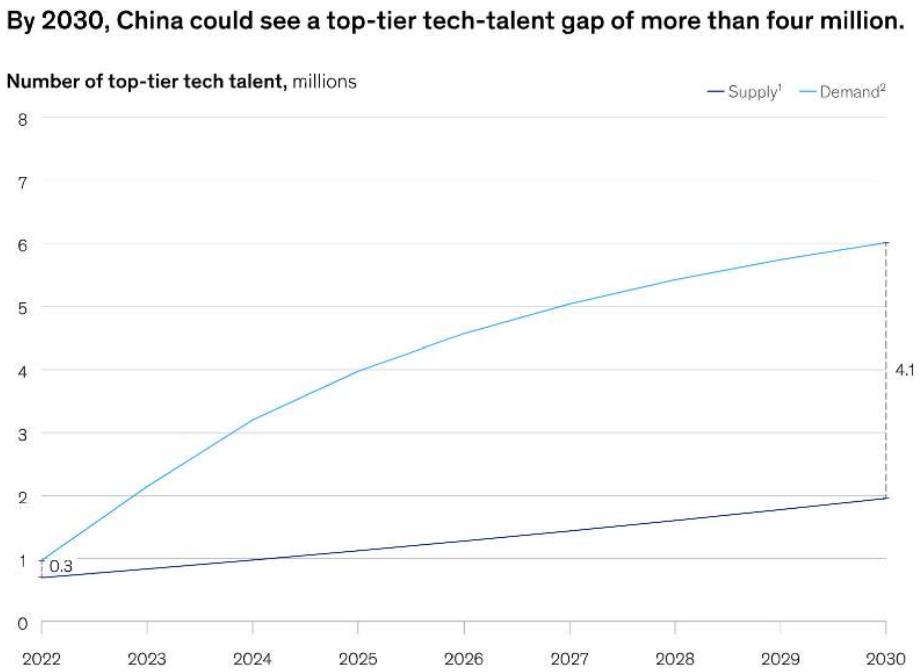

Figure 1: Variance of AI Talent Supply and Demand out to 2030 in China. Source: How businesses can close China's AI talent gap

third, become the major AI innovation center in the world by 2030." [1] Rand's study from 2020 highlights the innovative nature of the US research and development culture as one of the greatest strengths in the AI competition race, whereas for the Chinese because it is discouraged, it is considered a weakness. [H] One area that exemplifies the US's commitment to machine learning innovation through industry and academia is the quantum computing advancements that are likely to be a tech advancement by 2040. (See Quantum Computing)

The Harvard Kennedy School, in a review of AI supremacy between the US and China, gives the edge to the US in recruiting talent based on the ability to welcome any AI genius to the country, which is exactly what they did for over half of the top 100 recognized AI elite. [H] China, with its insular society of 1.4 billion Chinese speakers and only 1,000 foreign-born individuals becoming citizens in 2019, may outpace in sheer numbers, yet the United States excels in arenas valuing brilliance, creativity, and innovation. [H] Demand is growing six-fold by 2030 in AI for data scientists, data architects, data engineers, and machine learning engineers; the gap in tech talent coupled with low birth rates in China is a significant detriment to China's Next Generation AI Development Plan. [H]

The US National Institute of Standards and Technology (NIST) played a pivotal role in formulating an extensive strategy for the federal government's involvement in AI standards, sparked by Executive Order 13859. [H] This strategy focuses on reducing exposure to cyber threats, aligning with federal objectives to foster innovation, bolster public trust and confidence in AI technologies, and advocates for sustained, intensive participation in the creation of AI standards, aiming to accelerate the development of dependable and secure AI technology. [H]

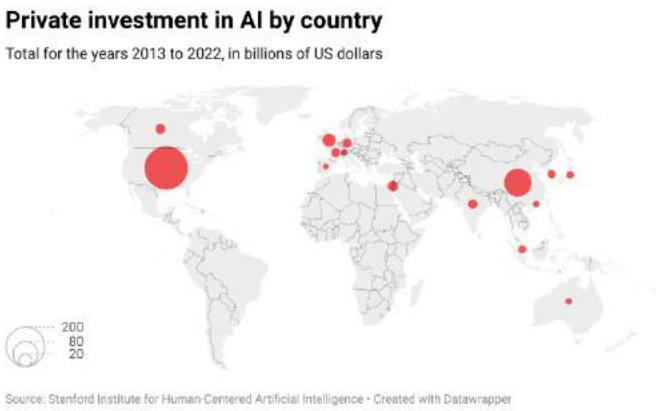

Figure 2: Private Investment in AI by Country. Source: To fully appreciate AI expectations, look to the trillions being invested

The overall investment internationally into AI is a private sector initiative that is spending upwards of $250 billion since 2021. [H] Countries globally

[1] *State Council Notice on the Issuance of the New Generation Artificial Intelligence Development Plan,* Full Translation: China's 'New Generation Artificial Intelligence Development Plan' (2017) (stanford.edu)

investing in AI through private partnerships is represented in Figure 2 from the Stanford Institute of Human-Centered AI; the circle represents US dollars in billions. [H]
On the other hand, ethical concerns regarding algorithmic decision-making prioritize the collective's well-being, with the Chinese Communist Party (CCP) asserting itself as the only legitimate voice for the collective rather than focusing on individual rights. [M] This issue is not without challenges as evident in the graphic in Figure 3 which highlights various Chinese actors that have attempted to address AI ethics concerns since 2017, the inception of the New Generation AI Development Plan. [M]

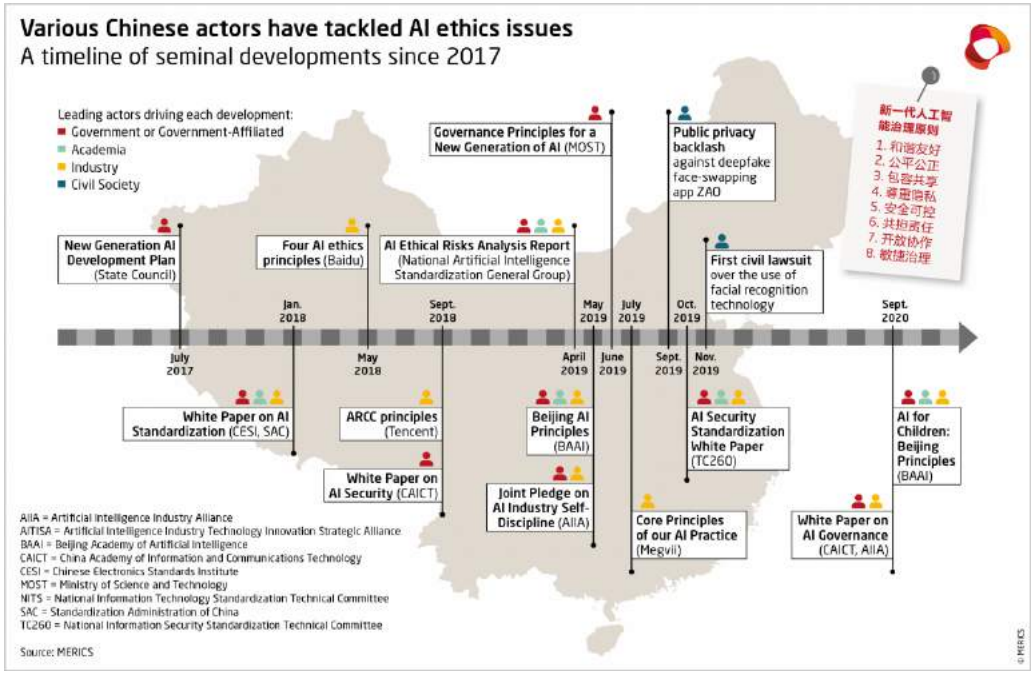

Figure 3: Chinese Actors Influential Attempts at AU Ethics Issues. Source: Lofty principles, conflicting incentives: AI ethics and governance in China

The White House's National Standards Strategy for Critical Emerging Technology (CET) is one example of the US effort to leverage international relationships and collaboration to maintain the competitive advantage over peer competitors like China. [H] The Department of State, NIST, the Department of Commerce, the Federal Communications Commission, the National Security Agency, the Office of the US Trade Representative, USAID, and other bodies participate in international platforms like the International Telecommunication Union, the Quad, the US-EU Trade and Technology Council, the G7, and the Asia-Pacific Economic Cooperation to exchange information on standards and CETs. [H] In addition to basic regulatory requirements over AI using facial recognition and privacy concerns in the US, there are also international policy and regulatory concerns with dual-use AI and lethal autonomous weapons systems (LAWS). (See Disputes in International Community)

Despite China's rapid ability to implement AI technology on a global scale, their unpredictable business climate, alongside the vast market for AI products and the eagerness of Chinese consumers to embrace these innovations, steers companies and investors towards favoring applied AI research that promises immediate financial returns over foundational research with the potential for enduring impact. [H] The US maintains a lead in semiconductor development and production through public-private partnerships, which is a key reason why China is unlikely to dominate the AI technology or research field by 2040. [H]

Analytic Confidence

The analytic confidence for this estimate is *high*. Sources were reliable and tended to corroborate one another. ChatGPT, SciSpace, Academia, Elicit, and Perplexity were used, and ideas from the results were utilized in further research. Elicit suggested sources that were validated and then used as references. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information.

Author: COL Erin H. Frazier

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Adaptability And Cultural Intelligence, Moral Acuity, And Digital Competency Highly Likely Selection Criteria For Human Machine Military Organizations By 2035

Executive Summary

Adaptability and cultural intelligence (CQ), deeply anchored in ethical standards and digital competencies (data literacy, technological competence, and artificial intelligence (AI) literacy), are highly likely (71-85%) to emerge as crucial selection criteria for military leaders of human-machine (HM) organizations by 2035. This shift is due to the critical need for leaders to not only grasp but also manage the integration of rapidly advancing technologies into military operations while sustaining digital competency. The complexity of these technologies and the ethical dilemmas they present almost certainly (76-99%) necessitate a deep-rooted understanding of ethical decision-making frameworks, reinforced by insights regarding moral injury. Critics are likely to argue that the rapid pace of technological evolution risks surpassing the capacity of leadership development programs to sufficiently equip leaders with digital competence and ethical grounding, all the while maintaining instruction in enduring leadership skills. However, the people likely to succeed will overcome this through a commitment to continuous learning and adaptation ensuring their strategies and decisions are informed by the latest developments in technology and ethical standards.

Discussion

With the rapid evolution of technologies like autonomous platforms and AI systems, adaptability presents challenges and opportunities for military leaders. [H] A recent study by the MITRE Corporation and Binghamton University identified high tolerance for ambiguity and openness to new experiences are key indicators of potentially adaptive leaders. [H] Venture technology investor Natalie Fratto (see Figure 1) mirrors this assessment by looking at leader adaptability, not past success, intelligence, or emotional intelligence to assess startups. [M] These qualities allow individuals to navigate the complexities and prospects of integrating emerging technologies such as 3D printing into military logistics and operations. (See 3D Print Systems Report) These traits are also likely to assist in the

Figure 1: TED talk discussing importance and measuring of adaptability in technology developers. Source: 3 ways to measure your adaptability

performance monitoring of high and low-automation systems. As an application's abilities through machine or deep learning expand, adaptability will likely be key to adjusting the level of autonomy and its integration with other systems to drive improvements in both resource allocation and organizational performance. [H] Finally, a Russian military conference report highlighted the multi-faceted, yet criticality of training and identifying adaptable leaders. In addition to tolerance for ambiguity, the reports cited cognitive flexibility, the ability to recognize situations has changed and adapt quickly, as a key indicator in identifying and developing adaptable leaders. [M] As the possibilities and challenges of technological advancements continue, adaptability is highly likely to continue to serve as a key leadership trait to combat the many ambiguities and opportunities of the future.

CQ is the ability to comprehend and function effectively across diverse cultural contexts and will be important for HM leaders. [H] Just as cross-culture teams can struggle to communicate effectively due to language barriers and cultural differences; HM integrated groups will likely have communication challenges. These differences can lead to misunderstandings and conflicts, making it difficult for team members to work together effectively. [H] CQ enables leaders to adapt their leadership styles and strategies to meet the demands of hybrid teams. [H] Leaders with high CQ are better able to spot indicators or cues leveraging the strengths of both human and machine elements for optimizing overall performance. [H] This will help to ensure clear communication, foster collaboration, and build trust. [H] Finally, this skillset is likely to remain a human-dominated endeavor. [M] While AI is likely to develop emotional intelligence (EI) capabilities, CQ goes beyond the EI step. (See Advancements In Natural Language Processing) It is understanding and recognizing the differences and similarities in behavior across cultures and involves identifying common and unique patterns in behavior, as well as those that are neither typical nor unique. [M]

As military operations become increasingly dependent on HMI technologies, leaders will highly likely be grounded in ethical decision-making training, including moral acuity. [M] This is particularly relevant in technology-driven organizations like the military, where ethical leadership is essential for establishing ethical norms and fostering an atmosphere that encourages ethical decision-making. [H] Using new technologies

Figure 2: Dr. Brian Klassen provides an overview of moral injury and how it relates to military service. Source: What is moral injury?

like augmented reality or virtual reality trainers (AR/VR), leaders are likely to train subjects like emotional regulation, forecasting, self-reflection, and information integration. (See Ethical Decision-Making Training) However, to achieve moral acuity, this training is likely to include moral injury. Moral injury is the lasting psychological, spiritual, or ethical damage caused by witnessing or participating in events that deeply violate a person's moral code. [H] Chaplin Timothy Mallard further highlights the significance of ethical considerations, underscoring the potential psychological impact of actions taken in complex HMI environments and the necessity of moral grounding in leadership roles. Future leaders are likely to need to be aware of their moral values and how their actions reflect those values to avoid and address moral injuries. (See Chaplain (COL) Mallard Interview) Given the evolving understanding of moral injury, it is likely moral acuity will become a focus for ensuring militaries remain persistent in their commitment to ethical leadership and decision-making. [H]

The evolving digital battlefield will likely necessitate leaders who are adept in digital tools, enhancing operational effectiveness through improved situational awareness and data-driven decision-making. [H] Digital competency balanced with foundational leadership qualities is highly likely to be a significant factor in military leadership development by 2035. (See Digital Competency In Leadership Development) As military organizations transition towards enhanced HMI, digital competency is also highly likely to become an important selection criterion for leaders within these organizations. [M] Proficiency with digital tools and platforms enables leaders to make informed decisions, streamline operations, and leverage data for operational and strategic advantages. [H]

The rapid pace of technological evolution will likely continue to present challenges in both the military and business leadership realms as both equip leaders with digital

Figure 3: A historical lifelong learning model example used by the Spanish military. Source: The learning process to become a military leader

competence and ethical grounding while maintaining instruction in enduring leadership skills. [M] However, the dynamic nature of HMI technologies necessitates a commitment to continuous learning and professional development among military leaders. (See Military Training and Education) This commitment will likely help leaders remain abreast of the latest technological advancements and are equipped to integrate these tools into their planning and execution. [M] Lasandra Conliffe of Ontario Tech University highlights the impact continuous learning has on organizational culture that values innovation, encourages trying new ideas, and supports ethical practices. [M] By prioritizing education and professional development using a lifelong learning model (see Figure 3), military organizations can cultivate leaders who are not only technologically proficient and ethically grounded but also adaptable and forward-thinking. [MHH]

Analytical Confidence

The analytic confidence for this estimate is *moderate*. Sources were generally reliable and strongly corroborate one another. The analyst worked alone and had adequate time to research. In addition to traditional research methods, Perplexity.ai, Copilot, and Google Gemini were used but all results were reviewed, further researched, and validated against sources. Furthermore, the rapid pace of technology change, the role of human leaders in future battlefield operations, the developing understanding of moral acuity and digital competency, the impact of technology on ethical boundaries, and the length of time, this report is sensitive to change due to new information.

Author: COL Robert F. Jordan

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Attributes Supporting Digital Competency – Data Literacy, Technological Competence, And Artificial Intelligence Literacy – Highly Likely Included In Military Leadership Development Models By 2035

Executive Summary

By 2035, it is highly likely (71-85%) military leadership development models will change to address attributes to support digital competency. This is due to evolving requirements of digital tools that support data-driven decision-making, attracting and retaining military talent, and developing a data-driven culture. Critics likely (56-70%) will argue that a focus on digital proficiency could overshadow the development of traditional leadership qualities necessary to prepare a force for the complexities of future warfare. However, integrating data literacy, technological competence, and artificial intelligence (AI) literacy does not replace these foundational leadership qualities but rather enhances them. Instead, a balanced approach is highly likely required, where digital proficiency complements and enhances, rather than replaces, foundational leadership attributes such as decision-making, critical thinking, and the ability to inspire and motivate.

Discussion

Digital competency almost certainly (86-99%) includes data literacy, technological competence, and AI literacy. [HHHM] According to the European Union, digital competence involves the confident, critical, and responsible use and engagement with digital technologies for both learning and work and is characterized by a blend of knowledge,

Figure 1: A Framework for AI Literacy Competency. Source: AI Literacy

skills, and attitudes. [H] Data literacy, as defined by the Massachusetts Institute of Technology professor Catherine D'Ignazio and research scientist Rahul Bhargava, "includes the ability to read, work with, analyze and argue with data." [H] Thus, data literacy supports digital competence and can be tailored to specific roles and responsibilities. For example, data literacy for a logistics officer includes using and understanding supply chain management software, while a commander would use it to analyze real-time data feeds. Next, Duri Long and Brian Magerko of the Georgia Institute of Technology outline AI literacy as a competency that enables individuals to critically evaluate AI technologies, and communicate and collaborate with them in different situations. [HH] For example, AI literacy includes deciding how and when AI should be used and how data limitations affect performance. [H] Incorporation of digital competencies into leadership development models is highly likely to help prepare leaders for future military leadership challenges.

Future battlefields are likely to be characterized not only by a military's physical capabilities but also by the leaders' proficiency in harnessing digital tools for strategic and tactical advantage. [H] The integration of digital competence into development models is likely to improve the effectiveness of military operations by enhancing situational awareness and enabling leaders to make data-driven decisions in complex environments. [H] For example, McKinsey & Company found that the top-performing companies had

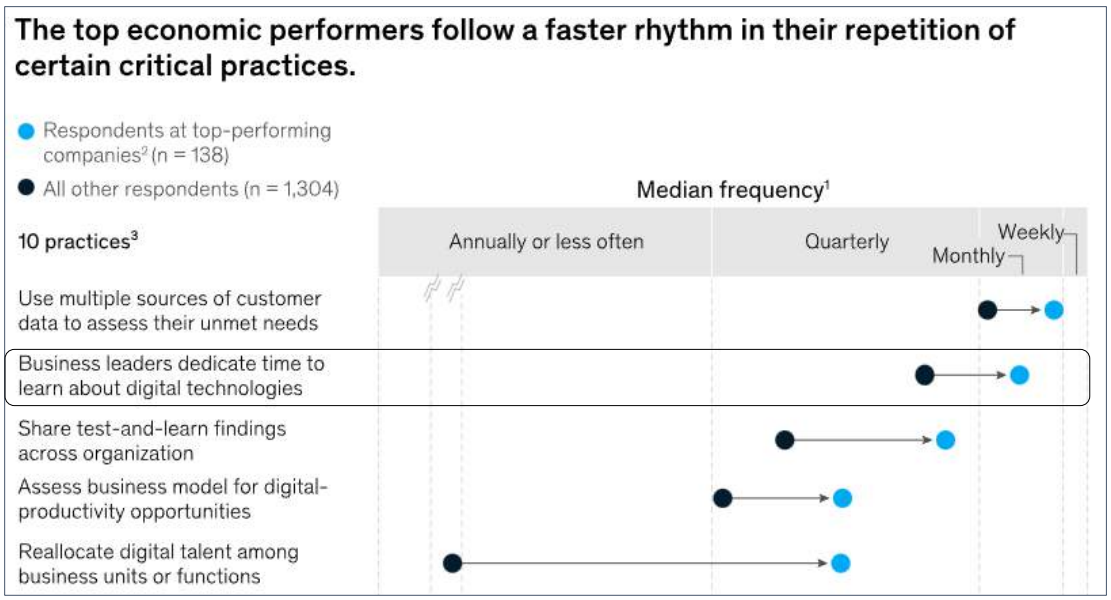

Figure 2: Chart excerpt highlights leaders of top performing companies dedicate more time to developing digital competency. Source: The drumbeat of digital: How winning teams play

senior leaders who took time to improve their knowledge of digital tools and practices. [H] Military leaders are highly likely to need to leverage digital tools to gather, analyze, and interpret data from various sources such as battlefield sensors, intelligence feeds, and social media to gain a comprehensive understanding of the situation. [M] Digital competency will also allow leaders to collaborate and communicate effectively with

geographically dispersed teams and integrate emerging technologies such as autonomous systems and AI into their decision-making processes. [MM] While integrating these digital competencies into leadership development models may encounter challenges, such as concerns about the overshadowing of essential leadership qualities by technological reliance, it is almost certain that such integration is critical. [H] Thus, militaries are likely to adopt a highly balanced and adaptive approach to leadership development. [H]

The integration of digital competence into development models is likely to enhance recruitment and retention efforts by alignment of expectations and skill sets of a new generation of soldiers. [M] A study by Nexus IT group highlighted that employer branding, which demonstrates a company's digital savviness, has become pivotal in attracting and retaining talent in fields like digital marketing. [M] A RAND study showed that modern individuals are attracted to organizations that demonstrate a commitment to both technological advancement and innovation. [H] The digital proficiency of future bosses will likely be an important factor in retaining such individuals who are seeking environments where their native digital skills are valued and further developed. [H] The retention of digitally competent individuals is more likely when they observe a clear pathway for utilizing and enhancing their skills within the organization. [M] As junior leaders' basic understanding of data-driven technologies improves, mid-grade and senior leaders will almost certainly need to embrace ways to improve their aptitude and commitment. [HM] Opponents of changing the leadership development model to support this are likely to point out this is the same as remaining aware of the capabilities and limitations of emerging technologies, however, digital competence is more than technology. [MH]

Given the purpose of leadership development is to prepare individuals to take on critical leadership roles, it is likely the shift will require a reassessment of the impact of data-driven decision-making on military leadership development models. [HHM] This is rooted in the idea that future leaders will need to be competent in their understanding of the analytical, digital, and technological tools supporting decision-making. [M] Leaders must grasp these concepts to navigate the adoption and implementation of new technologies effectively. [M] Concurrently, it is also important to highlight that high consumption or use of technology also does not necessarily create digital competency. [HM] Leaders will likely require a structured and comprehensive learning approach that keeps pace with the digital tool evolution. [MM] Updates are likely to drive culture change and support the continuous professional development initiatives needed to ensure military leaders remain adept in the rapidly evolving strategies and capabilities. [M]

Analytical Confidence

The analytic confidence for this estimate is *moderate.* Sources were reliable and corroborate one another. The analyst worked alone, used a structured method, and had adequate time to research. In addition to traditional research methods, ChatGPT4, Microsoft Copilot, Google Gemini, and Perplexity.ai were used but all results were reviewed, further researched, and validated against other sources. Furthermore, given the potential resistance to change, potential slowdown in technological advancements, integration challenges in adapting leadership development models, and budgetary constraints limiting new training programs, this report is sensitive to change due to new information.

Author: COL Robert F. Jordan

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Future Support Infrastructure

Military Units Operating In Isolated Locations Will Almost Certainly Require Collaboration Centers And Power Generation To Successfully Implement Human-Machine Integration By 2040

Executive Summary

Human-machine integration compels a fundamental reimagining of military facilities that will almost certainly (86-99%) require command centers to include human-AI collaboration centers and self-sustained power generation. The slow and ineffective defense acquisition process likely (56-70%) challenges implementing necessary technologies, impacting the military's ability to compete with adversaries. Addressing this "defense innovation readiness gap" likely requires redefining acquisition incentives and enhancing the Department of Defense (DoD) transparency to better bridge innovation with military application.

Discussion

"Ultimately, it is the human's internal acceptance of the robot into the workforce and warfighting systems, broadly defined, that will determine the nature, and indeed the success, of HMI." – Source: RAND Australia Report [H]

Future commanders and leaders will need a relationship with artificial teammates for collaboration. [H] Current command centers, designed for hierarchical decision-making, must evolve to include collaboration centers where humans and artificial intelligence can seamlessly work together. [H] The goal of the center is to create a common task environment (see Figure 1), a peer-like relationship between artificial teammates and humans. [H]

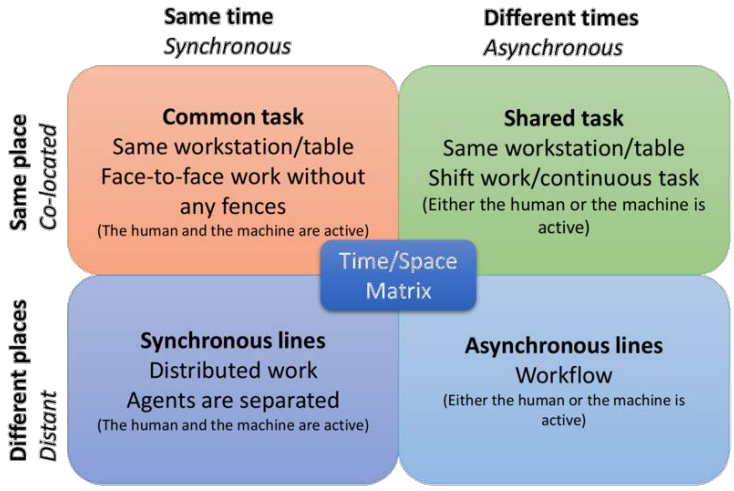

Figure 1: Time-space matrix for robot-supported cooperative work. Source: Engineering Human–Machine Teams for Trusted Collaboration

These spaces will facilitate shared situational awareness and joint decision-making between humans and AI-powered systems. [H] Data fusion, visualization tools, and intuitive interfaces will empower human operators and their machine counterparts to analyze complex battlespace information and formulate effective strategies. [H] These centers will require dedicated spaces to allow interaction with the equipment (technology

such as headsets with augmented and virtual reality, high-powered computers, and data storage centers) to create a common task work environment. [HM]

A Harvard Business Review study of 1,500 firms of different industries found that "the biggest performance improvements come when humans and smart machines work together, enhancing each other's strengths." [H] Additionally, MIT conducted a study and found that organizations tend to focus too much on technology instead of being 'people-centered,' meaning that "AI technology should be amplifying human strengths," not replacing humans. [M] Studies on human-AI teaming in sectors like healthcare and finance suggest that dedicated spaces facilitating joint analysis and data visualization can improve outcomes. [H] Military infrastructure can adapt this model by creating joint workspaces for human analysts and AI-powered systems. Real-time data from battlefield sensors, processed by AI algorithms and presented alongside human-gathered intelligence, can enable faster, more informed strategic decisions in a rapidly shifting environment. [H]

The 2023 DoD Operational Energy Strategy states that energy substitution and diversification efforts "will explore hybridization, electrification, SAF [sustainable aviation fuels], hydrogen, and other energy technologies, to power land, sea (surface and subsurface), and air platforms." [H] An emerging technology that will require energy is drones. The employment of unmanned aerial drone systems by Ukraine against Russia in 2023 has shown the significance of drones in warfare. [H] Power requirements to maintain a stock of charged batteries will highly likely be linked to sustaining drone deployment.

Microgrids and portable power sources are two options for a forward-stationed unit to harvest energy. Integrating traditional generators with renewables and energy storage in microgrids is a growing trend, offering resilience, power quality, and the ability to operate in an island mode, independent from other grids. [H] This integration is particularly important in transforming the electric power distribution system, where microgrids and distributed generation systems play a crucial role. [H] The flexibility, modularity, and scalability of microgrids make them an ideal solution for adopting renewable sources at the point of power demand in forward locations. [H] A mobile solar-powered microgrid trailer was recently showcased in Georgia.

Figure 2: Garmin's Instinct 2x Solar Tactical GPS watch has unlimited battery life due to the efficient energy harvesting from its solar face. Source: Garmin

[M] The trailer can power refrigeration, phone and computer charging, medical device charging, and other basic needs in a disaster response and recovery situation. [M] Advancements in solar cell efficiency and battery technologies will enable compact, lightweight power sources suitable for troops on the move. [H] Fuel cells are becoming lighter per power output, and integrating flexible solar cells into wearables is bringing wearable power into reality. [H] This is already incorporated commercially; Garmin released a smart-GPS tactical watch (see Figure 2) with unlimited battery life as the solar face harvests more energy than is needed. [H] It is stressed that when designing portable solar power stations, it is crucial to prioritize reliability, convenience, and cost-effectiveness. [H] These advancements collectively suggest a promising future for compact, lightweight, and efficient power sources suitable for troops on the move.

These technological requirements will likely encounter the hurdle of an ineffective defense acquisition process that hinders the warfighter from deterring or winning a conflict against an adversarial nation. [H] A March 2024 report stated that "the security environment is rapidly evolving, and the current PPBE [planning, programming, budget, and execution] process is not capable of responding as quickly and effectively as needed to support today's warfighter." [H] The inability to move from innovation to employment is a "defense innovation readiness gap." [H] This gap is due to the DoD structure separating innovation and employment by policies and funding. [H] To reduce the gap between innovation and employment, the DoD will likely need to change how it incentivizes the acquisition system by defining goals and increasing transparency. [H]

Analytic Confidence

The analytic confidence for this estimate is *high*. Sources were generally reliable and corroborated one another. ChatGPT 4, Elicit, Perplexity, and other generative AI sites were used, and ideas from the results were utilized in further research. Elicit and Perplexity suggested sources that were validated and then used as references. There was adequate time, but the analyst worked alone and did not use a structured method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information, especially any hurdles or discoveries that may affect development.

Author: LTC Allan S. Jackman

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Battery Output Will Highly Likely Triple By 2040 With Lithium-Sulfur Batteries, The Replacement For The Aging Lithium-Ion Batteries

Executive Summary

Research to increase the energy storage capacity in batteries is a highly likely (71-85%) development to occur before 2040 from advancements in lithium-sulfur (Li-S) battery research. This progress is driven by the increasing demand for electrically powered technologies, private-sector research, and the availability of resources. Despite critics' concerns about the short life cycle and rapid decline in capacity, known as “polysulfide shuttling,” researchers are not deterred. They are integrating modified separators and advanced cathode materials to trap polysulfides and experimenting with electrolyte additives and protective anode coatings to stabilize the battery's chemistry and enhance its longevity.

Discussion

The quest to increase the energy storage capacity of current batteries by 2040 highlights the scientific community's drive toward innovation. [H] This advancement is catalyzed by the global demand for more efficient energy solutions, private-sector research, and the availability of resources. [HHH] While challenges such as the short lifespan and capacity decline, known as "polysulfide shuttling," persist, ongoing research into modified separators, advanced cathode materials, electrolyte additives, and protective anode coatings is paving the way for more stable and long-lasting Li-S batteries. [H]

There is a growing demand for unmanned vehicles and drones in military operations with state and non-state actors to defeat opponents. [H] Azerbaijan, for example, successfully used drones to attack Armenia during the second Nagorno-Karabakh War, and the

TWh Electricity Generation	2016	2017	2018	2019	2020	2025	2030	2035	2040
Coal	31	23	17	7	6	0	0	0	0
Gas	143	137	131	132	111	80	73	68	65
Nuclear	72	70	65	56	50	56	65	70	80
Hydro	5	6	5	6	7	7	7	7	7
Wind	37	50	57	64	75	116	156	175	200
Solar	10	11	13	13	13	16	20	23	25
Bioenergy	30	32	35	37	39	39	39	39	39
Total	329	328	323	315	301	315	360	382	416

TWh Electricity Generation	2025	2030	2035	2040
Gas	80	44	9	0
Total	315	331	323	351

Figure 1: Two tables showing UK prediction for coal and gas reliance reaching zero by 2025 and 2040, respectively. Source: An In-Depth Life Cycle Assessment (LCA) of Lithium-Ion Battery for Climate Impact Mitigation Strategies

Houthis are currently employing drones in the Red Sea against the United States. [HH] The transition to clean energy (see Figure 1), driven by the need to combat climate change, is another key demand driver for developing new battery technologies. [H] The US climate strategy relies heavily on renewable energy, with battery energy storage systems playing a crucial role in mitigating climate impact. [H] Furthermore, "government plans to phase out internal combustion engine (ICE) vehicles over the next 10 to 30 years" is driving rapid advancements in battery technology for electric vehicles. [H]

Lithium-ion batteries (LIBs) have been the dominant energy storage solution, but their energy density is reaching its limit. [H] Lithium-sulfur Li-S batteries are a promising alternative, offering triple the energy density with 90% less energy. [H] However, their limited recharge cycles have hindered commercialization. [H] Li-S batteries are prone to "polysulfide shuttling," a severe power output reduction with each charge. [H] Recent advancements in solid-state Li-S batteries, including improved electrode and electrolyte materials, offer potential solutions to this challenge. [H] The commercialization of Li-S technology is further supported by the development of high-performance electrodes using a novel hybrid model with a data-driven approach. [H] Despite these advancements, the transition from LIBs to Li-S batteries presents challenges, including the need to rapidly transfer new concepts and a better understanding of degradation phenomena. [H] A solution (see Figure 2) to this hurdle was recently stumbled upon by Drexler University. [H] Theion, a solid-state battery producer, anticipates usability in 2024 for mobile and wearable devices. [H]

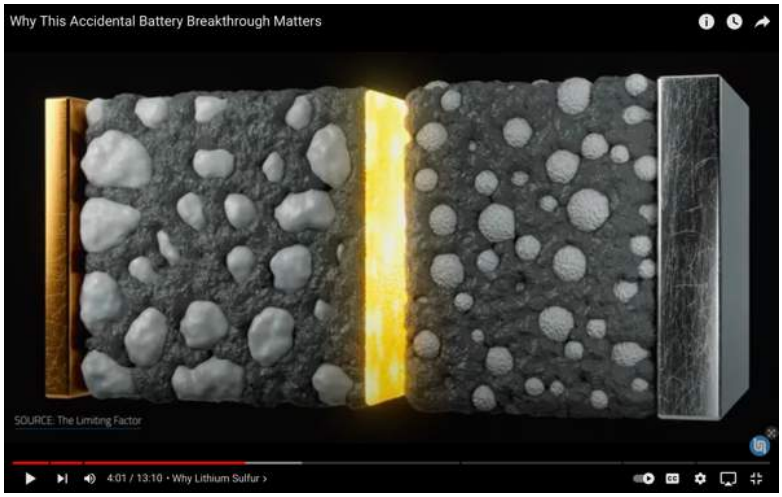

Figure 2: Researchers overcoming a major hurdle to commercialize Li-S batteries. Source: Why This Accidental Battery Breakthrough Matters

Compared to lithium-ion batteries, Li-S batteries use more readily available minerals with less environmental impact. [H] The use of cobalt in lithium-ion batteries, particularly from the Democratic Republic of Congo (DRC), raises concerns about the ethical and environmental implications of its mining. [H] The DRC employs modern-day slavery and unsustainable destructive techniques to mine cobalt. [H] Resources to produce LIBs are becoming scarce, and harmful mining practices are employed in regions that do not value human rights. [H] On the other hand, "sulfur is the tenth most abundant element on the Earth, and local sources are usually available in any chosen location in the world." [H]

Furthermore, lithium reserves have been discovered along the Oregon-Nevada border. [H] The abundance and location of sulfur and lithium are highly likely to provide a more economical and accepted means over resources used for lithium-ion batteries.

The development of next-generation Li-S batteries will likely face several challenges, including technical, safety, and manufacturing aspects. [H] However, research and development efforts are actively addressing these challenges, with advancements in materials science, electrolyte design, and manufacturing processes holding the potential to overcome these hurdles. [H] While widespread adoption might not happen in the immediate future, continued advancements are highly likely to solidify Li-S as a game-changer in the energy storage landscape by 2040.

Analytical Confidence

The analytic confidence for this estimate is *high*. Sources were reliable and tended to corroborate one another. Bard, Elicit, and other generative AI sites were used, and ideas from the results were utilized for further research. Elicit suggested sources that were validated and then used as references. There was adequate time, but the analyst worked alone and did not use a structured research method. Furthermore, given the lengthy time frame of the estimate, this report is sensitive to change due to new information.

Author: LTC Allan S. Jackman

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Deployable 3D Print Systems Highly Likely Standard Capability For Military Sustainment By 2030 And Almost Certainly A Standard Capability For Frontline Units By 2035

Executive Summary

Deployable 3D printer systems are highly likely (71-85%) to be standard for large-scale combat-capable military sustainment units by 2030 and are almost certainly (86-99%) to be incorporated into standard frontline unit capabilities by 2035 due to the rapid progress in 3D printing technology, its operational impact in the Ukraine conflict, and governments' increasing investments into 3D printing capabilities. Opponents are likely (56-70%) to cite cybersecurity threats such as design manipulation or intellectual property theft, but these cybersecurity concerns are being addressed through broader cybersecurity protocols.

Discussion

As 3D printing availability, capability, and reliability increase, the price for entry into 3D Printing will continue to shrink. [M] With a flooded market, basic economics demand companies rapidly improve, find a niche, or be driven out. [M] This means an already capable technology is highly likely to quickly evolve over the next ten years. One example which has military implications is 1000 Kelvin, in conjunction with Fieldmade, has successfully paired 3D printing software with artificial intelligence (AI) and made it commercially available. [M] AI pairing with software improves the optimization of builds, provides constant monitoring, enables preventive corrections, and assists in troubleshooting. [M] This monitoring is likely to address many concerns over the quality control of 3D printed parts. Another improvement is pulsed electrochemical machining

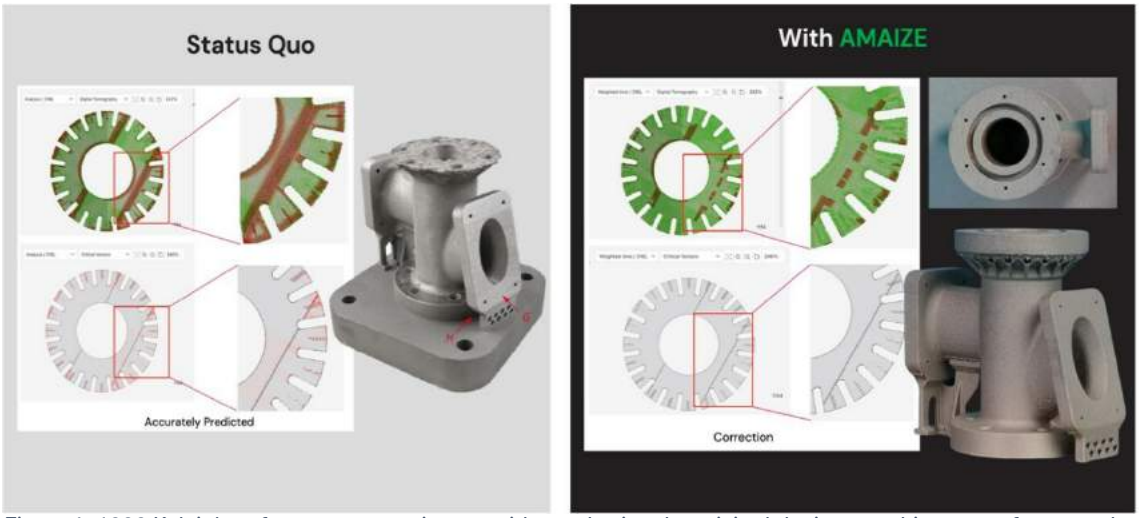

Figure 1: 1000 Kelvin's software corrects issues without altering the original design to achieve a perfect part the first time. Source: 1000 Kelvin's AI-Powered Copilot for 3D Printing Goes Commercial, Adopted by Leading Manufacturers

(PECM) which can reduce the surface roughness of metal parts. PECM is being used to produce civilian aviation parts. [M]

Since the invasion of Ukraine by Russia in 2021, both Russian and Ukrainian forces have used 3D printing to support weapon repair, drone manufacturing, construction, and medical care. [LMM] Ukraine expanded its usage when it received a mix of over 40 different aged Soviet Union era equipment and newer Western vehicles. [H] These items have been invaluable, but many needed repair parts are no longer in production and require special tools. [M] In 2023, the US provided seven Spee3D industrial-grade 3D printers to increase Ukrainian sustainment capabilities. [M] Since this is the first use in an active combat zone, it has created a proof of principle for 3D printing to support on-site engineering and repair with reduced dependence on historical resupply. [H] It is also worth noting Spee3D is not the only printer which has been provided for frontline operations. The Nexa3D Company provided Essentium and KVG Rapid 3D printers to assist in the Ukrainian war efforts. [M]

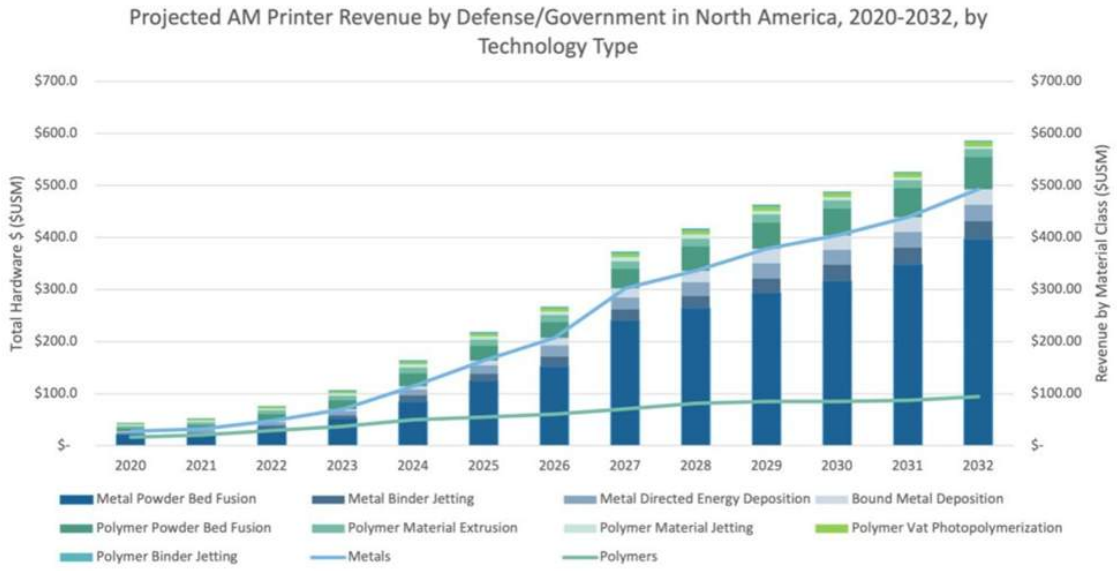

Figure 2: US 3D Adaptive Manufacturing Market Analysis and Forecast. Source: United States Additive Manufacturing for Military and Defense: Market Analysis and Forecast

Government military investments in 3D printing are steadily accelerating, driving the potential for distributed logistical support and continuous innovation. [M] A recent "Research and Markets" financial report projects US Department of Defense (DoD) spent $0.3B in 2023 on 3D printing capabilities with projected estimates rising to $1.8B in 2032. [H] In fiscal year 2023, DoD awarded a five-year blanket purchase agreement which included $23.4M to 6K Additive. This contract supports the expansion of upcycle scrap capacity to support higher demands for high-grade metal printing supplies. [M] This investment demonstrates the need for not only better and more capable machines, but also a reliable and sustainable material supply chain. Outside the United States, the

Norwegian Armed Forces have a historical working relationship with 1000 Kelvin, discussed earlier, and 1000 Kelvin's production of deployable military-grade print facilities. [M] Concerning construction printing, military services are using printable construction to create buildings, bunkers, and even stabilize runways. Finally, multiple European governments recognize the impact this capability has on military preparedness for both logistics, crisis response, and battlefield innovation and are providing the necessary funding to move this technology to be fully fielded in the not-too-distant future. [MMMM]

Opponents to the widespread use of 3D printers operating on DoD networks are likely to cite the US Army Inspector General (IG) findings on the security failures regarding flagged 3D printing systems which resulted from organizations treating the machines as tools and not technology needing cybersecurity controls. [M] Since 2021, DoD now applies Security Technical Implementation Guides (STIGs) to 3D printers and in December 2023 Velo company announced its Velo3D metal system meets these rigorous requirements. [M] Organizations can address these risks using a comprehensive approach, integrating robust cyber protocols (e.g., STIG), checking systems regularly, segmenting networks, and comparing printed parts to twins. [M]

Analytical Confidence

The analytic confidence for this estimate is *moderate*. Sources were generally reliable and strongly corroborate one another. The analyst worked alone, used a structured method, and had adequate time to research. In addition to traditional research methods, Perplexity and Google Gemini were used but all results were reviewed, further researched, and validated against sources. Furthermore, given potential production delays, the chance for contract protests with government procurement processes, and length of time, this report is sensitive to change due to new information.

Author: COL Robert F. Jordan

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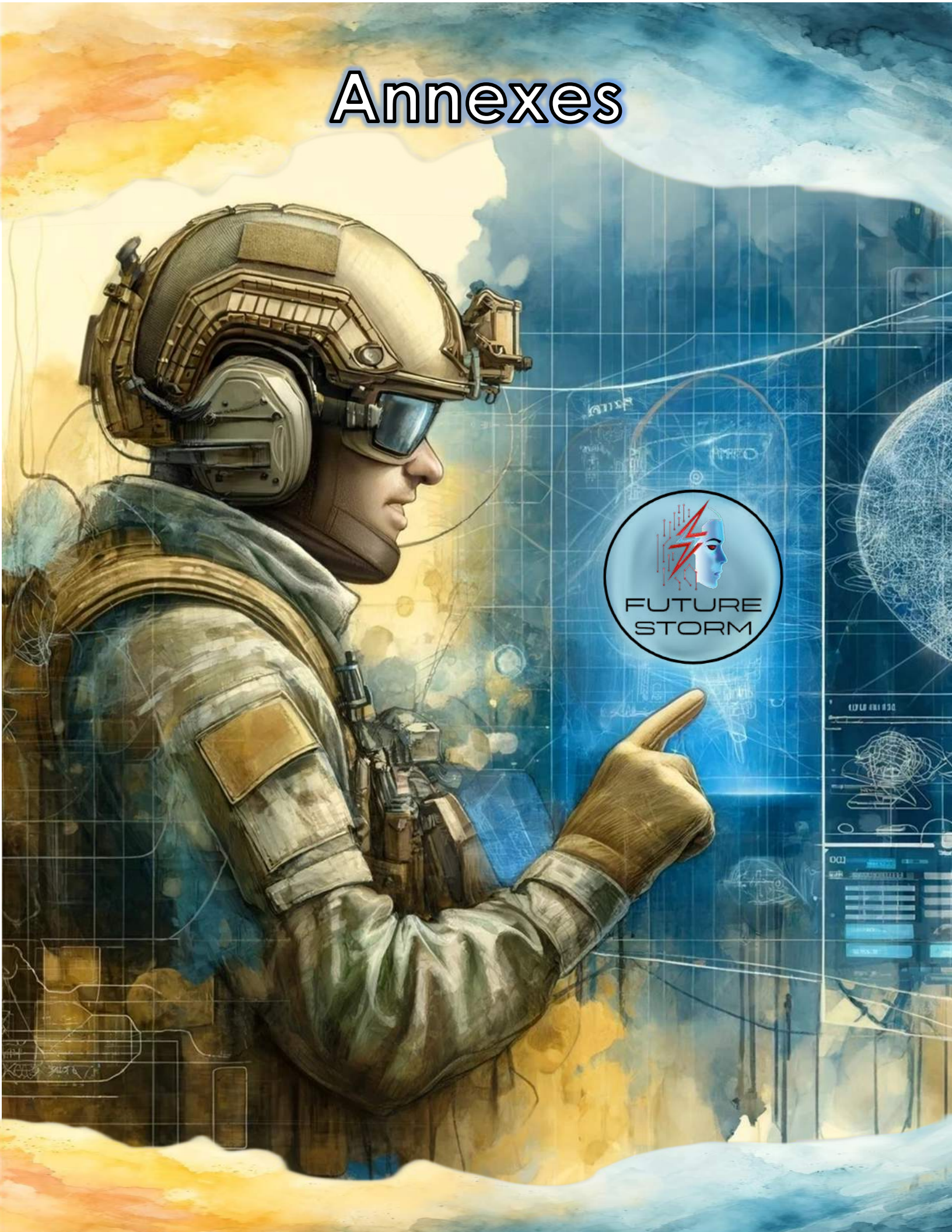
Annexes



Annex A – Terms of Reference

Terms of Reference:
Human Machine Integration 2030-2040

For:

GEN James Rainey
CDR, US Army Futures Command

By:

Team Future Storm
USAWC

December 18, 2023

Terms of Reference:
Human Machine Integration 2030-2040

Requirement:

How will human-machine integration (HMI) between 2030 and 2040 likely evolve the character of warfighting and necessitate changes across DOTMLPF-P to gain or maintain a competitive advantage in future military conflicts?

- What functions will likely remain human/CDR centric, aided by machines?
- What processes, educational initiatives, and tools will likely develop a military workforce that can ask the right questions and frame decisions to fight and win in a data-centric environment?

Methodology:

In general, the team intends to gather information through various means, including but not limited to data collection from open-source outlets and interviews with scientists, technology experts, industry, and artificial intelligence futurists.

The team plans to execute this project in overlapping phases. While these phases will be executed simultaneously between December 2023 and April 2024, the primary focus of the team's efforts will shift as the team models, researches, analyzes, and communicates its findings.

- Phase 0: Define the question – Converse with GEN Rainey to develop his question, time period, and priority of effort
    - Secure GEN Rainey's endorsement of this Terms of Reference

- Phase 1: Model the Problem – Begin to break down the problem into parts to develop a starting point for guiding collection in phase 2
    - Dissect the problem into identifiable elements
    - Identify likely subject matter experts which could provide insight into understanding the question

- Phase 2: Research, Collect, Learn – Operating within the challenges listed in this document, dive deep into subject matter and explore existing literature, academic papers, industry reports, and reputable sources to gain insights into elements of the problem identified in phase 1 and facilitate analysis in phase 3
    - Seek out subject matter experts to gain understanding of the trajectory and capabilities of human machine integration
    - Identify and evaluate the expected environment that will drive machine evolution

    - Identify existing technologies, those in development, and those in concept
    - Consider lessons learned from modern human machine integration operations
    - Explore education requirements to gain and sustain competency in machine integration
    - Explore the projected limits on what machines and humans will likely be capable of preforming in the time period

- Phase 3: Analyze – Using the knowledge and understanding gained in phase 2 pull together the different elements from research to analyze the problem and formulate a likely answer
    - Determine the boundaries and assumptions which may be required to answer the problem
    - Consider alternative scenarios or potential future outcomes based on different assumptions, variables, and drivers
    - Consider how to improve human capability to participate in human machine integration
    - Consult with subject matter experts in the field to gain perspective on the predictions

- Phase 4: Production and Communication – Compile a professional report that includes the team's findings regarding optimal human machine integration and training the future force to operate effectively with machines
    - Compile concepts and prepare complete report and executive summary format as requested
    - Create out-brief presentation to communicate findings
    - Out-brief GEN Rainey and his team

Challenges:

- The team's personnel are pursuing this project to complete a master's degree at the US Army War College and a full course load
- The estimate must be complete by April 2024
- The amount of information relative to this topic is new, and may be challenging to find differing opinions
- Due to time and equipment constraints, the team can access only open-source information, and the final product will be unclassified
- Limited funding is available to support travel and other expenses
- The final product will be an unclassified document
- The difference in time zones can present scheduling challenges coupled with a very busy and highly sought-after principal

Resources:

- The team will draw upon the comprehensive databases and resources of the US Army War College, including its archives, research libraries, digital platforms, and relevant resources from commercial and educational institutions
- The team will identify and connect with government, international, organizational, and private sector subject matter experts
- The team will analyze open-source media and research publications from reputable academic and professional institutions
- The team comprises Army and Air Force officers with diverse backgrounds (Active Duty, Reserve, Acquisition, Sustainment, Civil Affairs)
- The team will leverage their strong personal and professional relationships with colleagues from various sectors, including military, government, academia, organizations, and institutions, both domestically and internationally

Administration:

The final product will be provided in PDF format and is for the sole use of GEN James Rainey, Commander, Army Futures Command. Formatting the final document is built into the research process, thus there is no "pre-release" of the report that will be available.

The outbrief will be ready for presentation upon completion of review by peers and US Army War College faculty. The final outbrief will be in April 2024. Team Future Storm will coordinate with GEN Rainey's staff to schedule the outbrief.

- Team Future Storm consists of:
  - Team Point of Contact
    - LTC Tyler Waterhouse (USAR)
  - Alternate Team Point of Contact
    - COL Erin Frazier (USA)
  - Other Team Members
    - Lt Col Joe Dolce (USAF)
    - LTC Allan S. Jackman (USA)
    - COL Robert F. Jordan (USA)
- Army Futures Command
  - Commanding General, Decision Maker
    - GEN James E, Rainey
  - Primary point of contact
    - MAJ Ashley Olds
  - Other points of contact
    - LTC Alexander Chung
    - MAJ Jamaal Smart

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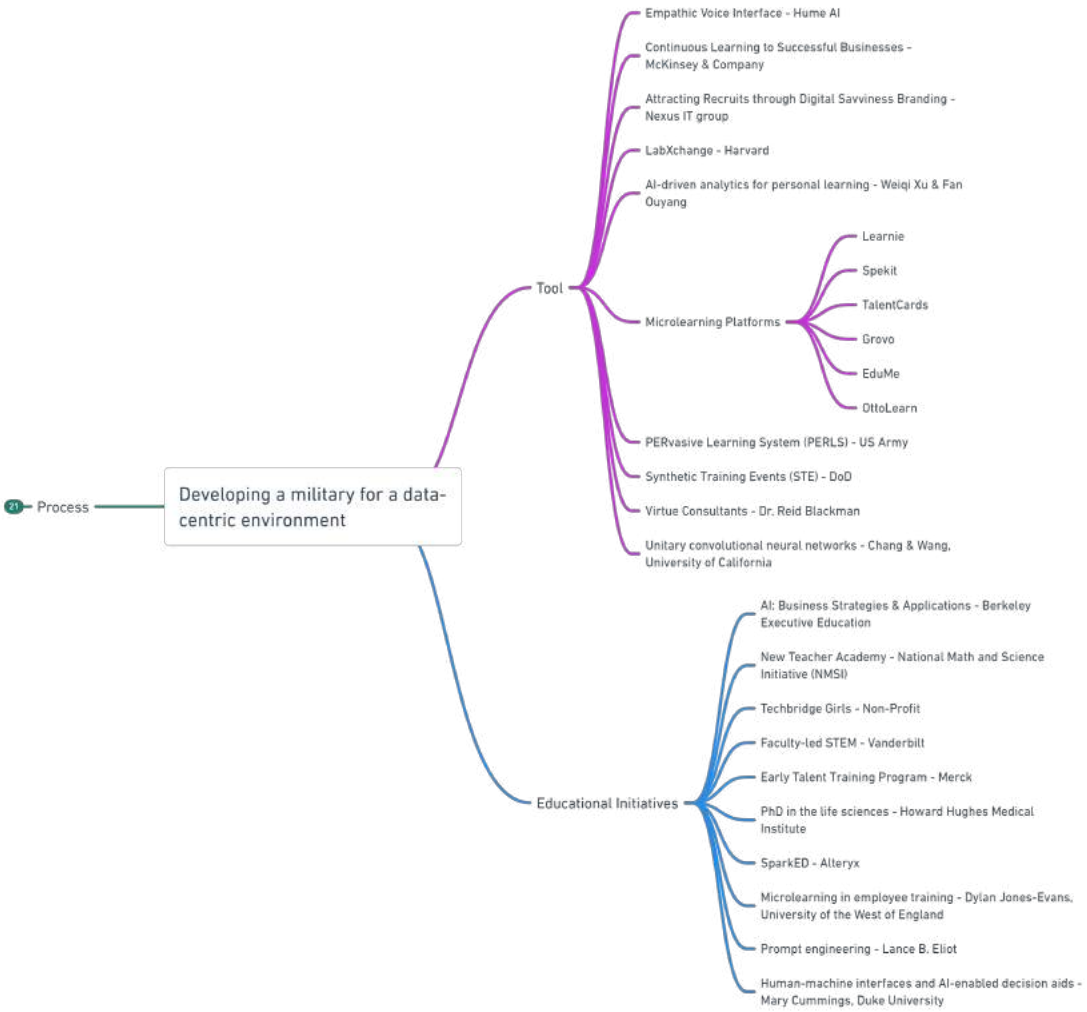
Annex B – Mindmap Of Processes, Educational Initiatives, And Tools To Develop A Military Force



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Annex C – Interview With Chaplain (COL) Mallard

Emailed Interview Summary Concerning Moral Injury With Chaplain (Colonel) Timothy Mallard, Ph.D., On 6 March 2024

Great conversation this morning and thanks for raising some poignant questions. Here are some summary thoughts:

1. Moral Injury, as a concept, is based on either the transgression or betrayal of a deeply held value, principle, attitude or belief. For many people, these interior factors are often unexamined, and are internalized and unconsciously held as an outcome of their prior moral formation as children, youth, or young adults. For others, these interior factors are examined and consciously held, often becoming moral boundaries that frame their daily, ethical decision-making and actions. This level of self-awareness and conscious moral and ethical consonance of behavior is vital to our leaders in the profession of arms, and thus is a goal towards which we strive in strategic professional military education. Nevertheless, moral injury can be framed from such interior ethical conflicts as something one did, failed to do, had done to them, or even witnessed as a non-participant. In this way, moral injury is highly subjective.

2. The oft-used trope of "Human/Machine Teaming" is, in my opinion and on its face, grounded in a fallacy: namely, that humans and machines are somehow equal in nature. Teams can only be made of moral equals, and since machines are human inventions (and so derive their existence from humans) and they cannot reason morally on their own and do not possess equal capacities with humans in autonomous will, they lack true moral agency and are thus not truly independent beings. In fact, their existence is conditioned by their human creators, so they are dependent at best—highly advanced, but dependent nonetheless.

3. This, then, leads to their status in the current and future profession of arms. In the current scholarly discussion amongst ethicists, there is cause to understand that since machines (and I believe by extension Artificial Intelligence and AI-enabled Weapons Systems) are created and dependent in nature, then none ever really rise to the level of being truly autonomous, even in war. Even if they are loosed on a current or future battlefield from direct, tactical command and control by a human, ontologically they are never "out of the loop" (to use a current phrase) because at a minimum they retain the values, principles, attitudes, and beliefs of the human being who programmed and/or coded their software in the first place. This is why, for example, in current or future war, such machines cannot and will not ever be charged with a violation of the law of armed conflict, because we do not hold them responsible as moral agents. However, their

programmers or software engineers or the warrior who knowingly releases them into battle apart from direct, tactical command, these we would hold to be so liable. Humans are always moral agents; machines are not.

4. To return to moral injury, however, this does not mean that such machines cannot be the conduits for moral injury in people—they most certainly can. The recent wars in Armenia-Azerbaijan, Ukraine and Russia, and Israel and Gaza are bearing this out. Even in battlefield instances where humans let loose UAS, for instance, either the operator or the target of that system may experience moral injury for its achieved effects, but this will be entirely dependent on the person in question and how they frame the ethics of the situation, as again, moral injury is highly subjective. What these same conflicts remind us of, however, is that such moral injury is never confined only to the forces in question but to the civilian populations in which those forces fight. If current and future war will likely be fought in and amongst peoples and people groups—particularly in urban contexts—then societies will have to deal with effects of moral injury both during and after conflict. To my mind, this makes all the more important the requirement to stringently control the programming and coding of all machines in war and to explicitly agree to and enforce the embedding of established, organizationally validated human values, principles, attitudes, and beliefs (for example, prudentialism in targeting as a principle of the Just War Tradition). Will machines always achieve an ethically consistent outcome in war and thus never err in their limited autonomy? No, they will not. However, four conclusions present here as outcomes:

- This, again, is the reason that we will never hold such machines legally responsible for a war crime but we are bound to do so for the programmers, coders, and/or operators of such machines in war;

- This necessitates why moral and ethical education of leaders in PME is and will remain more vital to achieving competitive advantage and victory in future war (vice less so)

- This necessitates the implied task for (in the U.S. context) the joint force and service leaders in the Defense Acquisition Process to explicitly agree to and enforce the embedding of established, organizationally validated human values, principles, attitudes, and beliefs, and even to lead this discussion amongst the allied and partner nation forces with whom we will fight, and;

- This necessitates at the nation-state level that we must incorporate into our future *jus as bellum* decision-making to go war the realization that any conflict will entail a manifold, post-war cost of civilian moral injury as an accepted cost of

war, though perhaps at an order of magnitude greater than initial projections may forecast.

I trust this helps Rob and, as always, I am available to dialogue with you further on this topic.

Grace and peace,
Timothy

Timothy S. Mallard, Ph.D.
Asst. Professor, Director of Ethical Development & College Chaplain
Chaplain (Colonel) U.S. Army
U.S. Army War College

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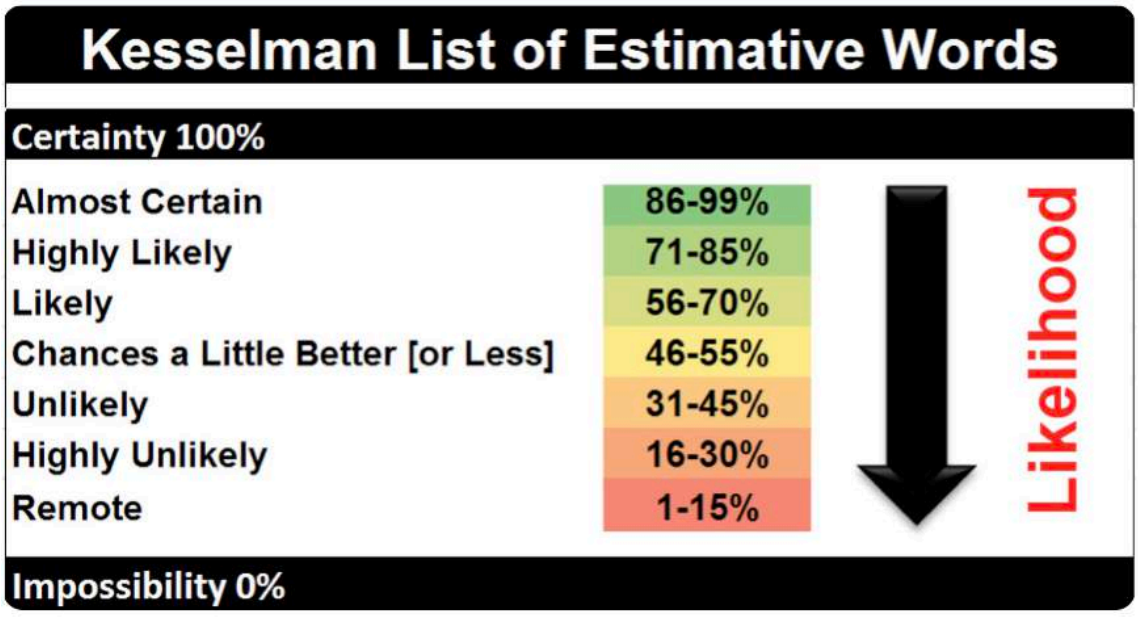
Annex D – Kesselman List Of Estimative Words



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Annex E – Assessing Analytic Confidence

Peterson Factors

- How reliable are the sources?
- How well do the independent sources corroborate each other?
- What is my/my team's level of expertise?
- How effective was my analytic collaboration?
- Did I use any structured techniques in my analysis?
- How difficult did I perceive the task to be?
- Did I have enough time to complete the task?

Friedman Corollaries

- Is my estimate within the range of reasonable opinion surrounding the question?
- How likely is it that new information will change my estimate?

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Annex F – Trust Scale And Website Evaluation Worksheet

Trust Scale and Web Site Evaluation Worksheet (Updated OCT 2013)										
Piece of Evidence #:			**Art 1**	**Art 2**					**Score**	**Trust Scale**
Criteria	**Tips**	**Value**	**Y or N (1 or 0)**	**Y or N (1 or 0)**	**Y or N (1 or 0)**	**Y or N (1 or 0)**	**Y or N (1 or 0)**	**#REF!**	**17.5**	**15-20 High**
Content can be corroborated?	Check some of the site's facts	2	1	1					4	**11-15 Moderate**
Recommended by SME?	Doctor, biologist, country expert	2	1	1					4	**6-10 Low**
Author is reputable? Google for opinions,	Google for opinions, ask others	2	1	1					4	**5-0 Not Credible**
You perceive site as accurate?	Check with other sources; check affiliations	1.5	1	0					1.5	
Information was reviewed by an editor or peers?	Science journals, newspapers	1.5	1	1					3	
Author is associated with a reputable org?	Google for opinions, ask others	1.5	0	1					1.5	
Publisher is reputable?	Google for opinions, ask others	1.5	1	1					3	
Authors and sources identified?	Trustworthy sources want to be known	1	1	1					2	
You perceive site as current?	Last update?	1	1	1					2	
Several other Web sites link to this one?	Site only link to other sites they trust	1	1	1					2	
Recommended by a generalist?	Librarian, researcher	1	1	1					2	
Recommended by an independent subject guide?	A travel journal may suggest sites	1	1	1					2	
Domain includes a trademark name?	Trademark owners protect their marks	1	0	0					0	
Site's bias in clear?	Bias is OK if not hidden	1	1	1					2	
Site has professional look?	It should look like someone cares	1	1	1					2	
Total			17.5	17.5	0	0	0	0		
19 Dec 2001: The criteria and weighted values are based on a survey input from 66 analysts. For details see: http://daxrnorman.googlepages.com/analysis. Edited for simplicity by Kristan J. Wheaton, Oct 2013										
3 Feb 2012: Excel Spreadsheet which adds auto-sum was produced by Bill Welch, Deputy Director, Center for Intelligence Research Analysis and Training, Mercyhurst College.										
26 Jan 2013: Trust Scale and Web Site Evaluation Worksheet is in the PUBLIC DOMAIN.										

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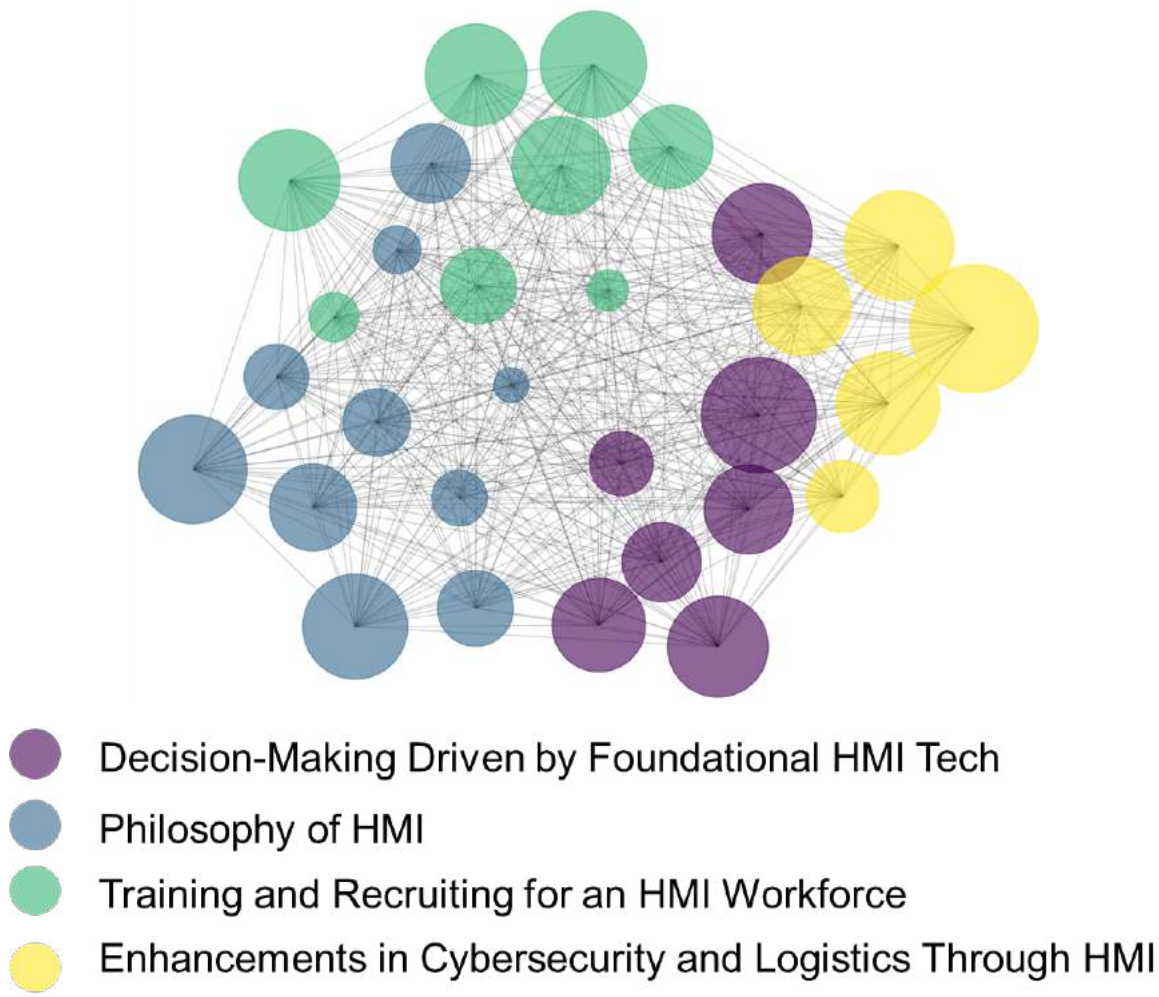
Annex G – Network Analysis And Adjacency Matrix



Inset of the cross-analysis of individual reports. The actual digital document has been uploaded into the PDF version of this document.

	Near Real-Time Connectivity With Limited Setup Time for Military Devices In the Field Will Be Highly Likely By 2040	Advanced Cybersecurity Tools Will Highly Likely Increase The Resiliency of Data For Faster Decision Making By 2040	Neuromorphic Technologies Will Likely Increase The Speed And Reduce Power Needs For Military Decision-Making By 2040	New Military Recruits Will Likely Have Skills In STEM For Daily Use Of Human-Machine Integration By 2040	Micro-Learning Is Almost Certainly How The Military Trains For A Human-Machine Integrated Battlefield by 2040	Ethical Arounc Machir Integra Lethal Weapc Systen the Ch Charac Highly Remai Conter Throug
Near Real-Time Connectivity With Limited Setup Time for Military Devices In the Field Will Be Highly Likely By 2040	0	3	1	1	0	
Advanced Cybersecurity Tools Will Highly Likely Increase The Resiliency of Data For Faster Decision Making By 2040	3	0	2	0	0	
Neuromorphic Technologies Will Likely Increase The Speed And Reduce Power Needs For Military Decision-Making By 2040	1	2	0	0	0	
New Military Recruits Will Likely Have Skills In STEM For Daily Use Of Human-Machine Integration By 2040	1	0	0	0	3	
Micro-Learning Is Almost Certainly How The Military Trains For A Human-Machine Integrated Battlefield by 2040	0	0	0	3	0	
Ethical Concerns Around Human-Machine Integration and Lethal Autonomous Weapons Systems, Within the Changing Character of War, Highly Likely to Remain Contentious Through 2040	0	0	1	0	0	
Augmented Reality (AR) and Virtual Reality (VR) technology are highly likely (71-85%) to be critical components of future superiority on the battlefield by 2040	3	3	3	3	2	
Several Concerns Around Human-Machine Integration, Lethal Autonomous Weapons Systems, and Human Trust in Those Systems are Highly Likely (71-85%) to Drive the United States Policy on Limiting Their Use on the Battlefield Through 2040	0	0	0	0	0	
Training in Prompt Engineering is Highly Likely						

	Near Real-Time Connectivity With Limited Setup Time for Military Devices In the Field Will Be Highly Likely By 2040	Advanced Cybersecurity Tools Will Highly Likely Increase The Resiliency of Data For Faster Decision Making By 2040	Neuromorphic Technologies Will Likely Increase The Speed And Reduce Power Needs For Military Decision-Making By 2040	New Military Recruits Will Likely Have Skills In STEM For Daily Use Of Human-Machine Integration By 2040	Micro-Learning Is Almost Certainly How The Military Trains For A Human-Machine Integrated Battlefield by 2040	Ethical Concerns Around Human-Machine Integration and Lethal Autonomous Weapons Systems, Within the Changing Character of War, Highly Likely to Remain Contentious Through 2040	Augmented Reality (AR) and Virtual Reality (VR) technology are highly likely (71-85%) to be critical components of future superiority on the battlefield by 2040	Several Concerns Around Human-Machine Integration, Lethal Autonomous Weapons Systems, and Human Trust in Those Systems are Highly Likely (71-85%) to Drive the United States Policy on Limiting Their Use on the Battlefield Through 2040	Training in Prompt Engineering is Highly Likely (71-85%) to be a Critical Requirement for Military Leaders and Soldiers Operating in a Human-Machine Integrated Environment by 2040	Advanced Biofeedback Devices, Immersive Simulations, and Improved Intuition Drills are Likely Core Elements of Effective Ethical Decision-Making Training by 2040	Artificial Neural Networks likely Improve Military Decision-Making Speed Between 2035-2040	Future of Artificial Wisdom: Embracing Emotional Intelligence, Ethical Decision-Making, and Multidisciplinary Approaches Unlikely By 2040.	Advancements in Anthropomorphic AI Predicted to Impact Military Commands and Revolutionize Warfare By 2040	Military Commanders Highly Likely to Use AI to Inform Morale and Welfare Concerns, but Will Almost Certainly Remain Enduring Human Function	Artificial Intelligence Use in Strategic Decision-Making Likely, but Human Involvement Highly Likely Especially During Crises Response	Tripling Battery Energy Storage Highly Likely As Lithium-Sulfur Aims To Eclipse Lithium-Ion By 2040	The Advent Of Quantum Computing Will Likely Be A Reality By 2040	Brain-Computer Interface Technology Highly Likely To Enhance A Soldier?s Efficiency With Cognitive And Physical Enhancements By 2040	Human-Machine Integration And Autonomous Equipment Is Almost Certain To Transform Soldiers From Battlefield Brawn to Technical Savvy	Military Units Operating In Isolated Locations Will Almost Certainly Require Collaboration Centers and Power Generation To Successfully Implement Human-Machine Integration by 2040	Perspective Taking, Performance Monitoring, and Conflict Resolution Likely Crucial Human Tasks for Human Machine Integration in 2030s	Deployable 3D Print Systems Highly Likely Standard Capability for Military Sustainment by 2030 and Almost Certainly a Standard Capability for Frontline Units by 2035	Advancement in Natural Language Processing Likely to Add Near Complete Explainable and Emotional Intelligence Military Artificial Intelligence Applications by 2035	Attributes Supporting Digital Competency–Data Literacy, Technological Competence, And AI Literacy–Highly Likely Included In Military Leadership Development Models By 2035	Chances that Comprehensive Yet Tiered Needs in Digital Competencies and Basic Military Principles to Increase Training and Education Requirements up to 10% by 2035	Highly Likely That AI And Blockchain Will Create Advantages For Logistics On The Human Machine Integrated Battlefield In 2040	Artificial Intelligence Competitive Advantage Likely Maintained By United States In 2040 but China Aggressively Committing Resources Towards AI Dominance	Revolutionizing Military Operations – The Convergence Of Advanced Technologies Will Likely Pave The Way For Advanced Decision-Making By 2040	Adaptability And Cultural Intelligence, Moral Acuity, And Digital Competency Highly Likely Selection Criteria For Human Machine Military Organizations By 2035	Balancing Innovation with Moral Responsibility Highly Likely to be Critical to the United States Military by 2040
Near Real-Time Connectivity With Limited Setup Time for Military Devices In the Field Will Be Highly Likely By 2040	0	3	1	1	0	0	3	0	0	2	3	1	0	0	0	0	3	2	3	3	2	0	2	0	0	3	0	1	0	0
Advanced Cybersecurity Tools Will Highly Likely Increase The Resiliency of Data For Faster Decision Making By 2040	3	0	2	0	0	0	3	0	2	3	2	0	0	0	2	0	3	2	1	2	2	3	3	2	0	3	2	2	0	0
Neuromorphic Technologies Will Likely Increase The Speed And Reduce Power Needs For Military Decision-Making By 2040	1	2	0	0	0	1	3	0	0	0	3	0	3	0	1	1	2	2	0	1	0	0	2	0	0	1	2	3	0	0
New Military Recruits Will Likely Have Skills In STEM For Daily Use Of Human-Machine Integration By 2040	1	0	0	0	3	0	3	0	2	2	0	2	3	2	2	0	0	2	3	3	1	3	2	3	3	2	3	0	3	0
Micro-Learning Is Almost Certainly How The Military Trains For A Human-Machine Integrated Battlefield by 2040	0	0	0	3	0	0	2	0	3	2	1	2	2	1	2	0	0	2	2	0	3	2	3	3	3	1	3	0	3	0
Ethical Concerns Around Human-Machine Integration and Lethal Autonomous Weapons Systems, Within the Changing Character of War, Highly Likely to Remain Contentious Through 2040	0	0	1	0	0	0	0	3	3	3	0	2	1	0	2	0	2	2	2	0	1	0	3	2	0	0	3	0	1	3
Augmented Reality (AR) and Virtual Reality (VR) technology are highly likely (71-85%) to be critical components of future superiority on the battlefield by 2040	3	3	3	3	2	0	0	0	1	3	2	0	0	0	0	3	3	3	2	3	2	3	0	1	1	2	0	3	3	0
Several Concerns Around Human-Machine Integration, Lethal Autonomous Weapons Systems, and Human Trust in Those Systems are Highly Likely (71-85%) to Drive the United States Policy on Limiting Their Use on the Battlefield Through 2040	0	0	0	0	0	3	0	0	0	1	0	2	1	0	3	0	2	0	1	0	2	0	0	0	0	0	1	3	0	3
Training in Prompt Engineering is Highly Likely (71-85%) to be a Critical Requirement for Military Leaders and Soldiers Operating in a Human-Machine Integrated Environment by 2040	0	2	0	2	3	3	1	0	0	0	3	0	2	1	3	0	0	0	3	2	0	0	3	3	3	2	3	0	2	3
Advanced Biofeedback Devices, Immersive Simulations, and Improved Intuition Drills are Likely Core Elements of Effective Ethical Decision-Making Training by 2040	2	3	0	2	2	3	3	1	0	0	1	0	0	0	2	0	1	3	0	0	0	0	2	0	1	0	1	0	3	3
Artificial Neural Networks likely Improve Military Decision-Making Speed Between 2035-2040	3	2	3	0	1	0	2	0	3	1	0	0	1	1	3	0	3	1	2	3	1	0	1	2	1	3	2	2	1	0
Future of Artificial Wisdom: Embracing Emotional Intelligence, Ethical Decision-Making, and Multidisciplinary Approaches Unlikely By 2040.	1	0	0	2	2	2	0	2	0	0	0	0	2	2	2	0	0	0	0	0	1	0	1	0	0	1	2	2	3	3
Advancements in Anthropomorphic AI Predicted to Impact Military Commands and Revolutionize Warfare By 2040	0	0	3	3	2	1	0	1	2	0	1	2	0	0	0	0	0	0	2	1	3	0	3	3	0	1	2	1	1	0
Military Commanders Highly Likely to Use AI to Inform Morale and Welfare Concerns, but Will Almost Certainly Remain Enduring Human Function	0	0	0	2	1	0	0	0	1	0	1	2	0	0	0	0	0	0	0	0	1	0	0	2	2	0	1	0	3	1
Artificial Intelligence Use in Strategic Decision-Making Likely, but Human Involvement Highly Likely Especially During Crises Response	0	2	1	2	2	2	0	3	3	2	3	2	0	0	0	0	1	0	0	3	1	0	1	1	0	2	3	2	3	3
Tripling Battery Energy Storage Highly Likely As Lithium-Sulfur Aims To Eclipse Lithium-Ion By 2040	0	0	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	3	0	3	0	0	0	0	0	1	0	1	0	0
The Advent Of Quantum Computing Will Likely Be A Reality By 2040	3	3	2	0	0	2	3	2	0	1	3	0	0	0	1	0	0	2	0	3	0	0	2	0	0	3	3	3	0	0
Brain-Computer Interface Technology Highly Likely To Enhance A Soldier?s Efficiency With Cognitive And Physical Enhancements By 2040	2	2	2	2	2	2	3	0	0	3	1	0	0	0	0	3	2	0	0	1	2	0	0	0	1	1	1	3	0	3
Human-Machine Integration And Autonomous Equipment Is Almost Certain To Transform Soldiers From Battlefield Brawn to Technical Savvy	3	1	0	3	2	2	2	1	3	0	2	0	2	0	0	0	0	0	0	3	1	0	0	3	3	2	2	0	2	1
Military Units Operating In Isolated Locations Will Almost Certainly Require Collaboration Centers and Power Generation To Successfully Implement Human-Machine Integration by 2040	3	2	1	3	0	0	3	0	2	0	3	0	1	0	3	3	3	1	3	0	3	3	0	3	3	3	1	1	0	0
Perspective Taking, Performance Monitoring, and Conflict Resolution Likely Crucial Human Tasks for Human Machine Integration in 2030s	2	2	0	1	3	1	2	2	0	0	1	1	3	1	1	0	0	2	1	3	0	0	0	3	3	0	2	0	3	3
Deployable 3D Print Systems Highly Likely Standard Capability for Military Sustainment by 2030 and Almost Certainly a Standard Capability for Frontline Units by 2035	0	3	0	3	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	1	3	0	3	1	0
Advancement in Natural Language Processing Likely to Add Near Complete Explainable and Emotional Intelligence Military Artificial Intelligence Applications by 2035	2	3	2	2	3	3	0	0	3	2	1	1	3	0	1	0	2	0	0	0	0	0	0	3	2	1	2	3	3	1
Attributes Supporting Digital Competency--Data Literacy, Technological Competence, And AI Literacy--Highly Likely Included In Military Leadership Development Models By 2035	0	2	0	3	3	2	1	0	3	0	2	0	3	2	1	0	0	0	3	3	3	1	3	0	3	3	3	0	3	2
Chances that Comprehensive Yet Tiered Needs in Digital Competencies and Basic Military Principles to Increase Training and Education Requirements up to 10% by 2035	0	0	0	3	3	0	1	0	3	1	1	0	0	2	0	0	0	1	3	3	3	1	2	3	0	1	3	0	1	0
Highly Likely That AI And Blockchain Will Create Advantages For Logistics On The Human Machine Integrated Battlefield In 2040	3	3	1	2	1	0	2	0	2	0	3	1	1	0	2	1	3	1	2	3	0	3	1	3	1	0	0	2	0	0
Artificial Intelligence Competitive Advantage Likely Maintained By United States In 2040 but China Aggressively Committing Resources Towards AI Dominance	0	2	2	3	3	3	0	1	3	1	2	2	2	1	3	0	3	1	2	1	2	0	2	3	3	0	0	1	3	1
Revolutionizing Military Operations – The Convergence Of Advanced Technologies Will Likely Pave The Way For Advanced Decision-Making By 2040	1	2	3	0	0	0	3	3	0	0	2	2	1	0	2	1	3	3	0	1	0	3	3	0	0	2	1	0	1	1
Adaptability And Cultural Intelligence, Moral Acuity, And Digital Competency Highly Likely Selection Criteria For Human Machine Military Organizations By 2035	0	0	0	3	3	1	3	0	2	3	1	3	1	3	3	0	0	0	2	0	3	1	3	3	1	0	3	1	0	3
Balancing Innovation with Moral Responsibility Highly Likely to be Critical to the United States Military by 2040	0	0	0	0	0	3	0	3	3	3	0	3	0	1	3	0	0	3	1	0	3	0	1	2	0	0	1	1	3	0

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Annex H – Human Capabilities And Where Large Language Models Rank Relative To Humans As Of 2024

Capability	Benchmark	AI Performance	Human Performance	Estimated Time to Surpass Humans
3D Reconstruction from Images	Skoltech3D	Largest dataset of its kind (as of 2023)	-	-
Abstraction and Reasoning	ConceptARC	69% (as of 2023)	95.00%	3-5 years
Activity Recognition	Kinetics-400, Kinetics-600, Kinetics-700	Improving, but no direct comparison to human performance	-	-
Agent-Based Behavior	AgentBench	4.01 overall score out of 5 (GPT-4, as of 2023), indicating strong performance but not surpassing humans	-	2-4 years
Agent-Based Behavior	MLAgentBench	0% to 100% success rate across tasks (as of 2023)	-	-
Basic Reading Comprehension	SQuAD 1.1	Surpassed human performance in 2017	-	Already surpassed
Causal Reasoning	BigToM	Nearing human performance (as of 2023)	-	2-4 years
Causal Reasoning	Tübingen Cause-Effect Pairs	96% (GPT-4, as of 2023)	-	Less than 1 year
Coding	HumanEval	96.3% (as of 2023)	-	Less than 1 year
Coding	SWE-bench	4.8% of problems solved (as of 2023)	-	5+ years
Competition-level Mathematics	MATH	84.3% (as of 2023)	90.00%	1-2 years
English Language Understanding	SuperGLUE	Surpassed human performance in 2021	-	Already surpassed
Factuality and Truthfulness	TruthfulQA	0.6 score (as of 2023)	-	-
Factuality and Truthfulness	HaluEval	39.66% to 69.78% across models and tasks (as of 2023)	-	-
General language	HELM	0.96 mean win rate (GPT-4, as of 2023)	-	-
General Language	Chatbot Arena Leaderboard	1,252 Elo rating (GPT-4, as of 2023)	-	-
General Reasoning	GPQA	41% (as of 2023)	72.5% (expert human)	4-6 years
General Reasoning	MMMU	59.4% (Gemini Ultra, as of 2023)	82.6% (medium-level expert)	-
Image Classification	ImageNet	Surpassed human performance in 2015	-	Already surpassed
Image Editing	EditVal	0.11 to 0.59 editing accuracy across tasks (as of 2023)	-	-
Image Generation	HEIM	0.54 to 0.94 mean win rate across models and tasks (as of 2023)	-	-

Capability	Benchmark	AI Performance	Human Performance	Estimated Time to Surpass Humans
Image Instruction-Following	VisIT-Bench	1,349 Elo rating (GPT-4V, as of 2023)	1,338 Elo rating	Already surpassed
Image Segmentation	Segment Anything	Outperforms previous methods on 16 out of 23 datasets (as of 2023)	-	-
Mathematical Reasoning	GSM8K	97% (as of 2023)	-	Less than 1 year
Medium-level Reading Comprehension	SQuAD 2.0	Improving, but no direct comparison to human performance	-	-
Moral Reasoning	MoCa	Approaching human performance (as of 2023)	-	3-5 years
Multitask Language Understanding	MMLU	90.04% (as of 2023)	-	1-2 years
Natural language Inference	aNLI	Improving, but no direct comparison to human performance	-	-
Planning	PlanBench	34.3% of problems solved (as of 2023)	-	3-5 years
Sentiment Analysis	SST-5 Fine-Grained Classification	Performance data not available in the document	-	-
Speech Recognition	VoxCeleb	Performance data not available in the document	-	-
Text Summarization	arXiv, PubMed	Performance data not available in the document	-	-
Video Generation	UCF101	36 FVD16 score (as of 2023)	-	-
Visual Commonsense Reasoning	VCR	81.6% (as of 2023)	85.00%	1-3 years
Visual Reasoning	VQA	Surpassed human performance in 2020	-	Already surpassed

Source: AI Index Report 2024 – Artificial Intelligence Index

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Annex J – Acronyms

3D	Three Dimensional
AGI	Artificial General Intelligence
AI	Artificial Intelligence
AIOps	AI-powered IT operations platforms
*a*NLG	Abductive Natural Language Generation
*a*NLI	Abductive Natural Language Inference
ANN	Artificial Neural Network
AR	Augmented Reality
AW	Artificial Wisdom
BCI	Brain-Computer Interface
BCS	Brain-Inspired Cognitive Systems
C2	Command and Control
CAGR	Compound Annual Growth Rate
CDR	Commander
CET	Critical Emerging Technology
ChatGPT	Chat Generative Pre-Trained Transformer
CIS	Center for Internet Security
CNN	Convolutional Neural Network
CPS	Cyber-Physical Systems
CQ	Cultural Intelligence
DARPA	Defense Advanced Research Projects Agency
DDM	Data-Driven Decision-Making
DLT	Distributed Ledger Technology
DoD	Department of Defense
DOTMLPF-P	Doctrine, Organization, Training, Materiel, Leadership and education, Personnel, Facilities and Policy
EEG	Electroencephalogram
EI	Emotional Intelligence
ESM	Experience Sampling Method
EVI	Empathic Voice Interface
GPT	General Pre-trained Trainer
HCAI	Human-Centric Artificial Intelligence
HGTP	Hypergraph Transfer Protocol
HIPAA	Health Insurance Portability and Accountability Act
HM	Human-Machine
HMH	Human-Machine Hybrid
HMI	Human-Machine Integration
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure

IG	Inspector General
IoT	Internet of Things
iSIM	Integrated Subscriber Identity Module
IT	Information Technology
KSAO	Knowledge, Skills, Abilities, and Other Abilities
LAWS	Lethal Autonomous Weapons Systems
LIB	Lithium Ion Battery
Li-S	Lithium Sulfur Battery
M2	Movement and Maneuver
ML	Machine Learning
MVNO	Mobile Virtual Network Operators
NATO	North Atlantic Treaty Organization
NGO	Non-governmental organizations
NIST	National Institute of Standards and Technology
NLP	Natural Language Processing
NMSI	National Math and Science Initiative
OT	Operational Technology
PECM	Pulsed Electrochemical Machining
PMESII-PT	Political, Military, Economic, Social, Infrastructure, Information, Physical Environment, and Time
QIS	Quantum Information Science
Qubits	Quantum Bits
RAND	Research ANd Development (Organization)
REQUEST	Resource-Efficient Quantum Error Suppression Technique
RS	Recommender System
SAF	Sustainable Aviation Fuel
SFAR	Short Form Analytic Report
SIM	Subscriber Identity Module
SSVEP	Steady-State Visually Evoked Potential
STEM	Science, Technical, Engineering, Math
STIG	Security Technical Implementation Guides
THz	Terahertz
UAV	Unmanned Aerial Vehicle
US	United States
USAID	United States Agency for International Development
VR	Virtual Reality
WfF	Warfighting Functions
XAI	Explainable Artificial Intelligence

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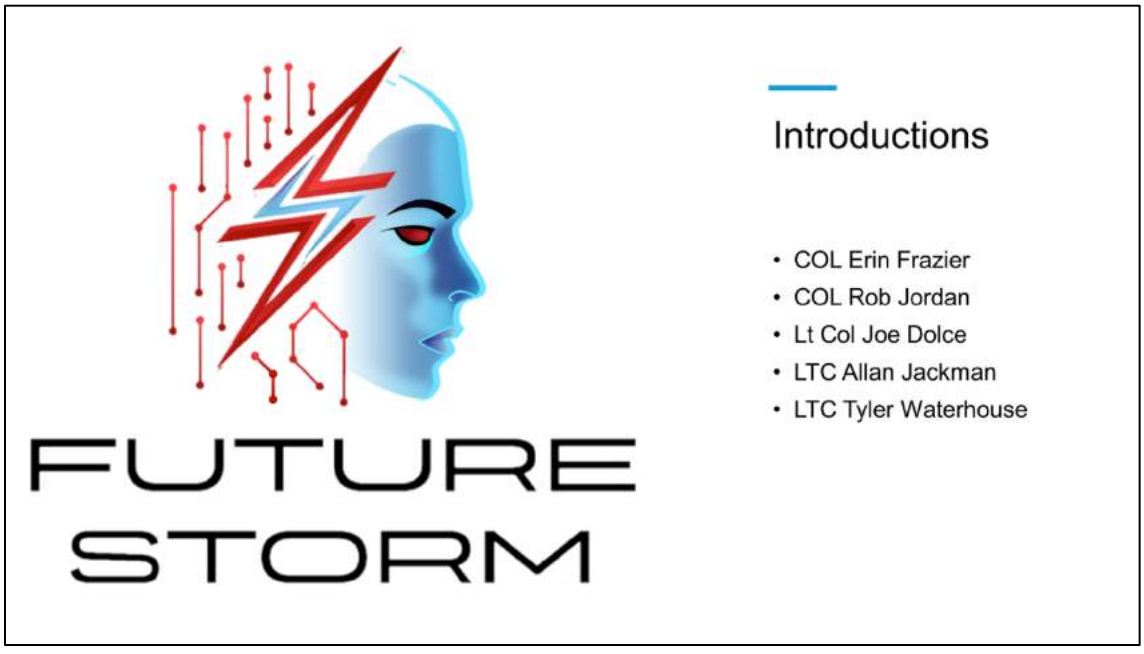
Annex K – Team Future Storm Presentation



Words of Estimative Probability

Kesselman List of Estimative Words

Certainty 100%	
Almost Certain	86-99%
Highly Likely	71-85%
Likely	56-70%
Chances a Little Better [or Less]	46-55%
Unlikely	31-45%
Highly Unlikely	16-30%
Remote	1-15%
Impossibility 0%	

Likelihood

Analytic Confidence and AI Support

SCISPACE

Elicit

OpenAI ChatGPT-4

Gemini

fiverr

perplexity

zotero

feedly

Terms of Reference

- How will human-machine integration (HMI) between 2030 and 2040 evolve the nature of warfighting and necessitate changes across DOTMLPF-P to gain or maintain a competitive advantage in future military conflicts?
  - What functions must remain human and commander centric, aided by machines?
  - What processes, educational initiatives, and tools can develop a military workforce that can ask the right questions and frame decisions to fight and win in a data-centric environment?

Key Findings –

The Impact of HMI on DOTMLPF-P is highly likely by 2040

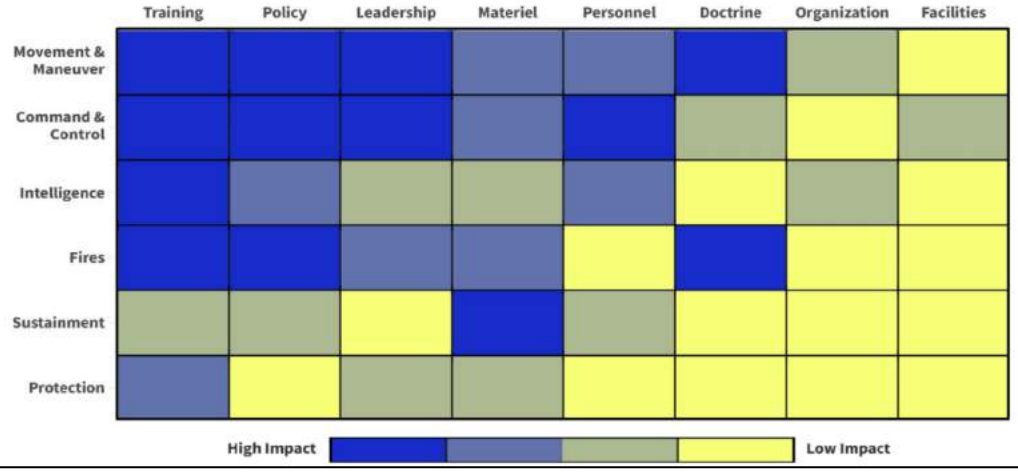
Key Findings –

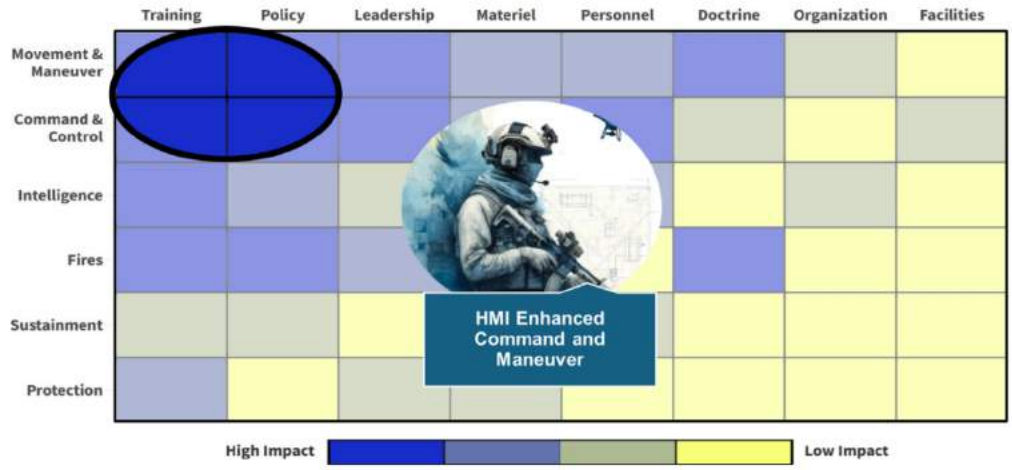
The Impact of HMI on DOTMLPF-P is highly likely by 2040

Key Findings –

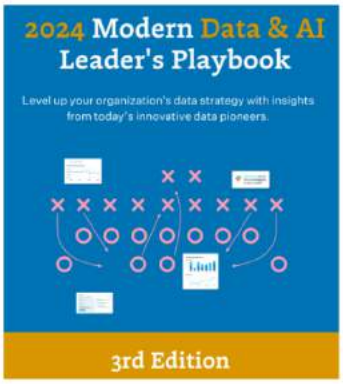
The Impact of HMI on DOTMLPF-P is highly likely by 2040

The Impact of HMI on DOTMLPF-P and WfF





Tactical Playbooks



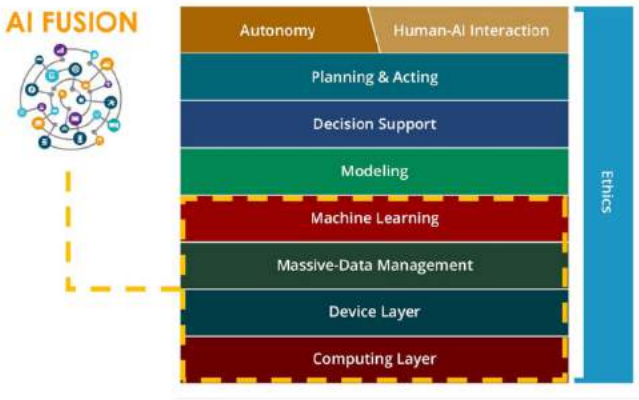
Advanced AR/VR

Brain Computer Interface

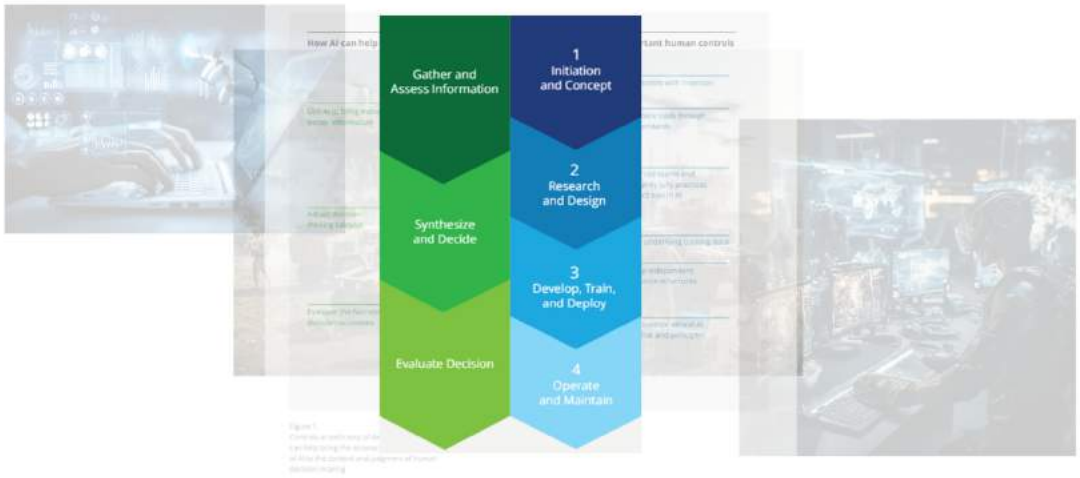
Advanced Microlearning

HMI Ethical Policy

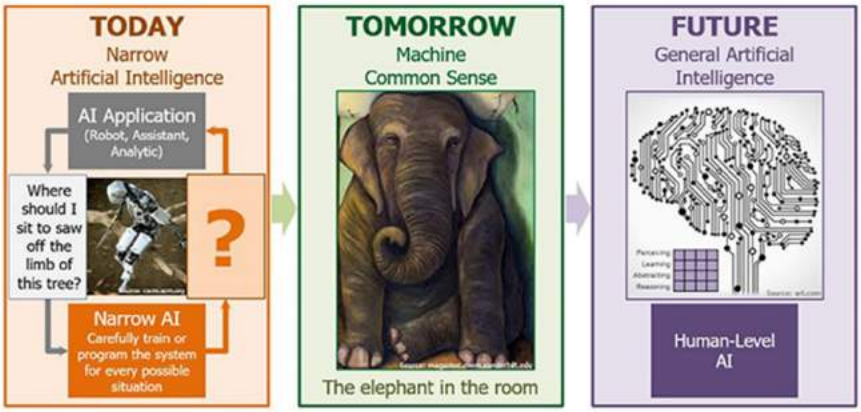
AI Stack



AI – Optimized Decision Making

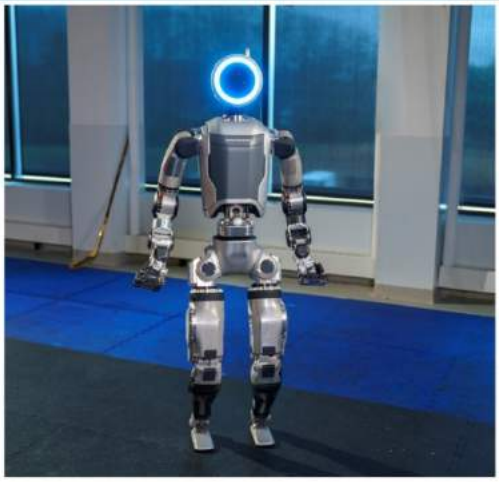


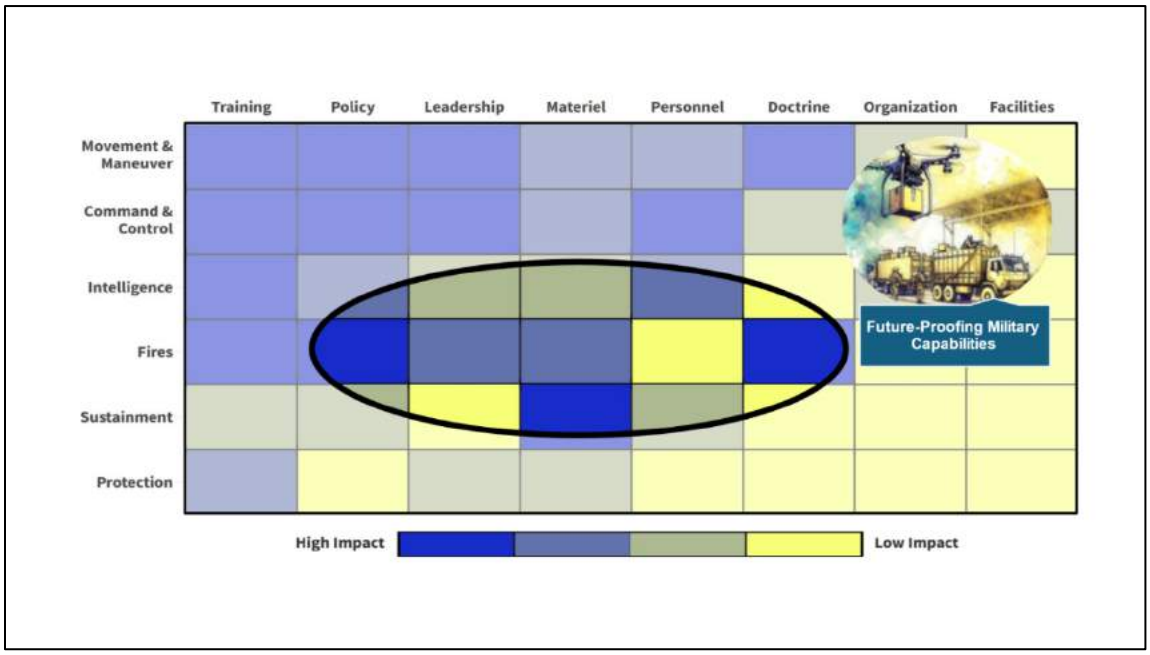
"Artificial Wisdom"

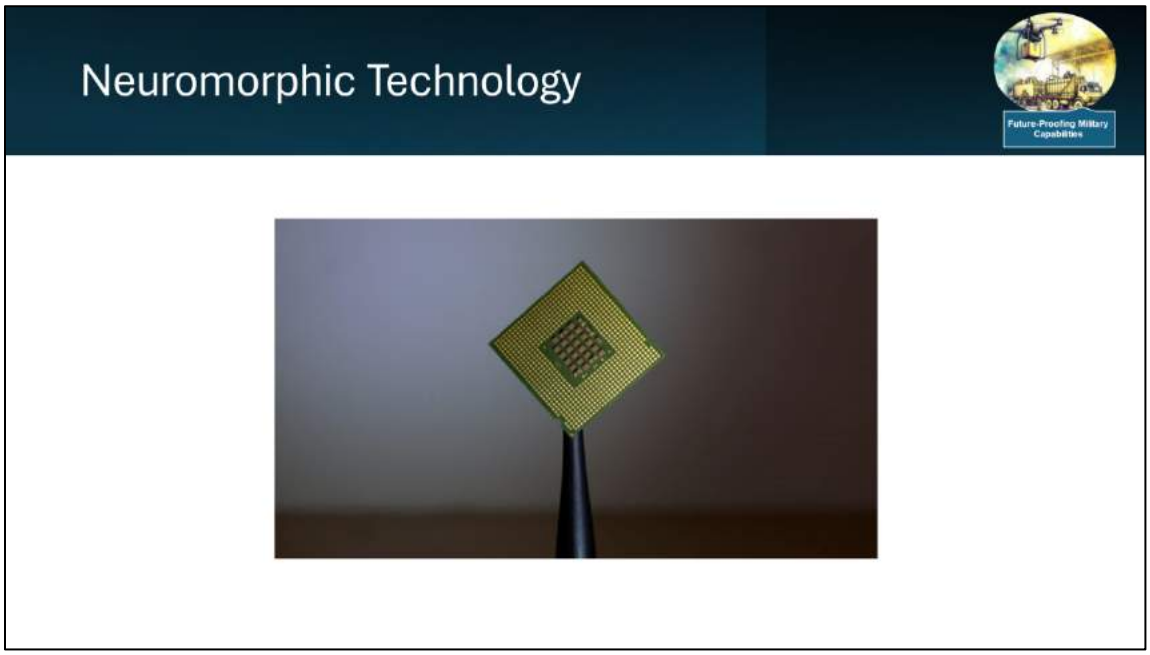


AI – Informed Crisis Management

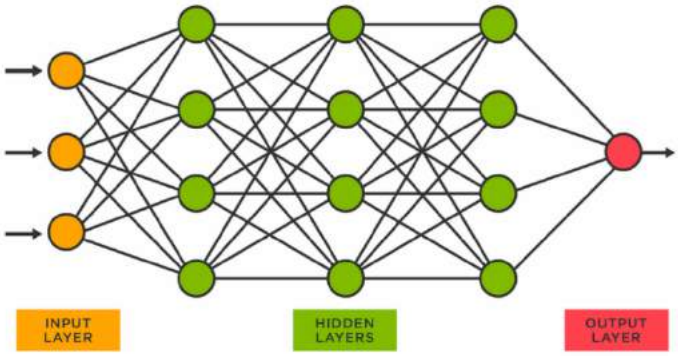
Anthropomorphism




Training
Policy
Leadership
Materiel
Personnel
Doctrine
Organization
Facilities
Movement & Maneuver
Command & Control
Intelligence
Fires
Sustainment
Protection
Future-Proofing Military Capabilities
High Impact
Low Impact

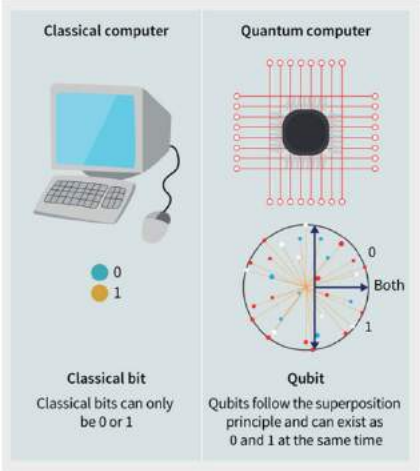

Neuromorphic Technology
Future-Proofing Military Capabilities

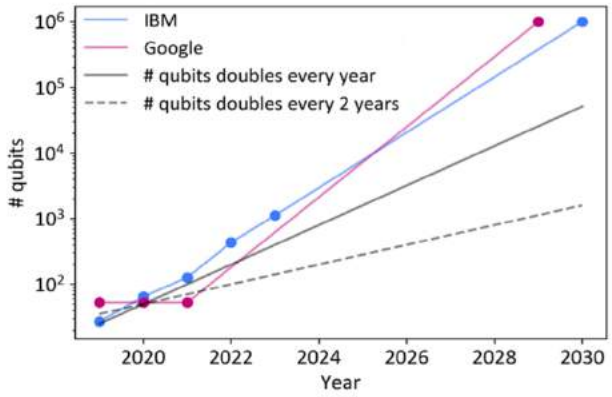
Advanced Neural Networks



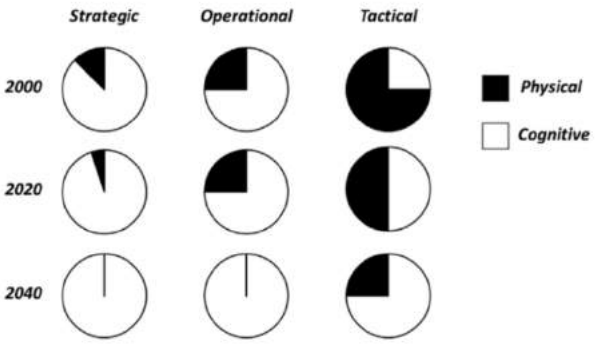
AI and Block Chain

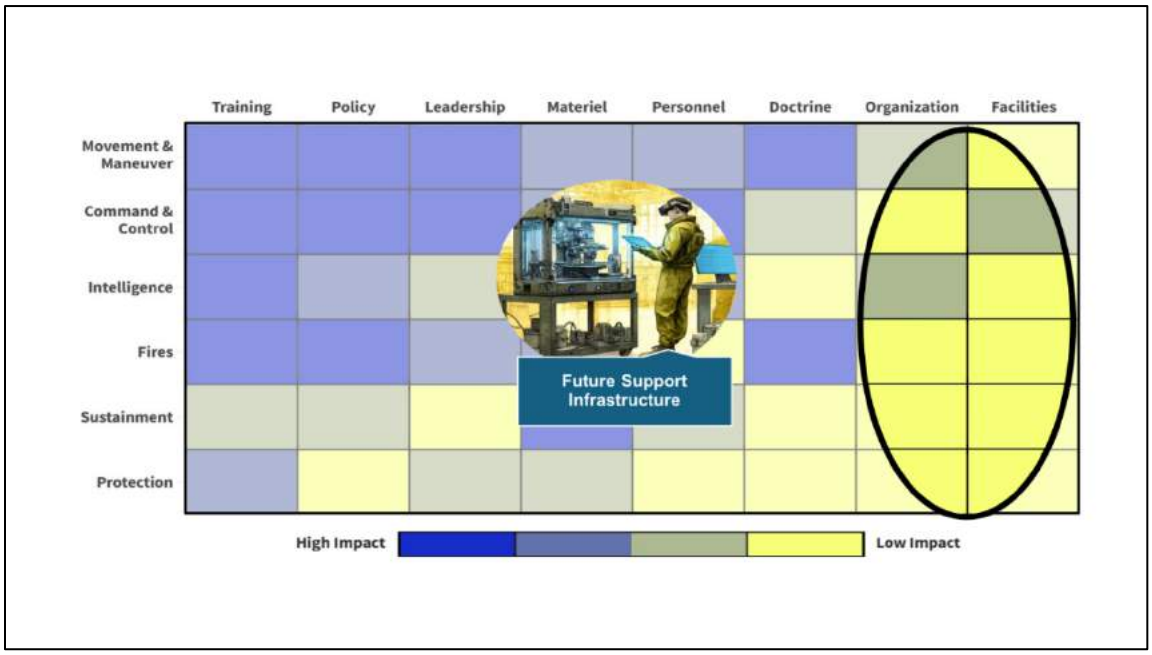
Quantum Computing





Military Cognitive Transition




Training
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Leadership
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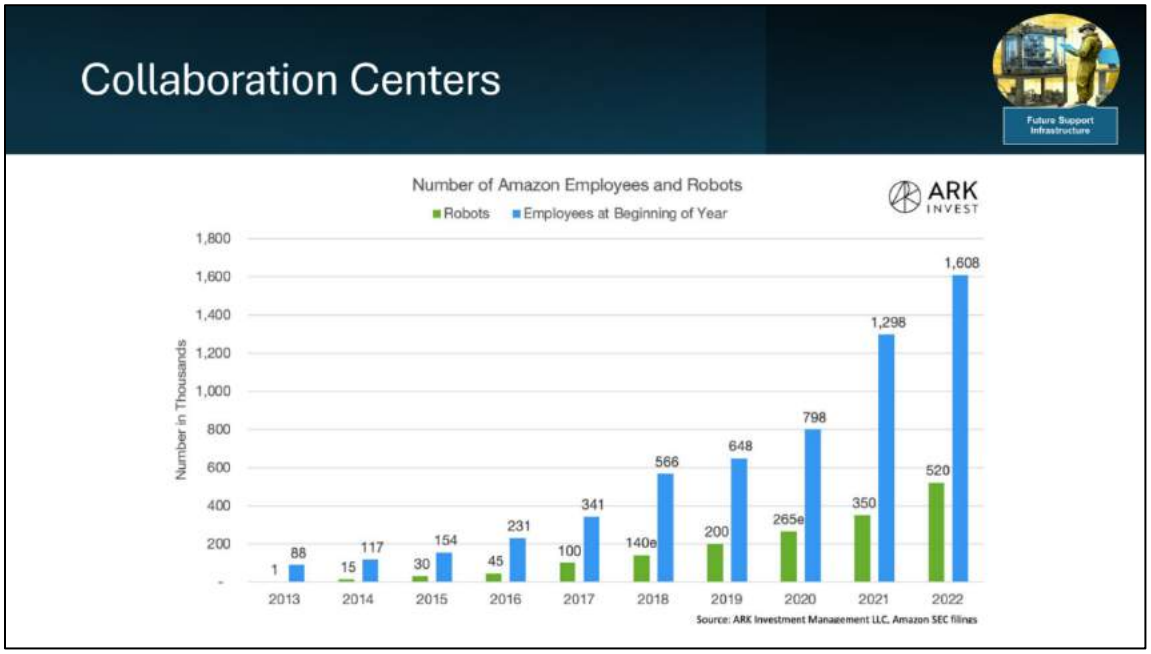
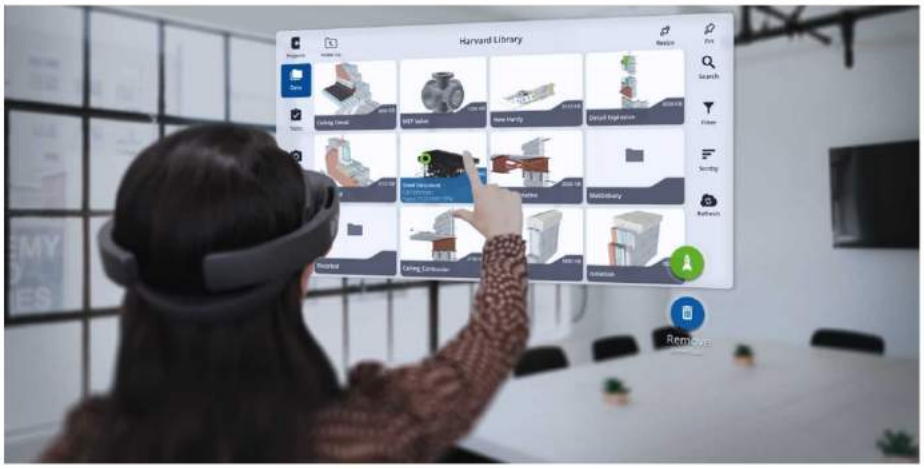
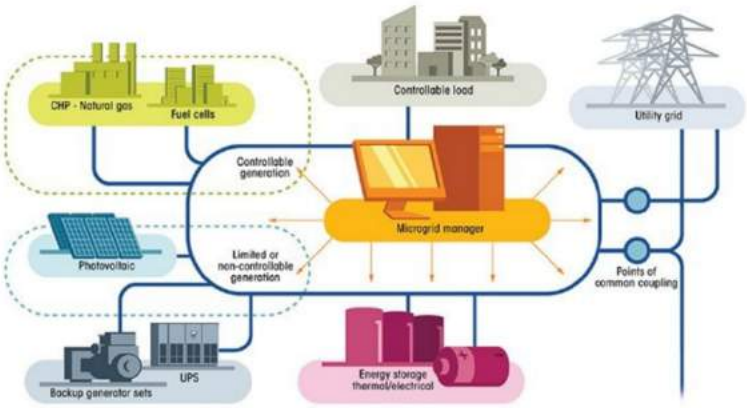
Organization
Facilities
Movement & Maneuver
Command & Control
Intelligence
Fires
Sustainment
Protection
Future Support Infrastructure
High Impact
Low Impact


Collaboration Centers
Future Support Infrastructure
Number of Amazon Employees and Robots
Robots
Employees at Beginning of Year
ARK INVEST
Number in Thousands
1,800
1,600
1,400
1,200
1,000
800
600
400
200
-
1
88
15
117
30
154
45
231
100
341
140e
566
200
648
265e
798
350
1,298
520
1,608
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
Source: ARK Investment Management LLC, Amazon SEC filings

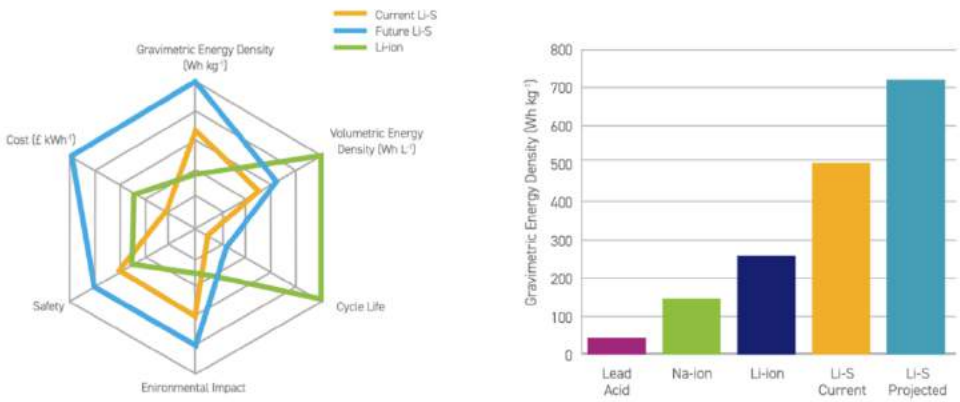
Collaboration Centers



Power Generation

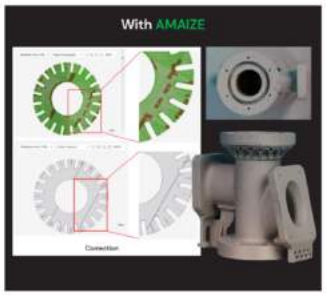


Power Generation



Source: Faraday Institute

3D Printing



Facilities Modernization

Key Finding –

It is highly likely that militaries will use network analysis to assess the impacts of HMI rather than relying on the DOTMLPF-P framework

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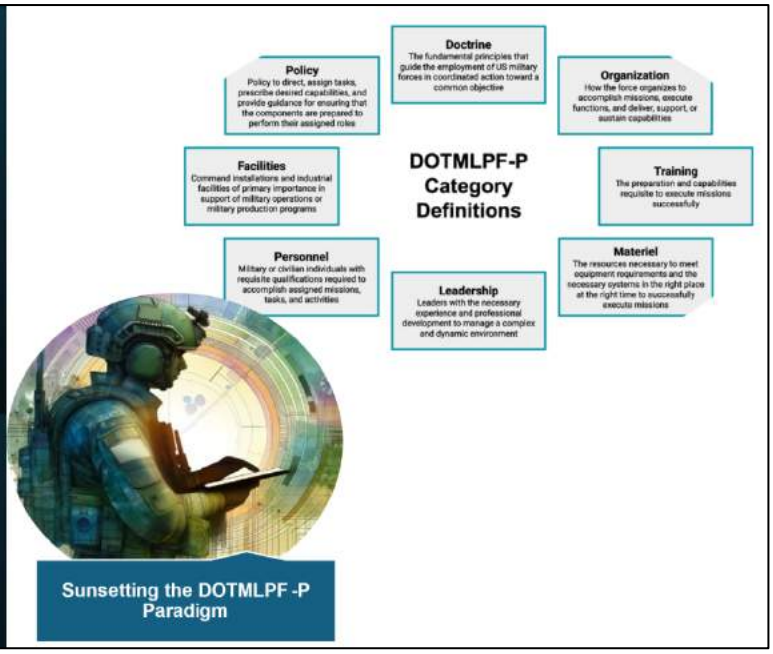
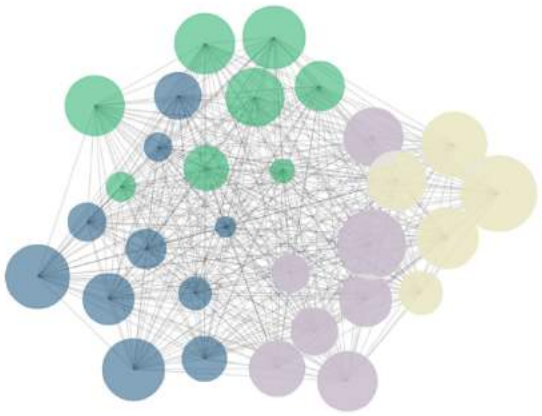
It is highly likely that militaries will use network analysis to assess the impacts of HMI rather than relying on the DOTMLPF-P framework



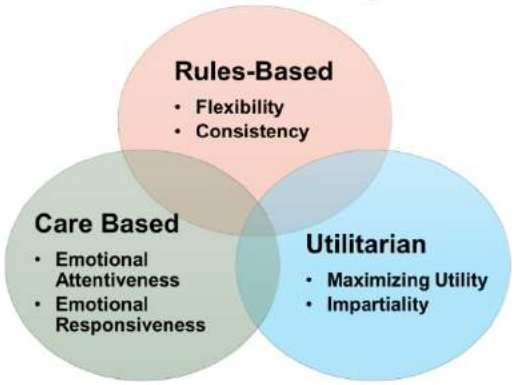
Network Analysis



- Philosophy of HMI
- Training and Recruiting for an HMI Workforce

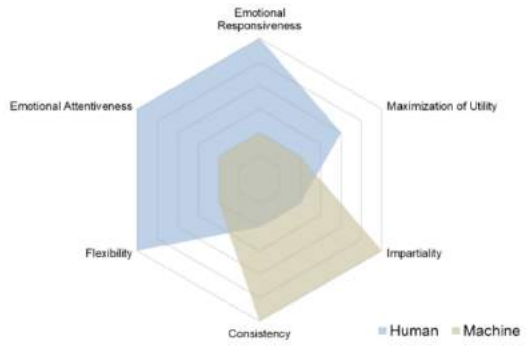
Philosophy of HMI

Ethical Frameworks for Decision-Making

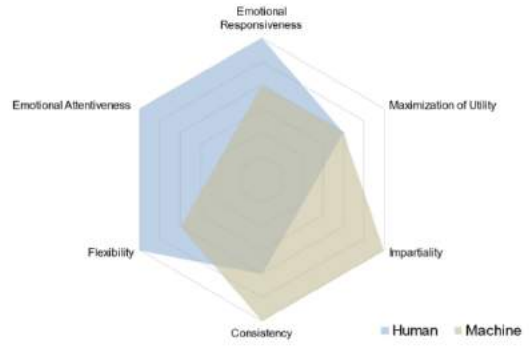


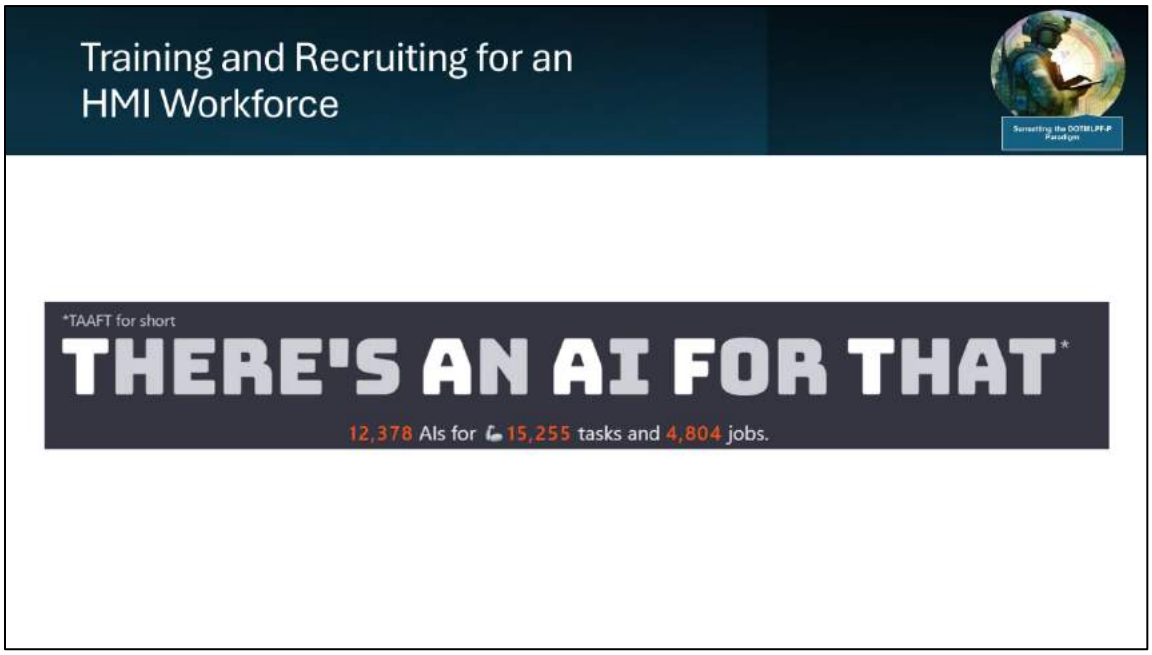
Philosophy of HMI

Ethical Decision Making Today



Ethical Decision Making 2040





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STORM